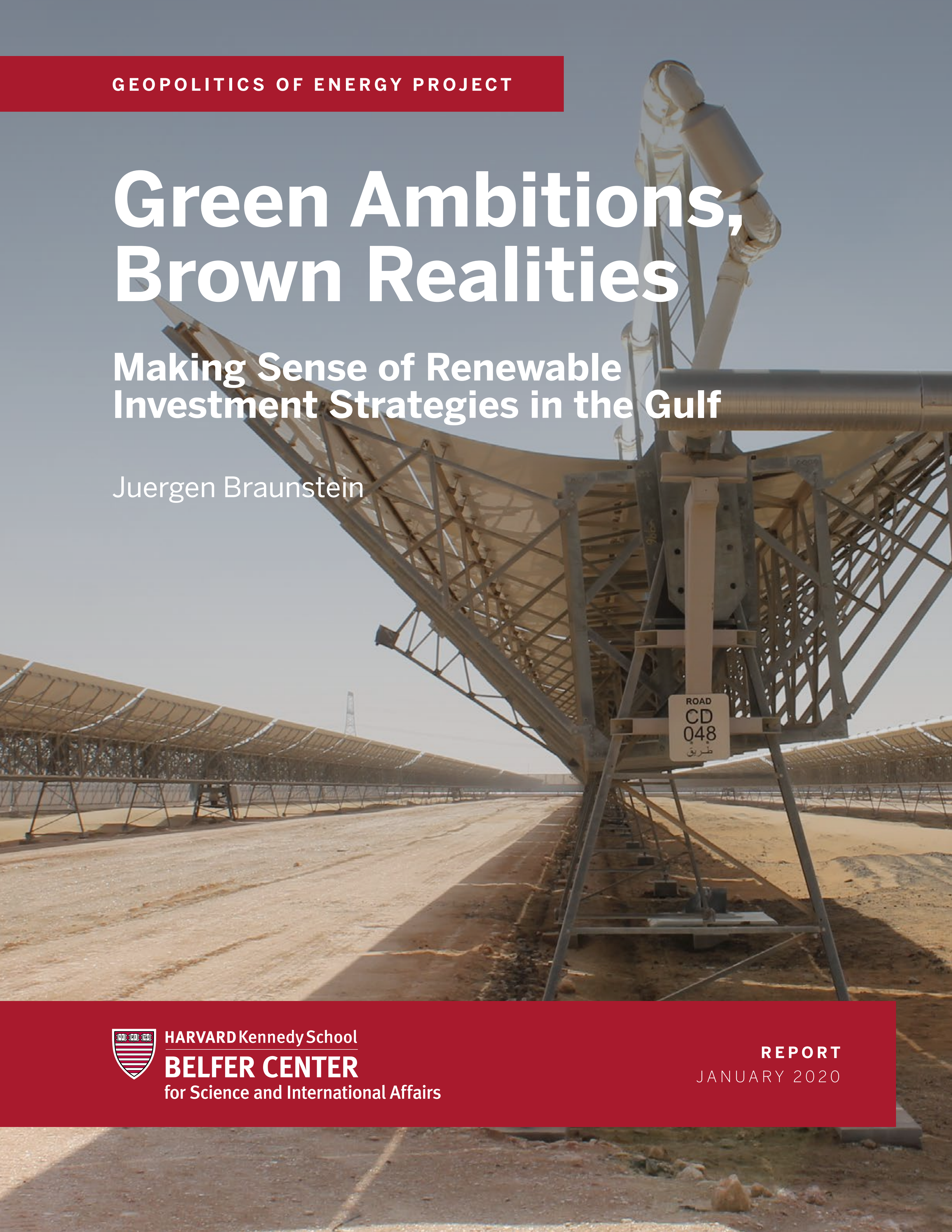
GEOPOLITICS OF ENERGY PROJECT

Green Ambitions, Brown Realities

Making Sense of Renewable Investment Strategies in the Gulf

Juergen Braunstein



HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

REPORT
JANUARY 2020

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About the Project:

The Geopolitics of Energy Project explores the intersection of energy, security, and international politics. The project, launched in 2011, aims to improve our understanding of how energy demand and supply shape international politics—and vice versa. It also endeavors to inform policymakers and students about major challenges to global energy security and, where possible, to propose new ways of thinking about and addressing these issues. The project focuses both on conventional and alternative energies, as both will influence and be influenced by geopolitical realities.

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About the Author:

Juergen Braunstein is a fellow at the Belfer Center for Science and International Affairs at Harvard Kennedy School, where he works on the Geopolitics of Energy Project. His research focuses on the drivers, and the consequences, of the green energy revolution's impact on global energy composition and international relations. He is currently working on a book project on the role of finance in the global energy transition. Dr. Braunstein is a member of the G20 task force on Investment, Social Cohesion and the State, and an Erwin Schrödinger Fellow of the Austrian Research Fund (FWF).

Previously, he coordinated the New Climate Economy (NCE) Finance Workstream at LSE Cities under the leadership of Nicholas Stern and Felipe Calderón. Dr. Braunstein is the author of *Capital Choices: Sectoral Politics and the Variation of Sovereign Wealth* (2019, Michigan University Press). Beyond his peer reviewed publications, he has published numerous articles in media outlets, such as FT, Forbes, Project Syndicate, and VoxEU. Dr. Braunstein was a post-doctoral researcher at Harvard Kennedy School. He holds a Ph.D. in Comparative and International Political Economy from the London School of Economics (LSE), a Master of Research in Political Science from the LSE, and a B.A. from the University of Vienna.

Glossary

bbl	Barrel
b/d	barrel per day
GCC	Gulf Cooperation Council
GWh	Gigawatt hour
HFO	Heavy fuel oil
INDC	Intended Nationally Determined Contributions
KAPSARC	King Abdullah Petroleum Studies and Research Center
kHw	Kilowatt hour
mb/d	Thousand barrels per day
mmb/d	Million barrels per day
MCD	Manufacturing Construction Development
mtoe	Millions of tons of oil equivalent
MW	Megawatt
O&M	Operations & Maintenance
REPDO	Renewable Energy Project Development Office

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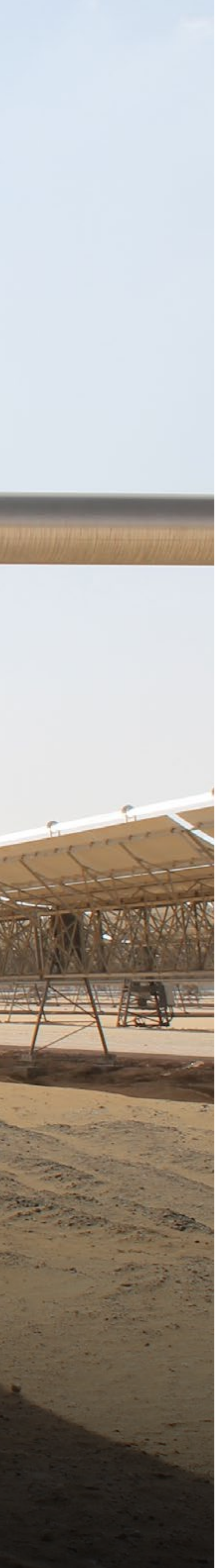
One of the parabolic mirrors arrays at the Shams-1 concentrated solar power plant in the UAE, January 2015.

IRENA photo, CC by-nc-sa 2.0



Executive Summary

Gulf Cooperation Council (GCC) countries have attracted worldwide attention as a result of their ambitious plans to restructure their carbon-driven economies. These plans include efforts to "green" their economies and investments, notably via massive infrastructure projects. The renewable energy targets of GCC nations are remarkable. As of 2018, Saudi Arabia, the UAE, Qatar, and Kuwait collectively planned to develop solar energy production by 2030 to about 15 percent of today's total worldwide solar capacity. The major drivers behind this trend are Saudi Arabia and the UAE.

Gulf countries have hailed their investments in renewable energy, but some basic questions remain about the extent to which it makes sense for GCC states to invest aggressively in renewables. The sheer magnitude of such investments will require these countries to mobilize significant public resources. Therefore, such an assessment requires these countries to focus on national interests, not just a desire to be perceived as constructive participants in the global transition away from carbon energy.

This report starts by identifying four common strategic justifications for investing in renewable energy in GCC countries. Each of these rationales highlights a different aspect of renewable energy investments. In addition, each rationale is based on different assumptions about the underlying drivers of such investments, and each rationale is based on different assumptions about the future of energy.

First, the *revenue maximization* argument relates to the inefficiencies of burning expensive oil, which could otherwise be exported. Second, the *job creation* rationale perceives renewable investments as an effective means of achieving socioeconomic goals. Third, the *hedging* argument considers renewable investments to be a way to address the risk of heavy reliance on oil; namely, asset stranding and low income from oil in a low-price environment. Finally, the geopolitics argument considers renewable investments as a means to gain geopolitical benefits, such as increasing domestic energy security and building reserve oil capacity.

For smaller Gulf economies, notably the UAE and Kuwait, only the *geopolitics* argument, and in particular the *energy security* aspect of that argument, makes sense as a driving rationale for investing in renewable energy. By contrast, for Saudi Arabia, the *revenue maximization*, *hedging*, and *geopolitical* arguments all serve to justify large investments in renewable energy. For Qatar, all of the potential arguments for investing in renewable energy are weak, at least when compared to how those justifications apply to the other GCC countries (see Tables 1 and 2).

Findings and Policy Implications

- Contrary to popular belief, from a national strategic perspective, job creation should not be the key driving rationale behind aggressive renewable investments in GCC countries.
- Saudi Arabia is in the nascent stage of implementing its ambitious renewable targets. But in order to fulfill the *geopolitics*, *revenue maximization*, and *hedging* rationales, Saudi Arabia needs to significantly increase its investments in renewable energy production. .
- Kuwait's effort to replace oil-based energy production with renewable energy production, in order to free up more oil for export, will have a much smaller economic impact than Saudi Arabia's effort.
- Kuwait needs to step up its renewable investments in order to be aligned with the expectations of the *energy security* rationale, but Qatar's renewable energy agenda makes little sense in relation to any of the four investment rationales described above.
- The UAE's announced renewable targets are reasonable in terms of an energy security goal, but it needs to increase investment. In comparison with its GCC peers, the UAE is most advanced in the implementation of its renewable energy targets.

Table 1: Rationales behind renewable investments across Gulf Council Cooperation countries

	Rationales					
	Revenue maximization	**Job creation**	**Hedging**		**Geopolitics**	
	From additional fossil fuel export	*Jobs created directly from renewables*	*Asset stranding risk*	*Low oil income risks*	*Maximize energy security*	*Increase spare oil capacity*
Saudi Arabia	Strong	Weak	Weak	Depends	Depends	Strong
UAE	Weak	Weak	Weak	Depends	Strong	Weak
Kuwait	Depends	Weak	Weak	Depends	Strong	Strong
Qatar	Weak	Weak	Weak	Weak	Weak	Weak

Table 2: Are the renewable targets large enough to address the rationales?

	Rationales					
	Revenue maximization	**Job creation**	**Hedging**		**Geopolitics**	
	From additional fossil fuel export	*Jobs created directly from renewables*	*Asset stranding risk*	*Low oil income risks*	*Maximize energy security*	*Increase spare oil capacity*
Saudi Arabia	Depends	N/A	N/A	No	N/A	Yes
UAE	N/A	N/A	N/A	No	Depends	N/A
Kuwait	Depends	N/A	N/A	No	Depends	Depends
Qatar	N/A	N/A	N/A	N/A	N/A	N/A

1. Introduction

Gulf Council Cooperation (GCC) countries have attracted worldwide attention in response to ambitious restructuring plans for their carbon-driven economic systems.[1] At the center of their development plans are efforts to "green" their economies and investments, notably via massive infrastructure projects. Their renewable energy targets are remarkable. As of the end of 2018, the total of announced solar projects of Saudi Arabia, the UAE, Qatar, and Kuwait (i.e., 68 gigawatt, GW) is equivalent to almost 15 percent of today's total worldwide installed solar capacity.[2] The major drivers behind this trend in the region are Saudi Arabia and the UAE. The UAE set a target of producing 44 percent of its power from renewables, which will require at least one GW of projects per year until 2050.[3] Also, policy makers in Qatar and Kuwait have announced plans to step up their efforts in diversifying the local energy mix by 2030 with a renewable target of 20 percent and 15 percent of the electricity mix respectively from almost zero in 2018.[4]

Given the abundance in energy resources among GCC countries, combined with a number of pressing socio-economic issues, such as the need to create jobs, the following question emerges: Does it make sense for Gulf countries to invest aggressively in renewables? In answering this question, this report seeks to evaluate issues such as: How much do GCC countries actually invest in renewables in comparison with other regions and countries? Are such investments appropriate for addressing their national policy goals and energy strategies? To what extent do renewable investments among GCC countries contribute to the goal of effectively freeing domestic oil consumption for export? And to what extent do renewable strategies and investments help diversify their economies and contribute to the goal of job creation? How can investments in renewables help GCC countries hedge against risks of asset stranding in a post-oil era, and what is the geopolitical dimension of renewable investments in GCC countries?

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1 Council of Economic and Development Affairs, 2016; Government of Abu Dhabi, 2018; Government of Dubai, 2018; Government of Kuwait, 2017; Government of Qatar, 2008.

2 See Appendix 1.

3 Gnana, 2018; International Renewable Energy Agency, 2019a.

4 See Appendix 2.

To respond to these questions, this report engages with a number of arguments that are used in contemporary debates on renewable energy finance and geopolitics.[5] Drawing on these debates, we start by identifying four strategic rationales frequently used to justify renewable investments in fuel exporting economies. Each of these rationales highlights different aspects of renewable energy investments and shares different assumptions about the underlying drivers of renewable investments and the trajectory of the energy future. Accordingly, each of the rationales suggests a different course of action in terms of their renewable investments regarding size, timing, and coordination with other policy areas.

The first rationale on "revenue maximization" relates to the inefficiencies of burning expensive oil, which could otherwise be exported.[6] Substituting oil in electricity production through renewables helps in generating more revenue from oil exports.[7] The revenue maximization argument was originally put forward by energy economists such as Paul Stevens, who, together with Glada Lahn, highlighted in a widely publicized Chatham House report the inefficiency of electricity production via oil in Saudi Arabia.[8]

The second rationale of "job creation" considers renewable investments as an effective means of achieving socioeconomic goals, notably job creation. The International Renewable Energy Agency (IRENA), in their Annual Review on Renewable Energy and Jobs, illustrates how "countries reap socioeconomic benefits from renewables."[9] For example, policy makers and officials in Saudi Arabia refer to this rationale to justify large renewable energy projects vis-à-vis the local population.[10]

In the third rationale of "hedging," renewable investments are seen as (a) a way of addressing the risk of asset stranding, and (b) as a way of hedging against the risk of low income in a low oil price environment. From this

5 Akhonbay, 2018; Fattouh et al., 2018; International Energy Agency, 2018a.

6 Al-Sheri, 2018.

7 Fattouh et al., 2018; Sultan, 2013.

8 Lahn and Stevens, 2011.

9 "Renewable Energy and Jobs - Annual Review 2018," n.d.

10 "Saudi Arabia's PIF signs MoU with China on renewable energy cooperation - Al Arabiya English," 2019.

perspective, investing in renewables is a way of getting exposure to income streams that are negatively correlated with the prices of fossil fuels (i.e., oil).

In the fourth rationale of "geopolitics," renewable investments are considered as a way to benefit geopolitically from the global energy transition in a number of ways, such as in terms of increasing energy independence. Another aspect of renewable investments relates to the possibility of maximizing spare capacity of oil, which has been a major source of geopolitical leverage.[11]

The purpose of this paper is not to explain why some GCC countries are more advanced in the implementation of their renewable targets. Rather, the purpose of this report is to evaluate whether the announced renewable strategies and targets make sense vis-à-vis a set of rationales that are frequently used in the academic and policy debate to justify these targets. While energy efficiency efforts (e.g., in the utilities sector, infrastructure, heavy industry, residential and other buildings, and transport) and the systemic integration and design of renewable programs are critical to the role that renewables can play in the energy mix and thus to how much oil or gas can be freed up, this paper's focus is primarily on the appropriateness of the announced headline numbers and deployment figures. We assume that the electricity generated from renewables is less than the electricity demand at any given point in time.[12] If electricity supply from renewables is larger than electricity demand, then we assume that there are flexibility measures in place, such as storage, to balance the renewable energy intermittency.

Although renewable sources such as nuclear and wind power play an increasingly important role in the region, this report focuses on renewable targets in solar photovoltaic (PV) and concentrated solar power (CSP), because they have the greatest potential in terms of size. The findings of this report help to assess the extent to which GCC countries are on track to achieve their ambitious renewable energy targets.[13] As such, the report offers policy makers of petro states a perspective that recognizes the complex interrelationships among different areas of government policy. Such a perspective is not only valuable to policy makers but also to investors and

11 Lahn and Stevens, 2011.

12 That is a reasonable assumption given the GCC members respective targets of renewable electricity generation (see Appendix 2).

13 See Appendix 2.

renewable manufacturers because it provides important high-level strategic insights for actors who consider moving resources into the renewable energy sector of GCC countries. It helps to determine whether such significant resource mobilization makes sense and aligns the goals of firms with the long-term strategic thinking of countries.

1.1 Research Design, Methods, Data and Findings

This report uses a case study approach in comparing renewable investments across four petro-exporting countries (i.e., Saudi Arabia, Kuwait, the United Arab Emirates, and Qatar).[14] The four cases share a number of similarities and differences that make them ideal for investigating the four rationales. Common to Qatar, Saudi, the UAE, and Kuwait is that all are low-cost oil producers with a significant part of their national assets located in carbon-intensive sectors, which are said to be increasingly exposed to risks of asset stranding.[15] These countries are in a similar geopolitical region and they have no hydroelectric capacity nor domestic coal production. In parallel, these four countries experience rising domestic fossil fuel consumption, specifically for the production of electricity.[16] Beyond that, Qatar, Saudi Arabia, the UAE, and Kuwait have limited possibilities of using monetary policies to stimulate their economies.[17] Instead, they are left only with government spending as a way to stimulate economic growth and job creation.[18] In turn, their budgets and spending capabilities are heavily exposed to a single source of income (i.e., oil and gas), which is extremely volatile.

To assess the extent to which renewable investments are in line with a *revenue maximization* strategy, we analyze whether announced renewable energy targets are appropriate to substitute oil through renewables in

14 Oman and Bahrain are not included because of their different macroeconomic and carbon profiles. For example, Ohman and Bahrain have much lower carbon reserves and reserve-to-production ratios than Kuwait, Qatar, Saudi Arabia and the UAE (British Petrol, 2018).

15 World Economic Forum, 2018.

16 International Energy Agency, 2018a.

17 Common to these countries is that they have their currencies pegged to the US$ or a currency basket.

18 International Energy Agency, 2018a.

electricity production. To evaluate the *socioeconomic impact* of renewables, we look at the extent to which announced renewable investments help GCC countries in their aim of addressing unemployment. To consider the role of renewables as a means of *hedging*, we compare reserve to production ratios with the average production cost per barrel across oil-producing countries. Then, we look at how the announced renewable targets would affect the income streams of GCC countries in a low oil price environment. To analyze the *geopolitics* of renewable investments, we look at the link between renewables and aspects of energy security, global market shares in oil, and the United Nations Framework Convention on Climate Change (UNFCCC) goals.

In analyzing the question of whether it makes sense for Gulf countries to invest in renewables, this report draws on public sources, interviews, reports, announcements, and a newly compiled comprehensive set of data on green project finance. For this dataset we use Thomson Reuters' Securities Data Company (SDC) Platinum database as a baseline source. SDC Platinum is a comparable data resource on project finance across the globe. Using the search function for *renewable energy, solar, wind, hydro-electric, geothermal,* and *biomass,* the SDC Platinum database picked up 4,799 discrete announcements worldwide with an estimated value of $1.6 trillion between 2004 and 2018. By comparison, the total cumulative of global green investments (including project and commercial finance) over the same period is estimated at $2.9 trillion.[19] To provide a comprehensive picture of renewable investments in the Gulf this report complements the SDC database with a variety of other publicly available sources, such as Bloomberg and IRENA. Differences between investments in one country versus other countries helps to make sense of energy strategies and projects financed, planned, and implemented, as well as targets and debates.

19 Frankfurt School-UNEP Centre and BNEF, 2018.

1.2 **Article Map**

Part One of the report involves an overview of renewable projects (and their GW capacity) across the world and in GCC countries. That helps us to compare renewable energy targets, renewable energy projects announced, and those that have been completed across GCC countries. From this comparison, we can then see similarities and differences. Having a better grasp of this variation is important to assess the question of whether it makes sense for Gulf countries to invest aggressively in renewables vis-à-vis the perspectives presented in the second part. Following a qualitative literature review, the second part of the report identifies the four arguments that are regularly used to justify renewable investing, including: revenue maximization in terms of freeing oil from domestic consumption for export, hedging against asset stranding risks and low oil income, renewable investments as a means for job creation, and renewable investments as geopolitical tools in terms of increasing hard and soft power. The report then outlines and defines the expectations of each of these arguments and examines them vis-à-vis empirical evidence in the four cases.

2. Background conditions and trends in renewable investments across GCC countries

There are a number of conditions in place strongly suggesting that GCC countries could become leaders in renewables.[20] First, GCC countries are entering the global solar market at a point in time where a clearer picture has emerged about the economics of renewables.[21] Drawing on the experience of other countries, and by taking advantage of falling PV costs—thanks to China—GCC countries could benefit from being a late adopter of renewables.[22] Furthermore, GCC countries are starting to grow their renewables from a very low level, which suggests room for further growth that could last 10 to 15 years, before the Saudi Arabian market becomes saturated.[23] The growth potential of renewables among GCC economies is further backed by ambitious official goals, and an overall sound fiscal position across these countries.

Second, the region is well endowed with solar and wind resources. Developing only one percent of the suitable area in the region could lead to 470 GW of PV capacity and 60 GW of wind capacity.[24] Furthermore, GCC countries are located on a continent with a high future demand for electricity. Beyond the Arabian peninsula, Africa is expected to be a principal site of economic growth and energy demand growth over the coming decades.[25] For example, utility scale PV farms in West Saudi Arabia could feed in to the GCC Interconnector[26] and supply evening demand for Dubai or Muscat.[27] Initial steps toward creating a Pan-Arabian electricity market have already been taken with the creation of the GCC Interconnection Authority in 2001, which aims

20 *Saudi Gazette*, 2019.

21 Al-Sheri, 2018.

22 Poudineh et al., 2018.

23 Al-Shehri, 2018.

24 International Renewable Energy Agency, 2016.

25 Khan, 2018.

26 The GCC Interconnector refers to a electrical transmission link between the GCC member states.

27 Wogan et al., 2018b.

to interlink the energy infrastructure among Oman, Bahrain, Qatar, Kuwait, Saudi Arabia, and the UAE.[28]

Third, renewable energy investments are considered critical to meet the Paris commitments of the UNFCCC. To date, the four GCC countries are among the highest per capita producers of CO_2, surpassing the OECD country average (see Figure 1).[29] By 2018, all four had submitted their Intended Nationally Determined Contribution (INDC) to the UNFCCC. According to Osamah Alsayegh, Executive Director of the Energy & Building Research Center at the Kuwait Institute for Scientific Research, these numbers have a political influence, by commitment of major oil exporters to CO_2 emissions mitigation.[30]

Saudi Arabia and the UAE were among the first GCC countries in 2016 to submit the INDC to the UNFCCC Secretariat. Both countries have identified the critical role of renewables in reducing their CO_2 emissions by emphasizing the role of solar PV, solar thermal, wind and geothermal energy, and waste-to-energy systems. Saudi Arabia has highlighted mitigation co-benefits ambitions of up to 130 million tons of CO_2 avoided by 2030.[31] That is an ambitious goal, given that over the period between 2007 and 2017, Saudi Arabia experienced an average annual increase of emissions by 4.7 percent from 392.5 million tons in 2007 to 594.7 million tons in 2017.[32] By comparison, over the same period France decreased its emissions by -1.9 percent, which was equivalent to 44 million tons of CO_2 equivalents.[33] Similarly, Italy experienced an average annual decline of -3.2 percent in emissions (equivalent to a total of 116 million tons of CO_2 by 2017).[34] The UAE has set a target of increasing clean energy contribution to the total energy mix from 0.2 percent in 2014 to 24 percent by 2021.[35] By contrast, Qatar and Kuwait followed a more cautious approach by not stating any specific benchmarks or targets.[36]

28 However, to date most of this interconnection capacity remains underutilized (Poudineh et al., 2018). According to an industry expert, the issue of energy independence and energy security is what blocks energy interconnection (Padmanathan, 2018).

29 Howarth *et al*., 2017.

30 Alsayegh, 2018.

31 Kingdom of Saudi Arabia, 2015.

32 British Petrol, 2018.

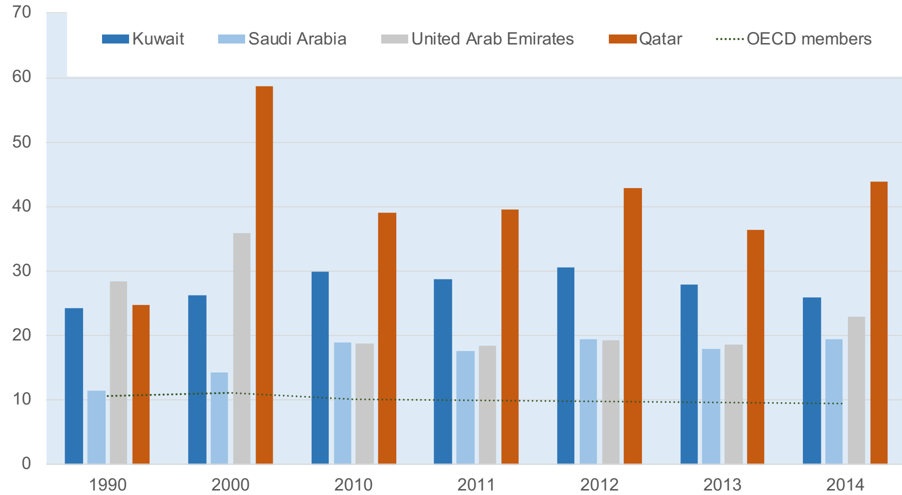
33 Ibid.

34 Ibid.

35 Government of the UAE, 2015.

36 State of Qatar Ministry of Environmnet, 2015; The State of Kuwait, 2015.

Figure 1: Growth in CO_2 Emissions in GCC countries versus OECD members between 1990–2014 (in metric tons per capita)



Source: World Bank data, 2018.

Fourth, investments in green technologies and renewables could become important strategic components in helping GCC countries to increase, or, at least to maintain, their shares in the global oil market. According to Nader Sultan—the former chair of the Kuwait Petroleum Corporation—the image of the oil sector as "clean" will play an increasingly important role in the quest for market shares in the global energy scene, where oil faces increasing competition from other forms of energy, such as renewables.[37] A statement of Libya's former oil minister Ghanem that the "calling for cleaner motor fuels is forcing refiners to reduce the amount of sulfur and other chemicals in gasoline and diesel to extremely low levels" draws attention to pressure among GCC countries to invest in green technology.[38] That is illustrated by a number of refinery projects, such as the Clean Fuels Project and the Fourth Refinery (both in Kuwait), which will produce low-sulfur oil and are jointly expected to exceed investments of $30 billion.[39] GCC countries already have a very low greenhouse component in the production of their oil (see Figure 2).[40] According to Axel Pierru—research director at the King Abdullah Petroleum Studies and Research Center (KAPSARC)—the GCC's low carbon footprint in oil production is already a comparative advantage for selling their oil to countries that want to buy oil that is environmentally friendly.[41] If major oil importers, such

37 Sultan, 2018.

38 Ghanem, n.d.

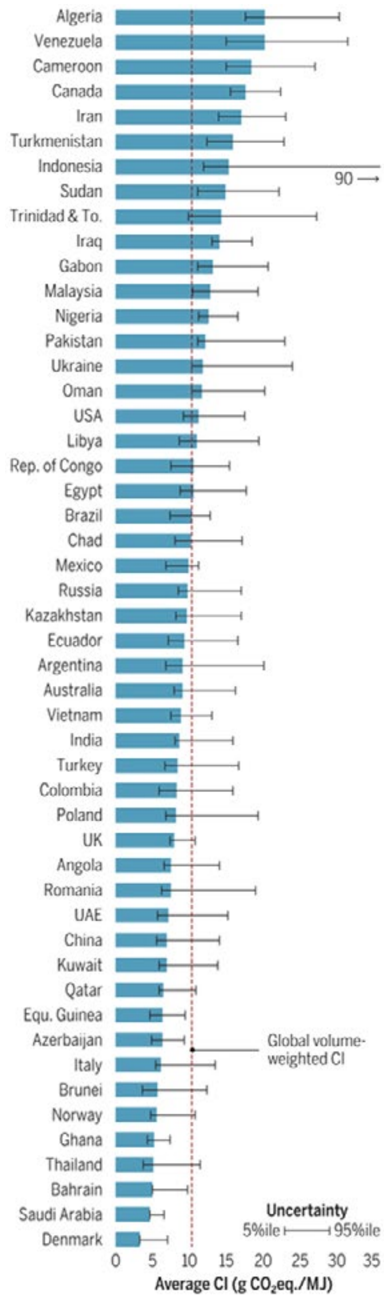
39 ExportGov, 2018.

40 Furthermore, see Oil-Climate Index, 2019.

41 Pierru, 2019a.

as China, start to phase out their most carbon-intensive oil imports, this could further shift market shares, to the advantage of GCC countries.[42]

Figure 2: National volume-weighted-average crude oil upstream GHG intensities in 2015



Source: Masnadi et al., 2018, p. 852

Note: The global volume-weighted carbon CI estimate is shown (red line, ~10.3 g CO_2eq./MJ). Error bars reflect 5th to 95th percentiles of Monte Carlo simulation to explore the uncertainty associated with missing input data (see SM 1.7 and 2.4).

42 “Aramco is cleanest supplier of oil to China, US research finds,” *Arab News*, n.d.)

2.1 Renewable investments across GCC countries

Renewable investment targets in GCC countries, notably in Saudi Arabia and the UAE, are large in relative as well as in absolute terms compared to other countries and regions. For the period 2008-2018, the total financing needs of both completed and announced renewable projects in Saudi Arabia, the UAE, Kuwait, and Qatar are $155bn.[43] There is large interregional variation in terms of announced renewable projects across GCC countries. If we take official 2030 targets, Saudi Arabia plans to have installed a capacity of 1.2 megawatt (MW) renewables per 1,000 people; the UAE a capacity of between 1.7–3.1 MW; Kuwait a capacity of between 1.2–2.5 MW; and Qatar a capacity of between 0.7–1.8 MW.[44]

Another remarkable characteristic of renewables in GCC countries is their project size. For example, Saudi Arabia announced in November 2018 a $1.2bn mega-solar PV project with a capacity of 1.8 GW.[45] On average, renewable energy projects in the GCC are much larger than in the US (see Figure 3).[46] While the US' $173 bn in announced renewable project finance deals between 2004-2018 refer to 610 projects, the GCC's $155bn relates to merely 49 projects—further subdivided into development stages. Hence, on average, a solar project in the GCC costs $3.2bn, whereas an average solar project in the US costs $283mn, which is slightly below the world average costs of $322mn.[47] The massive size of GCC projects can partly be explained by ownership characteristics. While in most countries the solar industry is organized by the private sector, in GCC countries the state is the major off-taker and agent for large-scale projects. For example, in Kuwait it is the Ministry of Electricity and Water, the Kuwait Petroleum Corporation, and the Kuwait Institute for Scientific Research, whereas in Qatar it is the Qatar General Water and Electricity Corporation and the Qatar Science and Technology Park. In Saudi Arabia, it is the Saudi

43 see Appendix 1 and database from SDC Plantinum (Thomson Reuters, n.d.)

44 Calculated with data from Appendix 2 by dividing MW solar PV and CSP targets through population number (both local and foreign) and multiplied by 1,000.

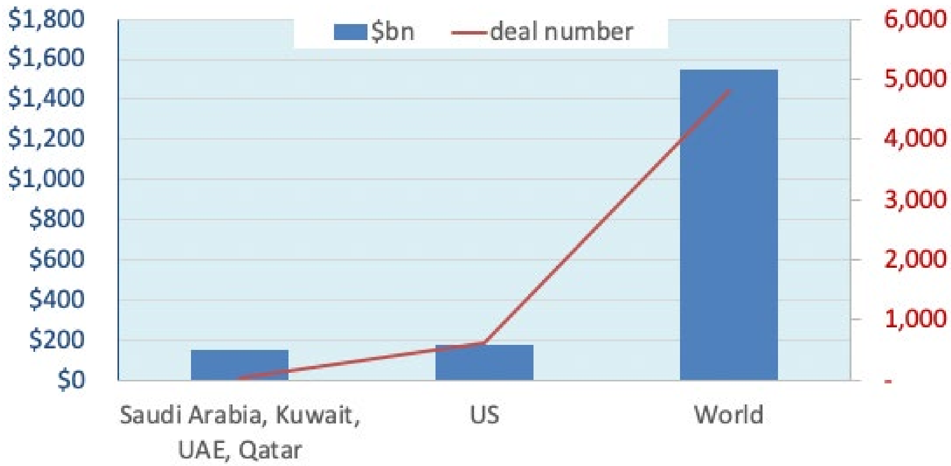
45 Martin and Nair, 2018.

46 See Appendix 1, and data from Thomson Reuters SDC Platinum database on 'Project Finance'.

47 Even by excluding the mega KA-CARE solar project (with 40 GW and project costs of US$ 112bn), the average GCC project would still be with US$ 908mn—more than three times as large as an average project in the US.

Electricity Company, together with Aramco and KACARE, and in the UAE, it is the Dubai Electricity and Water Authority and the Abu Dhabi Water and Electricity Authority and MASDAR.

Figure 3: Comparison of announced renewable deals and deal volume in $ (between 2004-2018)



Source: Calculated with data from Thomson Reuters SDC Platinum database on 'Project Finance'. Note: US and World referring to announced project finance deals only.

Between 2015 and 2018, renewable energy announcements showed an impressive growth across GCC countries (see Figure 4). That was also a period of lower oil and gas prices.[48] The abrupt drop in oil revenues in 2014 put pressure on public budgets of GCC countries, which in turn triggered reforms in economic diversification with the aim of reducing the dependency on fossil fuels.[49] Saudi Arabia's Vision—publicized in 2016—aims to triple non-oil economic activity by 2030, and Kuwait also announced in its National Development Plan their aim to develop a prosperous and diversified economy and to reduce its dependence on oil.[50] Similar goals were outlined in Qatar's National Vision 2030 and Abu Dhabi's Economic Vision 2030.[51] A central aspect in all of these future visions relates to the development of the renewable energy sector. Saudi Arabia aims to install 9.5 GW of capacity from renewables by 2023 and 40 GW from solar PV

48 There have been some renewable project announcements before 2015, but they came exclusively from Dubai— an Emirate that produces little oil.

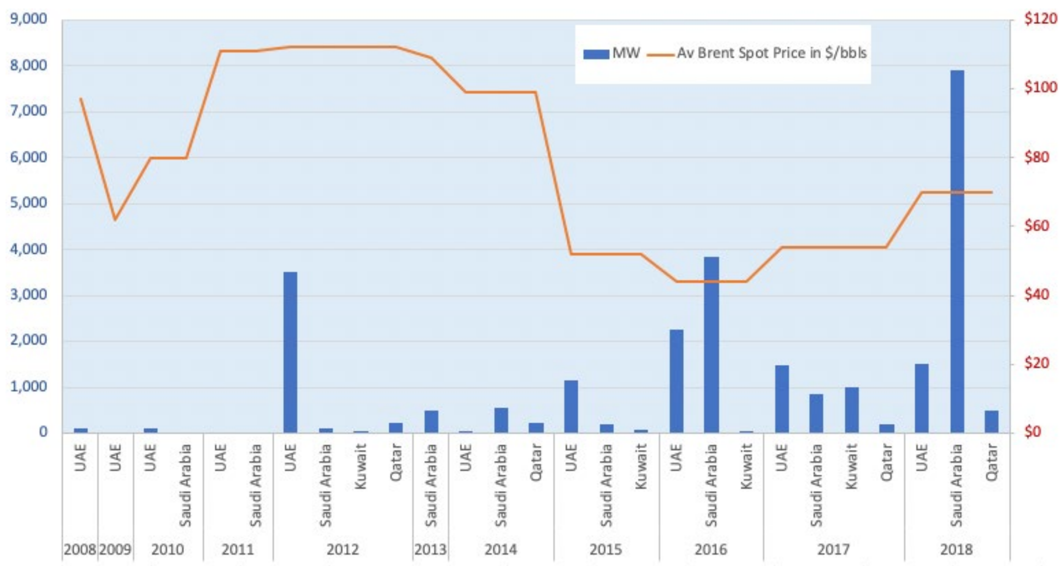
49 Wogan et al., 2018a.

50 Council of Economic and Development Affairs, 2016.

51 It should be highlighted that Abu Dhabi Economic Vision and Qatar Vision were already in place before the oil drop in 2014.

and CSP by 2030; the UAE aims to generate at least 25 percent of its electricity from renewables by 2030; Kuwait's National Development Plan projected to produce 15 percent of electricity from renewables by 2030 and Qatar aims to produce 20 percent of its electricity from renewables.[52]

Figure 4: Solar project announcements (in MW) and average price b/d between 2008—2018



Source: Data compiled from Appendix 1, and British Petrol, 2018.

Note: Excluding the 200 GW capacity announced by Softbank and Saudi Arabia in 2018; and excluding the 40 GW capacity announced by K-Care in 2012; and excluding the 40 GW of CSP and solar capacity announced by Saudi officials in January 2019.

Despite ambitious renewable energy targets, as of 2018, there is a huge gap between announced and completed projects (see Figure 5). This gap partly reflects the variance in the development timeline and the institutional supporting environment. While policy makers of all GCC countries have made ambitious renewable announcements, as of 2018, only the UAE has supporting policy frameworks and regulations in place for the deployment of renewables, such as feed-in tariffs, electric utility quotas, tendering, and investment production tax credits.[53] Beyond that, some of the GCC countries, notably Kuwait, have separate ministries for both oil and electricity/industry with diametrically opposed preferences toward fossil fuel prices. The Ministry of Electricity and Water as well as the Ministry of Commerce

52 See Appendix 2.

53 Alsabbagh and Al-Jayyousi, 2018; Griffiths and Orkoubi, 2018.

and Industry's preferences toward cheap fossil fuel has long hampered price reforms and the removal of fuel subsidies. Likewise, in Saudi Arabia the Ministry of Water and Electricity had a mandate of meeting domestic demand for electricity and water regardless of the effects on the country's oil export capacity.[54] The Saudi Electricity Company kept building new oil-fired power plants until the creation of a new Ministry of Environment, Water and Agriculture in 2016 with a broader mandate of conservation and protection of resources.[55]

In spite of a significant price drop in PV modules and onshore wind technology, renewables are still relatively too expensive vis-à-vis heavily subsidized fossil fuels in GCC countries. Regulated energy prices and generous fuel subsidies in the region remain a major obstacle to the widespread introduction of renewables.[56] Energy and water prices in GCC are amongst the lowest—until recently water remained free of charge to nationals in Qatar and Abu Dhabi and very low in other countries.[57] In GCC countries, retail residential electricity tariffs range from 0.007$/kWh in Kuwait, 0.013$/kWh in Saudi Arabia, 0.056-0.087$/kWh in Abu Dhabi, and 0.078-0.121$/kWh in Dubai.[58] By late 2016, all of the four GCC countries had started to embark on reform of subsidies, with differing levels of success.[59] The UAE is the only country among the four GCC economies where solar is competitive.[60]

54 Krane, 2018.

55 Ibid.

56 Wogan et al., 2018a.

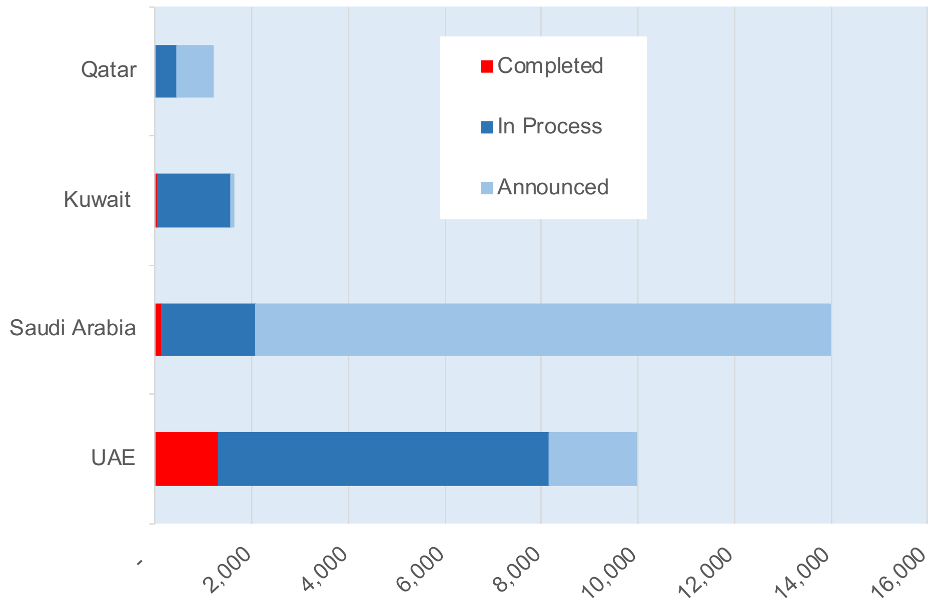
57 Lahn, 2016.

58 IRENA 2016, 49.

59 Lahn, 2016; Young, 2018.

60 Poudineh et al., 2018.

Figure 5: Total MW of solar PV and CSP announced, in process, and completed by 2018



Note: Excluding the 200 GW capacity announced by Softbank and Saudi Arabia in 2018; and excluding the 40 GW capacity announced by K-Care in 2012; and excluding the 40 GW of CSP and solar capacity announced by Saudi officials in January 2019.

To date more than 90 percent of all the renewable projects in the region are in the planning or process stage.[61] Renewable energy capacity in the MENA region remains well behind the rest of the world.[62] In high income countries, non-hydro renewables make up nearly seven percent of electricity capacity, whereas in MENA region it is well below one percent.[63] The number of projects completed by 2018 remains small in GCC countries. The majority of projects are still in the process stage. That can be partly explained by the development timeline, which for a utility scale solar power plant with a size of MW 250 can take up to six years.[64] While the actual construction phase for a utility scale solar plant requires one to two years, the development phase, including planning and site acquisition, negotiation of power purchase agreement (PPA), generator permission, and PPA approval and financing can take up to four years.[65]

61 See Appendix 1.

62 Poudineh et al., 2018.

63 Poudineh et al., 2018, p. 122.

64 Solar Energy Industries Association, 2019.

65 Ibid.

Narrowing this gap and realizing the energy transformation requires enormous technological and financial resources. By 2018 only the UAE, specifically the Emirate of Dubai, has completed a significant number of renewable projects. Dubai had already announced its ambitious solar plans in 2012, whereas the majority of other GCC countries have started announcing their projects from 2016 onwards. As of 2018, Saudi Arabia has completed seven solar projects with a total of 136 MW capacity.[66] This means that Saudi Arabia would need to add annually on average more than 2,000 MW to reach the 9.5 GW target by 2023; or more than 3,000 MW to reach the 40 GW target by 2030.[67]

2.2 Revenue maximization

Under the revenue maximization rationale, substituting renewables for oil in domestic energy production allows a country to maximize revenues from oil exports. Revenue maximization is a sensible rationale for GCC countries, which have emerged to become major fossil fuel consumers in absolute as well as relative terms over the last decades.[68] As of 2018, GCC countries generate almost 100 percent of their electricity by burning fossil fuels (i.e., gas and oil). Per capita energy use across GCC economies has been higher than in the US and OECD countries (see Figure 6). The dramatic increase in domestic oil consumption, particularly for the generation of electricity, could limit the capacity of GCC countries to export their oil, which constitutes the main source of state revenues in the region.[69] The IRENA estimates that around 80 percent of government revenues in the region come from the export of fossil fuels.[70] The idea behind investing renewables under a revenue maximization perspective is to replace the oil component of electricity generation with renewables, and export the oil instead.

66 See Appendix 1.

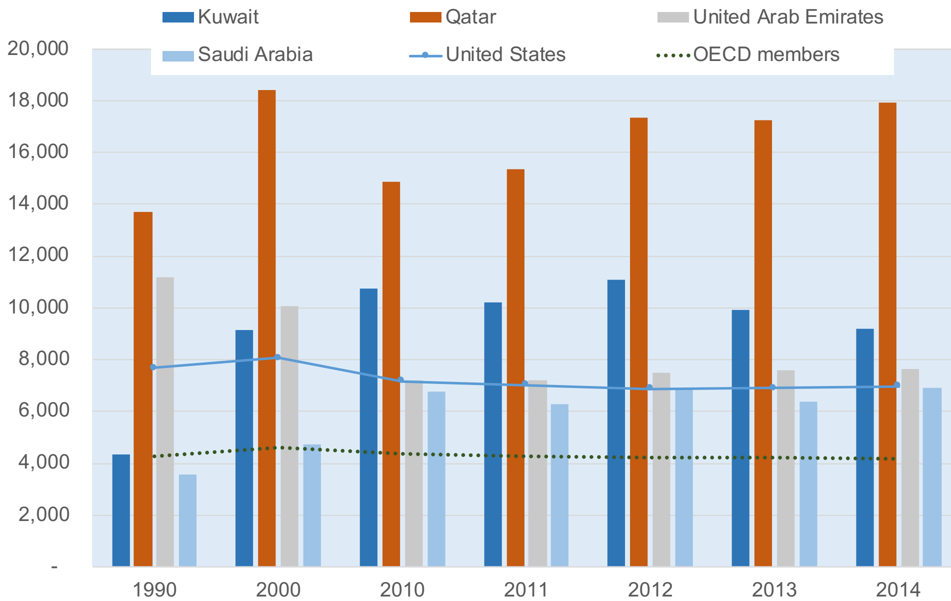
67 See Appendices 1 and 2.

68 Fattouh et al., 2018; Reiche, 2010; Sultan, 2013.

69 Lahn and Stevens, 2011.

70 International Renewable Energy Agency, 2016.

Figure 6: Per capita energy use in GCC countries, OECD members, and the US between 1990 and 2014 (in kg of oil equivalents)



Source: World Bank data 2018.

2.2.1 **Saudi Arabia**

In 2016, Saudi Arabia became the sixth largest oil consumer globally.[71] During the summer of 2015, the country consumed nearly one million barrels of oil per day (i.e., 0.9 mmb/d from July to August) for power generation (see Figure 7).[72] Reports warned that if this trend were to continue, then Saudi Arabia's growing domestic oil consumption for the production of electricity could limit its exports of oil over the next decade.[73] Although the oil consumption for power generation has decreased slightly since then, it still remains high.[74] What is remarkable is the increase in heavy fuel oil and the reduction of crude and diesel in the energy mix used for producing electricity from 2015 onwards.

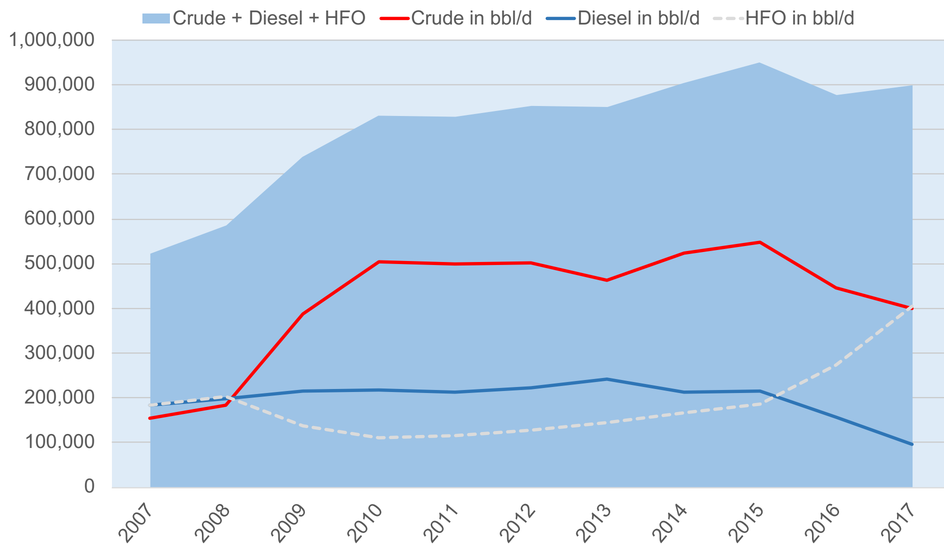
71 US Energy Information Administration, 2018.

72 US Energy Information Administration, 2019.

73 Lahn and Stevens, 2011.

74 Ibid.

Figure 7: Barrel of Crude/HFO/Diesel used for electricity generation per day in Saudi Arabia



Source: calculated with data from the Electricity and Cogeneration Regulatory Authority, 2019; Energy Information Agency.

Weather conditions and lack of water necessitates the increasing use of electricity for air conditioning and water desalination.[75] In 2018, Saudi Arabia reached the same level of electricity consumption as Italy, despite having only half the size of population and the per capita income being 35 percent lower than in Italy.[76] In terms of electricity generation, Saudi Arabia overtook the net electricity importer Italy already much earlier (see Figure 8). Concerning the use of oil for electric power generation, Saudi Arabia is the largest consumer in the world. Nearly half of the feedstock for the generation of electricity (i.e., about 40 percent) comes from oil and the remainder comes from natural gas.[77] To date, Saudi Arabia's gas consumption has been covered by its domestic production.[78]

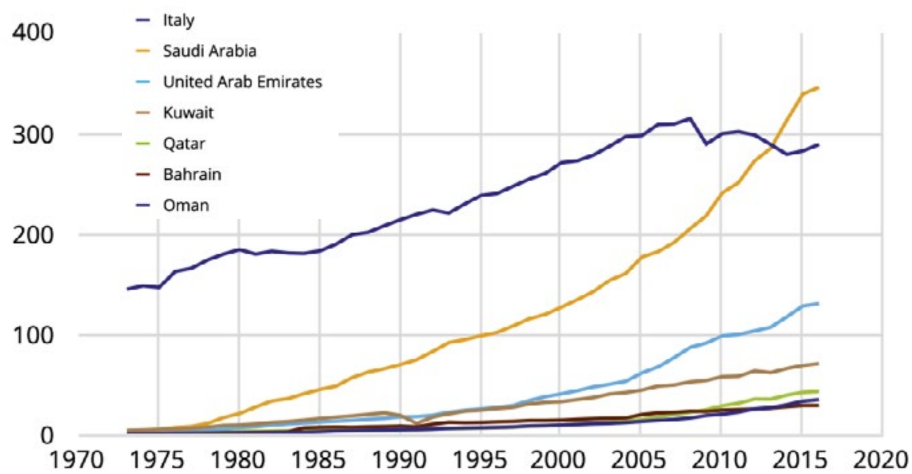
75 Van de Graaf, 2018.

76 International Energy Agency, 2018b.

77 British Petrol, 2018.

78 Saudi Arabia consumes all the gas it produces. Saudi Arabia is with 102 cu.m the world's ninth largest producer of natural gas and with 102cu.m the eighth biggest consumer of natural gas (Central Intelligence Agency, 2018a).

Figure 8: Growth of Electricity generation (TWh) in Italy and GCC countries between 1973 and 2016



Source: International Energy Agency, n.d.

Saudi Arabia's growing domestic oil consumption, particularly for the production of electricity, eats into its oil export capacity and thereby limits revenues from oil export. By burning up to 900 thousand brl of oil per day during peak season, Saudi Arabia forgoes revenues of up to $16 billion per year in a low oil price environment (i.e., $50/bbl). Over the past 10 years, the overall average daily oil consumption (including transport and petrochemicals) increased by 5.6 percent annually, at a much faster rate than oil production (i.e., 1.5 percent).[79] The average growth in electricity consumption increased even faster, with 6.6 percent between 2006 and 2016 at a much more rapid pace.[80] Some energy policy experts, such as Robert F. Ichford from the Atlantic Council, even estimate an 8-10 percent annual growth in Saudi Arabia's electricity over the coming years.[81] The share of oil in electricity generation has remained constant at around 40 percent over the past decade.[82] Therefore, if the share of oil in electricity production remains constant over the next several years, then Saudi Arabia could follow China's historical experience. The comparison illustrates the scenario by showing what could happen to an oil net exporter when linear increases in domestic oil consumption severely affect the export capacity of an oil-exporting country.

79 British Petrol, 2018. For average oil consumption and production 2006-2016 (see Appendix 3).

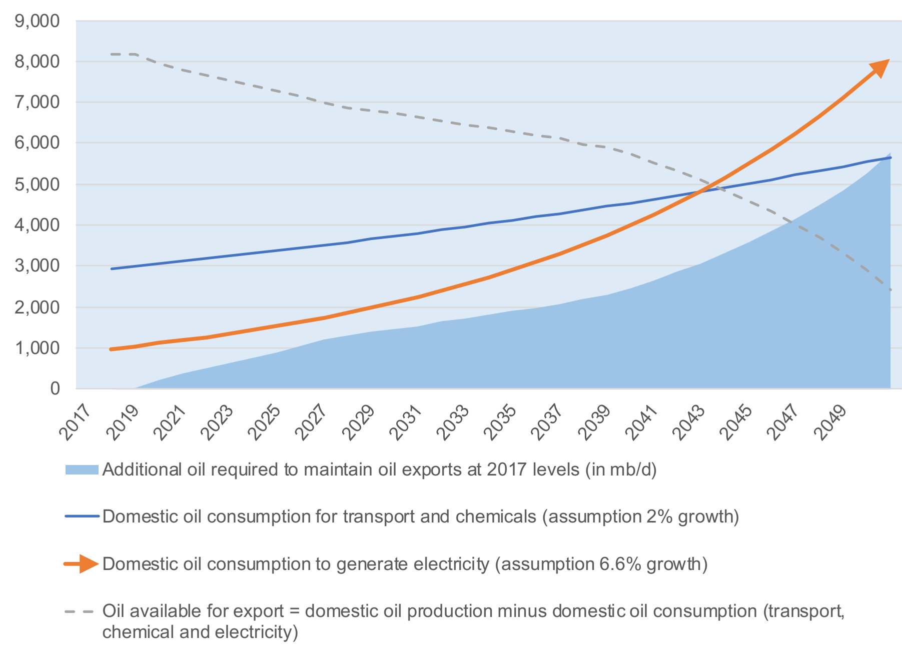
80 British Petrol, 2018.

81 Ichford, 2019.

82 British Petrol, 2018; Electricity and Cogeneration Regulatory Authority, 2018.

Even in a scenario where Saudi Arabia is able to increase domestic oil production significantly a linear growth in domestic oil consumption for electricity generation would still affect Saudi Arabia's oil export capacity. For example, maintaining Saudi Arabia's 2017 oil export levels would require the additional production of 1.5 mmb/d in 2030 and 3.3 mmb/d in 2043 (see Figure 9). Although according to former oil Minister Al-Naimi Saudi Arabia has the capability to build oil production capacity to 15 mmb/d it remains uncertain whether Saudi Arabia is able to increase its oil production to that extent.[83]

Figure 9: Additional oil needed in Saudi Arabia to maintain 2017 oil export levels under a linear electricity consumption scenario and growing oil production



Source: Calculated with data from Appendix 3.

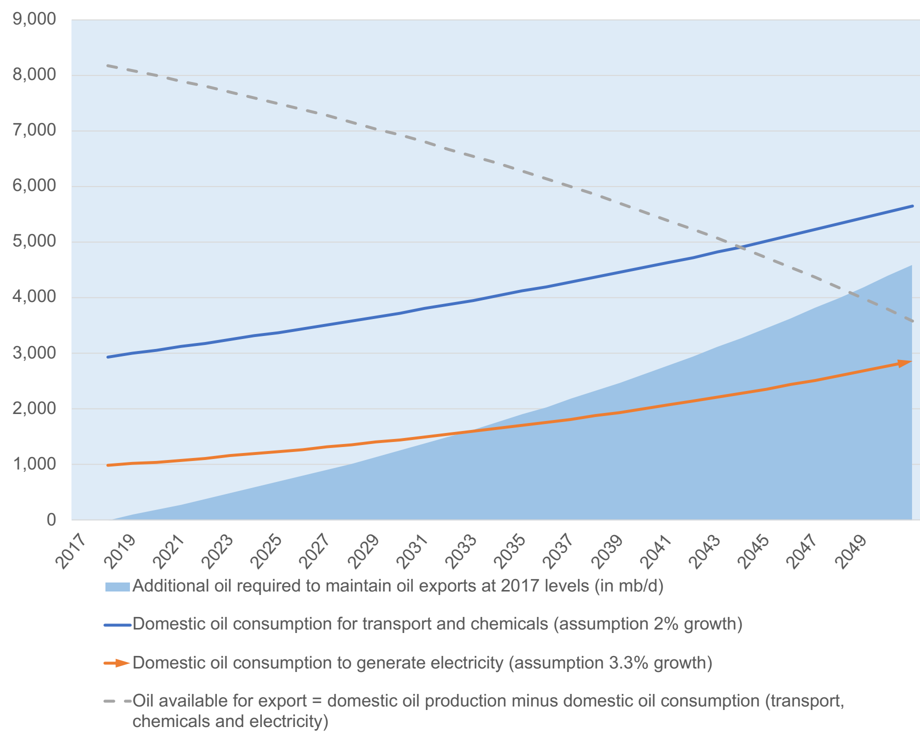
Given that oil consumption and electricity growth are critically linked to economic growth, a linear growth of oil consumption is not the most likely scenario for Saudi Arabia over the coming years. The relationship between slowing GDP growth and slowing oil consumption was illustrated by a sharp drop in GDP growth and electricity growth from 1.6 percent in 2016 to -0.7 percent in 2017 and a drop in electricity growth from three percent in 2016 and to 1.7 percent

83 "A Conversation with His Excellency Ali Al-Naimi, Minister of Petroleum and Mineral Resources, Kingdom of Saudi Arabia." 2013. CSIS.

in 2017.[84] Consequently, many observers, notably officials from the Renewable Energy Project Development Office (REPDO), don't see oil for domestic energy consumption in Saudi Arabia growing at the speed of the past.[85]

A more moderate growth scenario for the Middle Eastern region was proposed in Siemens' "Middle East Power Outlook for 2035."[86] The Siemens report estimates power demand growth of 3.3 percent per annum in the region.[87] That is half of the average growth rate of Saudi Arabia experienced between 2006—2016. Yet even under such a moderate domestic electricity consumption growth scenario and the assumption of increasing domestic oil production to 12.7 mmb/d in 2030 Saudi Arabia would still need to free around 0.777 mmb/d in 2030 in order to maintain 2017 export levels of oil (see Figure 10).

Figure 10: Additional oil needed in Saudi Arabia to maintain 2017 oil export levels under a moderate electricity consumption scenario and no oil production growth



Source: Calculated with data from Appendix 3.
Note: Holding oil production constant at 2017 levels (i.e. 12mmb/d).

84 British Petrol, 2018; World Bank, 2018a.

85 Al-Sheri, 2018.

86 Siemens, 2018.

87 Siemens, 2018, p. 4.

Replacing oil consumption for electricity generation with renewables in order to maintain oil exports seems a sensible choice for Saudi Arabia even in a moderate oil consumption scenario. As highlighted, a 3.3 percent increase in domestic oil consumption would require additional 0.777 mmb/d in 2030 if Saudi wants to maintain 2017 oil export levels.[88] Freeing up that amount of oil would require approximately 83 GW of solar PV.[89] While the announced 200 GW renewable target— by the Crown Prince earlier in 2019—would be more than enough to cover a moderate oil consumption growth for electricity production, the 9.5 GW renewable capacity target for 2023 (under Vision 2030) and the 40 GW target by 2030 is far below what would be required.[90] Hence, even if historic growth rates in oil use for electricity demand are not maintained, the scale of growth in relative terms is still profound and exposes a huge gap between the renewables ambitions and the reality of what will likely be possible to deliver.

However, if Saudi Arabia is successful in curbing domestic oil consumption growth to zero, then the 40 GW solar target would allow Saudi Arabia to replace around 350 mb/d burned for producing electricity every day. This would be equivalent to 4/5 of the crude component used in the oil mix (i.e. HFO, crude, diesel) for generating electricity (see Figure 7).

Renewable capacity by year	Capacity needed under a linear growth scenario	Capacity needed under a moderate growth scenario (3.3%)	Capacity Target
2023	81 GW	54 GW	9.5 GW
2030	163 GW	83 GW	40 GW

88 See Appendix 3.

89 We assume a capacity factor of 25 percent (i.e. the ratio of the actual output of a solar power plant over a period of time) and existence of flexibility measures, such as storage.

90 See Appendix 3.

2.2.2 **Kuwait**

Kuwait produces more than half of its electricity by burning oil. As in Saudi Arabia, domestic oil consumption in Kuwait has been steadily increasing, partially as a result of increased petroleum-fired electricity generation.[91] But in Kuwait, oil consumption is much lower in absolute and relative terms. Likewise, for Kuwait, the average domestic oil consumption growth between 2006 and 2016 was, with 1.8 percent growth, much lower than in Saudi Arabia.[92] Kuwait burns around one-sixth of the oil it produces for electricity generation and the desalination of water, which is around 340 to 350 mb/d.[93] According to Alsayegh and Fairouz, oil consumption for electricity and water could reach one-fifth of the total oil production in Kuwait by 2020.[94] This makes Kuwait the second largest consumer of crude oil for the generation of electricity in the region. The remaining electricity is produced by burning gas.[95]

Under the assumption that Kuwait can significantly increase domestic oil production the strategic effect of substituting for oil through renewables in order to free additional oil for export is much smaller for Kuwait than for Saudi Arabia. Thanks to Kuwait's relatively large domestic oil production and reserves relative to the small population, the country could continue burning oil for electricity production without seeing its oil export revenues severely affected.[96] Kuwait has around 24,047 bbl of oil reserves per capita, whereas Saudi Arabia has 8,060 bbl of oil reserves per capita, which means that the Kuwait reserve stock of oil per capita is three times higher than Saudi Arabia's, but with a much smaller population.[97] According to official sources Kuwait plans to increase production capacity to 4 mmb/d over the next decade and oil production is projected to reach 3.5 mmb/d in 2035 in a business as usual scenario.[98]

91 US Energy Information Administration, 2016.

92 See Appendix 3.

93 Alsayegh and Fairouz, 2011, p. 871.

94 Ibid.

95 Out of Kuwait's total domestic gas consumption of 845,538 TJ in 2016, around one-third was used for producing electricity (International Energy Agency, 2019a).

96 International Energy Agency, 2019a. See Appendix 3.

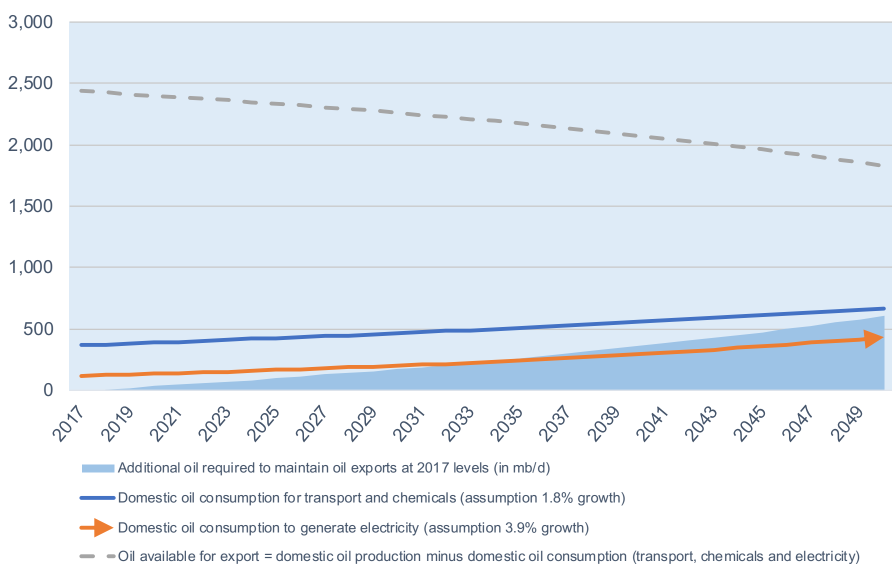
97 Calculated by using data from world demographic data and oil reserve data (OPEC, 2017; World Bank, 2018b).

98 KISIR, 2019.

However it remains highly uncertain whether Kuwait can significantly increase its oil production capacity over the next decades. Struggles in Parliament have inhibited foreign investment in the past. If Kuwait is not able to increase oil production significantly (i.e. beyond the 2.4 mmb/d in 2017) and if electricity demand continues to grow at 3.9 percent, Kuwait's ability to export oil would be affected (see Figure 11). For example, keeping 2017 oil export levels at around 2.4 mmb/d in 2030 would require an additional 176 mb/d.[99]

Freeing up that amount of oil would require approximately 19 GW of solar PV.[100] In a more moderate oil consumption scenario with only 1.6 percent growth, Kuwait would still need an additional 123 mb/d of oil to maintain 2017 levels of oil export. Replacing the 123 mb/d of oil in the electricity sector would necessitate around 13 GW of solar PV. In both, linear as well as moderate consumption growth scenarios of the GW solar targets required to replace additional oil consumption are above the renewable estimates for Kuwait in 2030 produced by IRENA (7.8GW) and KAPSARC (10.3GW).

Figure 11: Additional oil needed in Kuwait to maintain 2017 oil export levels under a linear consumption scenario (and no growth in oil production)



Source: Calculated with data from Appendix 3.
Note: Holding oil production constant at 2017 levels (i.e. 2.9mmb/d).

99 See Appendix 3.

100 We assume a capacity factor of 25 percent (i.e. the ratio of the actual output of a solar power plant over a period of time) and existence of flexibility measures, such as storage.

2.2.3 **UAE & Qatar**

Though electricity in the UAE and Qatar is almost fully generated by burning gas, both countries have also become major oil consumers. While Saudi Arabia and Kuwait use around half of the domestically consumed oil for transport, a quarter for electricity, and another quarter for petrochemicals, the UAE and Qatar have a higher share of oil consumption in the transport and petrochemical sectors.[101] The UAE and Qatar are regional logistic hubs with leading global port operators, such as Dubai Ports World and airlines such as Emirates, Etihad, Ari Arabia, FlyDubai, and Qatar Airways. Over the period 2006-2016 the UAE and Qatar experienced an average annual growth in domestic oil consumption of 6.4 percent and 9.6 percent, respectively. It is unlikely that oil consumption in the UAE and Qatar will grow at the same speed as in the past. Qatar experienced a slowdown in oil consumption to a growth of 3.1 percent between 2016 and 2017, much lower than the growth rate over the period 2006-2016. Likewise, the UAE witnessed a drop in the growth of domestic oil consumption from an average of 6.4 percent between 2006 and 2016 to 0.4 percent between 2016 and 2017. In both cases, the decline in domestic oil consumption growth corresponds with a drop in GDP growth.[102] This means that in Qatar and the UAE, the consumption growth in oil comes exclusively from the transport and petrochemical sectors.

Due to differences in the import/export components of the domestic gas mix, the introduction of renewables for freeing up gas for export impacts revenue maximization in the UAE and Qatar. Qatar covers 100 percent of its domestic gas consumption for electricity generation through domestic gas production and as such, the introduction of renewables would free additional gas for export. Out of Qatar's total gas production of 150 mtoe, about 10 mtoe were used in 2017 as an input for domestic power plants.[103] Qatar would need solar capacity of 20.8 GW in order to replace gas from the energy mix which was responsible for generating 45,555 GWh in 2017.[104] By assuming a natural gas price of 2.5$/mmBtu—which is a conservative estimate—replacing 10 mtoe through renewables would allow the country to generate almost one billion

101 International Energy Agency, 2017a, 2017b, 2017c, 2017d.

102 British Petrol, 2018; World Bank, 2018a.

103 International Energy Agency, 2018.

104 International Energy Agency, 2017h.

USD in additional revenues from the export of gas. Qatar's target of 4.9 GW would generate about $250 million in additional revenues from the export of gas that is freed up by renewables, which is not significant compared to Qatar's overall budget and existing revenue streams from the export of gas.

The situation looks different for the UAE, which is both a gas producer and a gas importer.[105] As of 2017, the UAE imported one-third of its gas from Qatar, most of it cheaply from legacy contracts that date back to the early 2000s.[106] Another portion of the UAE's gas is bought at market rates on the world LNG spot market.[107] However, with 70 percent of the costs for gas-fired power generation, the fuel cost goes up and down in the global spot market every day—adding additional costs.[108] As such, the introduction of renewables to displace gas in power generation makes an economic case for the UAE for reducing the exposure to price volatility in the world gas market. This then depends on the size of the gas component that is acquired on the international market.

105 The UAE produced 2.3 mill tetrajoules (TJ) in 2016, it imported around 800,000 TJ and re-exported around 285,000 TJ (International Energy Agency, 2019a).

106 The pricing formula between Qatar and the UAE was negotiated before the sustained rise in oil and gas prices in 2002. Qatar delivered gas at an initial price of $1.25/MMBtu with slight increases every year, it stood at $1.5 in 2012. UAE benefits from this low-cost gas (Krane and Wright, 2014, p. 5). In 2011 Dolphine resold Qatari gas in the UAE for between $7 and 10/MMBtu (Krane and Wright, 2014).

107 Padmanathan, 2018.

108 Ibid.

Table 2:

GW targets for 2030	Do renewable investments make sense to ensure oil/gas export levels?	Is the renewable investment target sufficient to ensure oil/gas export levels?	Comment
Saudi Arabia 40 GW**	Yes	Depends	• In a linear oil consumption scenario for electricity production, Saudi Arabia would need 163 GW by 2030 in order to maintain 2017 oil export levels. • In a more moderate oil consumption scenario for electricity production (3.3%), Saudi Arabia would need 83 GW. • In a zero consumption growth scenario, the 40 GW solar target would allow for replacing 4/5 of the crude component used in the oil mix (i.e. HFO, crude, diesel) for producing electricity (see Figure 7).
UAE 15.9GW*	No	N/A	Only a marginal amount of oil is burned for electricity generation. However, renewables could replace part of the gas in the electricity mix, which is sourced at the international market (for a detailed discussion see the geopolitics part).
Kuwait 5.1 GW*	Depends	No	If Kuwait is not able to increase domestic oil production under a linear as well as a more moderate oil consumption growth scenario for electricity generation then this could affect the country's export capacity over the long run.
Qatar 4.9 GW*	No	No	Almost 100% of its electricity is produced by gas. The effect of introducing 4.9GW in solar capacity on revenues from additional gas exports is minimal.

* Author's calculation of GW based on official government generation targets (see Appendix 2 for the calculation of country targets).

** Official government target specified in GW.

2.3 **Job creation**

Population growth has been accelerating in GCC countries and a growing part of the population will be entering the workforce over the next several years.[109] Traditionally in GCC countries, the public sector has absorbed a large portion of nationals. However, this has become increasingly difficult with lower oil and gas prices—especially during the period 2015-2018.[110] A

109 Population growth rate estimates as of 2017: Saudi Arabia (1.45%), Kuwait (1.46%), UAE (2.37%), Qatar (2.27%) (Central Intelligence Agency, 2018b).

110 International Monetary Fund, 2017.

decline in fiscal revenue has required cuts in public spending, which dampens growth in the non-oil sector and strains the sustainability of public employment.[111] Smaller GCC countries, such as Qatar, have more room to maneuver, whereas larger countries like Saudi Arabia are more constrained by the limitations of their resources.[112] Reflecting this fact, job creation in the public sector has slowed down specifically in Saudi Arabia.[113]

Creating productive jobs puts increasing pressure on the GCC governments.[114] As of Q4 of 2018, there are nearly one million Saudis registered as job seekers in Saudi Arabia.[115] According to a senior Saudi labor ministry official, Saudi Arabia would need to create 1.2 million jobs by 2022 in order to achieve a nine percent unemployment target.[116] This could become a major source of instability in the region.[117] At the end of 2018, unemployment was at 40.5 percent, highest for Saudi nationals in the age group 15-19, followed by individuals in the age group 20-24, with 36.6 percent.[118] Commentators expect this number to further increase.[119] According to data from the International Labour Organization (ILO), Kuwait follows Saudi Arabia in terms of youth unemployment, but Kuwait is at 16 percent, much lower than in Saudi Arabia.[120] In the United Arab Emirates, unemployment in the age group 15-19 was 6.6 percent, and 29.1 percent in the age group 20-24.[121] By contrast, youth unemployment was very low at 0.5 percent among Qatari nationals in 2018.[122]

Job creation is an important factor behind renewable investment decisions.[123] Saudi Arabia signaled its determination to create jobs via renewables, whereas other countries, notably Kuwait, are not following an

111 International Monetary Fund, 2016.

112 International Energy Agency, 2018a.

113 International Monetary Fund, 2017.

114 International Energy Agency, 2018a.

115 General Authority for Statistics, 2018.

116 Rashad and Kalin, 2018.

117 International Energy Agency, 2018a.

118 General Authority for Statistics, 2018.

119 Arabian Business, 2016.

120 International Laboure Organization, 2018.

121 Federal Competitiveness and Statistics Authority UAE, 2017.

122 Ministry of Development Planning and Statistics, 2018.

123 EIB and IRENA, 2015; International Renewable Energy Agency, 2016.

explicit job creation strategy along the same lines.[124] Jobs that are associated with renewable energy systems operation and maintenance (O&M) are not expected to make a significant contribution. However, the value chain of the direct and indirect businesses of renewable energy is expected to open new business opportunities and hence new jobs.[125] Other industries that could benefit from the growth in domestic PV, CSP, and wind power manufacturing include the liquid crystal display (LCD) sector, the thin film technology display technology industry (i.e., organic light-emitting diodes or OLED), the glass and fiber glass industry, fertilizers, the semi-conductor sector, and mining.[126]

While Kuwait's focus is on the operation and management aspect of renewable energy, which is much less job intensive, Saudi Arabia is interested in investing along the whole value chain, including the manufacturing, construction, and deployment (MCD) phases, due to the greater job creation potential.[127] To maximize this potential, the Saudi government is willing to pay a reasonable premium.[128] The aim is to anchor supply chains with local suppliers, thereby creating jobs.[129] Via the In-Kingdom Total Value Add program, Saudi Arabia aims to boost local content levels—70 percent by 2021—in the procurement process, and prioritizes localization in all commercial arrangements in a wide range of different sectors, including renewables.[130] The ultimate aim of Saudi Arabia's National Renewable Energy Programme is to create a globally competitive local industry. To this end, the REPDO has imposed demanding rules requiring 30 percent local content for projects awarded. Over the coming years REPDO wants to see more than 60 percent of equipment being made domestically.[131] However, it is unlikely that Saudi Arabia can manufacture these components competitively as long as China is able to produce and export cheap solar panels to the

124 Abate and Martin, 2017; "High-Performance Glass Fiber Market Increasing Demand, Growth Analysis and Future Outlook 2019 to 2025," n.d.; McGrath, 2018.

125 Alsayegh, 2018.

126 Abate and Martin, 2017; "High-Performance Glass Fiber Market Increasing Demand, Growth Analysis and Future Outlook 2019 to 2025," n.d.; McGrath, 2018.

127 Alsayegh, 2018.

128 Al-Sheri, 2018.

129 Musbeh, 2018.

130 IKTVA, n.d.; Musbeh, 2018.

131 Côté, 2018a.

whole world.[132] One of the greatest challenges to Saudi Arabia's renewable energy ambitions is the lack of technological expertise, trained workforce, and manufacturing capabilities to compete on a global scale.

The IRENA estimates that there are 3.4 million people employed in the global solar sector, with a total installed capacity of 485 GW as of 2018.[133] As such, the GCC nations announced projects with a renewable energy capacity of 68 GW represents an enormous potential of job creation in the region. Through its employment factor approach, IRENA's study offers a benchmark on the number of full-time equivalent jobs created per unit of installed peak capacity (expressed in MW). Together with the renewable energy targets from 2018, this enables us to calculate the potential of job creation of renewable investments across the GCC countries.[134] According to IRENA's employment factor approach, Saudi Arabia's target of 40 GW in solar PV and CSP by 2030 has the potential of creating about 750,000 jobs in the manufacturing, construction, and deployment phases of PV and CSP and about 30,000 jobs in the operation and management phase (see Table 3). This would fit well with Saudi Arabia's strategy of creating more than 450,000 jobs by 2020 through the nongovernment sector.[135] The potential number of jobs created by renewables could address the problem of unemployment among the local population in Saudi Arabia.

132 Braunstein and McPherson-Smith, 2019.

133 International Renewable Energy Agency, 2019b, p. 24; "Renewable Energy and Jobs - Annual Review 2018," n.d.

134 To estimate the total number of direct jobs created, the employment factor is multiplied by renewable energy capacity; the formula is accordingly (MW of installed capacity [x] employment factor per MW). Due to different phases in the value chain of renewables which reflects different labour intensity, the employment factor approach uses different employment factors for different phases of life cycle, such as manufacturing, construction, and deployment or operation and maintenance activities (International Renewable Energy Agency, 2013).

135 Kingdom of Saudi Arabia, n.d.

Table 3: Comparison of the job creation potential in CSP and PV along different stages of the value chain

Concentrated Solar Plants (CSP)	Job creation potential across the value chain	
	Manufacturing, construction, and deployment (MCD) phase (factor 17.9)	*Operation and management (O&M) phase (factor 0.3)*
Saudi Arabia 2030 target (10,000 MW)*	179,000	3,000
UAE 2030 (6,000 MW)	107,400	1,800
Qatar 2030 (600 MW)	10.740	180
Kuwait 2030 (1,000 MW)	17,900	300

Photovoltaic (PV)	Job creation potential across the value chain	
	MCD phase (factor 19)	*O&M phase (factor 0.9)*
Saudi Arabia 2023 (30,000 MW)*	57,0000	27,000
UAE 2030 (23,100 MW)	438,900	20,790
Qatar 2030 (2,400 MW)	45,600	2,160
Kuwait 2030 (6,800 MW)	129,200	6,120

Sources: (Gulf Business, 2019; International Renewable Energy Agency, 2019a, 2013, p. 42; KFAS, n.d.; PVTech, 2019; UAE Government, 2019; Wogan et al., 2017)

*assuming that three quarters of the 40 GW solar target is in solar PV and the rest in CSP.

For the O&M phase, the IRENA employment factor estimates seem to be accurate, especially for smaller plants. For example, in Kuwait only three individuals run a 10 MW PV plant, which is located at Shagaya.[136] Yet the potential for job creation changes with the economics of scale. According to a REPDO official, the bigger the project the fewer people are employed in relative terms, because only a certain number of technicians are needed.[137] Through the centralization of monitoring, many fewer people are required on the site of the renewable power plant.[138] For example, the developer of Saudi Arabia's SAKAKA PV plant (300 MW) was planning to have 25-30 people in the O&M phase. According to IRENA's PV factor of 0.9, this would create 270 jobs in that phase, which is more than 10 times the number the jobs that are actually created. There is wide variation in the estimates about the job creation potential of renewables. Blyth offers a

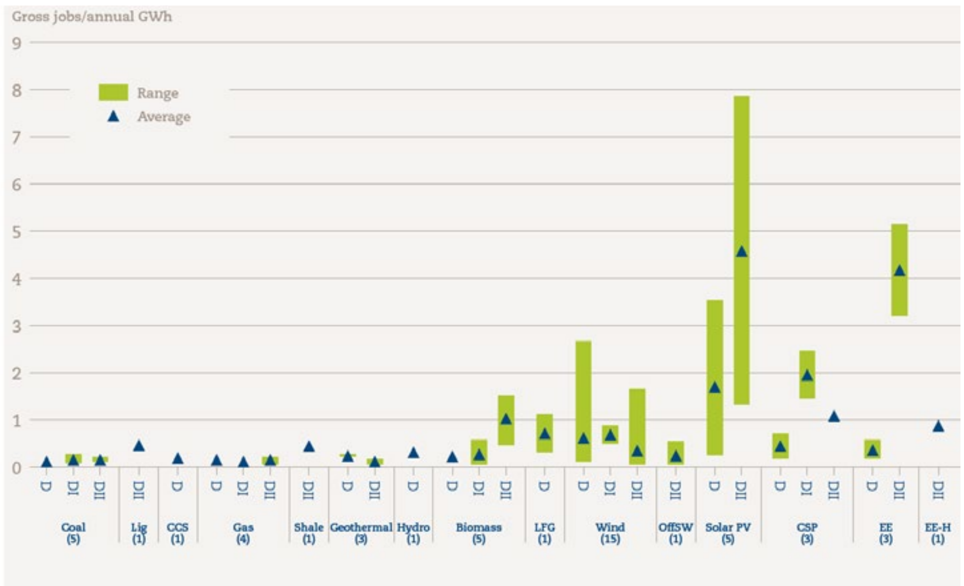
136 Alsayegh, 2018.

137 Anonym, REPDO interview, 27 October 2018.

138 Ibid.

useful comparison of 48 publications that quantify how many jobs are created by investments in renewable energy (see Figure 11).[139]

Figure 12: Estimates on gross jobs per annual GWh generated from different studies



Source: Blyth and et al, 2014, p. 34.

Notes: CCS (carbon capture and storage), LFG (land-fill gas), OffSW (offshore wind), CSP (concentrated solar power). PV (solar photovoltaic), EE (energy efficiency), EE-H (energy efficiency in households); D=direct jobs, DI=indirect jobs, DII=induced jobs.

Over time, through automation, learning by doing, new processes, and easier product installation, labor intensity goes down, therefore requiring fewer workers.[140] In the past, renewable energy projects required a lot of workers in the MCD phase.[141] Previously, significant levels of labor were needed to dig a foundation and cut cables, but in the future a large number of jobs will be replaced by machines and robots.[142] For example, the entire foundation of a recently constructed 800 MW plant in Abu Dhabi was laid by robots, using GPS to drill the holes, and by automatically punching the

139 Blyth et al. distinguish between (a) direct jobs, which arrive directly as a result of the renewable investment along the whole value chain, (b) indirect jobs, which are created in the supply chain to support a particular project of the renewable energy investment (e.g., a firm that creates the plastic needed for the solar frames), and (c) induced jobs, which are created as a result of increased household expenditure of direct and indirect jobs (Blyth and et al, 2014).

140 Bellini, 2018; Côté, 2018b; Dennehy, 2018.

141 Alsayegh, 2018; EIB and IRENA, 2015.

142 Padmanathan, 2018.

piles.[143] Similarly, in the MCD phase, most of the components are already semi- or fully manufactured by robots.[144] Practitioners, notably Padmanathan, note that renewable investments—even in the MCD phase—are not a panacea for unemployment.[145] While manufacturing solar panels or cells itself will not add a lot of jobs, the fact that cells are getting made in Saudi Arabia will attract other industries, such as glass/fiber glass, mining, semi-conductors, fertilizers, OLED, and LCD.[146]

Another question that arises is this: to what extent are the jobs created for the local population? In Saudi Arabia, the matter is complicated because, despite the fact that solar PV is the most labor- intensive technology in the energy sector, many of the jobs are of little interest to Saudi workers.[147] This is partly because of the lower wages offered for jobs in construction or operation and maintenance, and the general dislike for manual work.[148] Accordingly, few Saudis have invested in the skills required to work in these occupations.[149] Almost two-thirds of Saudi Arabia's citizens work in the public sector, while the private sector remains dominated by foreign workers.[150] To date, most of the construction workers in the Gulf are immigrants, mainly from India and Pakistan.[151] Jobs in the non-carbon private sector of the economy are unattractive to the local population because of lower wages and fewer benefits. Private employers in turn typically prefer expatriate workers, because nationals are more difficult to recruit, they leave the jobs more easily, and they are harder to fire than foreigners.[152] Under the status quo—without changes in labor legislation—a shift to more renewables across GCC countries would increase the number of temporary workers, with little impact on local employment.

A skills mismatch fosters the creation of jobs for migrants. The system on the vocational side in Saudi Arabia is not aligned with these rising job

143 Ibid.

144 Ibid.

145 Padmanathan, 2018.

146 ACWA Power, n.d.; Padmanathan, 2018.

147 Côté, 2018b.

148 Ibid.

149 Ibid.

150 Hertog, 2018.

151 Musbeh, 2018.

152 Hertog, 2018.

opportunities.[153] Indeed, technical and vocation training is where potential technicians and electricians would be trained. The total number of students enrolled in vocational programs in upper secondary education is low at five percent and many of the students are focused on fields such as business administration (males) and personal care (females).[154] Manufacturers complain about the lack of trained staff or blue collar workers in Saudi Arabia.[155] According to the founder of Saudi Arabia's Solar Industry Association, Browning Rockwell, "There is a Saudi Engineer but there is no Saudi Electrician."[156] To date, there is no apprenticeship program or vocational training comparable to other countries, such as Germany.[157] This mismatch is underlined by the former REPDO head who highlights that in Saudi Arabia there is an oversupply—in relation to actual jobs available—of students with a renewable engineering degree.[158] Part of this mismatch seems to be from an information asymmetry about the long- term opportunities in the job market.[159] Although some efforts are being made to provide more career information to students before they choose their educational path, a majority of Saudi students claim to have insufficient information about job opportunities or career paths.[160]

153 Côté, 2018a.

154 Côté, 2018b.

155 Rockwell, 2018.

156 Ibid.

157 Ibid.

158 Al-Sheri, 2018.

159 Côté, 2018a.

160 Côté, 2018b.

2.4 **Hedging**

Investing in renewables is one of many ways to protect (a) against the risk of lower oil revenues, and (b) against the risk of stranded assets. The latter refers to assets that suffer from unanticipated or premature write-downs or those that have become obsolete or non-performing well ahead of their anticipated useful life span. Apart from resources, such as oil underground, this could include other assets such as oil-fired power plants, which are designed to operate for many years.[161] For example, if we assume an average lifespan of 40 years for a combustion turbine plant, then as of 2019, many of Saudi Arabia's power plants are within their useful lifetime.[162] In the early 2000s the Saudi Electricity Company invested considerable amounts of money in the establishment of new oil-fired power plants.[163] Oil-fired plants that were designed to operate for decades would be under pressure to close if renewables are introduced on a massive scale or if nuclear power plants come online. Retiring these plants early would strain the budget of the Saudi Electricity Company and lead to the stranding of assets before the associated debt of oil plants would be paid off.[164]

Long-term uncertainty in oil demand, together with a new energy abundance (e.g., shale gas, new technologies, renewables) suggests that a large part of global carbon resources may never be consumed.[165] Authors, such as Fatthouh and Sen, highlight that the world is on the brink of another energy transition in which conventional energy sources like oil and gas will be replaced by low-carbon alternatives.[166] As more and more shareholder countries turn against carbon emissions, large institutional investors are becoming increasingly aware of the risks that climate change pose to their financial portfolios.[167] A number of studies recommend actions ranging from full divestment from fossil fuel assets to partial divestment.[168] These

161 Krane, 2019.

162 Al-Moneef, 2018; Mills et al., 2017.

163 MEES, 2014.

164 Al-Moneef, 2018.

165 Carbon Tracker Initiative, n.d.; Climate Policy Initiative, n.d.; LSE Grantham Research Institute, n.d.; Oxford Sustainable Finance Programme, n.d.; The Oxford Institute for Energy Studies, n.d.

166 Fattouh and Sen, 2018.

167 Sheppard, 2017.

168 Caldecott et al., 2016; Paun et al., 2015.

studies suggest that oil producers should use the proceeds from resource rents, notably oil, to diversify into renewables.[169] Initially, these discussions started with coal as well as oil sands, and more recently also included oil.[170]

The stranded assets debate is particularly pronounced in Western countries. Western policy makers, such as Bank of England Governor Mark Carney, warn about the potential that carbon assets might become worthless.[171] Reflecting this perspective, large international investors are also becoming more concerned about the possibility of asset stranding. For example, pension funds, such as Denmark's Pensionskassernes Administration, with assets under management (AUM) of $35bn, and insurance companies, which have traditionally been major holders of oil/gas assets, have started to divest from those assets and are increasing their exposure to renewables.[172] During the period 2013-17, the topic of stranded assets attracted considerable media attention in the US, the UK, and Australia (see Figures 13 & 14). For example, the Norway Pension Fund Global announced in 2017 the decarbonization of its portfolio. The NPFG holds around six per cent of its assets in oil and gas stocks, which is around $60bn of assets.[173] That is equivalent to the total market capitalization of ConocoPhillips—a Fortune 500 US oil company. Norway's move has sent out a strong signal to its peers in the institutional investor community. This is not just because the NPFG is capitalized by Norway's vast oil revenues but also because the NPFG is, with AUM of $1trn, the largest fund in the world. Also a group of institutional investors with approximately $33 trillion of assets under management (AUM) have announced their intention to invest in low-carbon assets.[174]

169 Ansar et al., 2013; Caldecott et al., 2016; Cust et al., 2017a.

170 Caldecott et al., 2016.

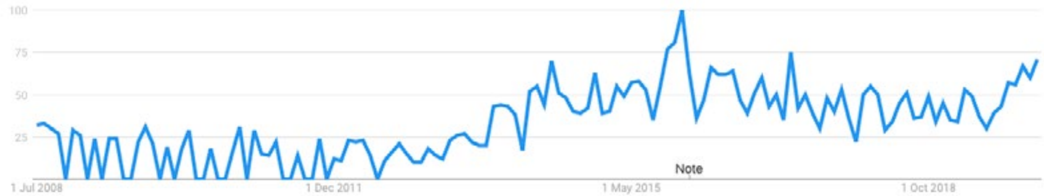
171 Carney, 2014.

172 Mooney, 2017.

173 Sheppard, 2017.

174 For example, European Long Term Investors—a group of 25 European national and supranational development banks—with AUM of Euro 2.2 trillion committed themselves in 2015 to contribute to a low-carbon economy transition (European Association of Long Term Investors, n.d.). Similarly, the Institutional Investor Group on Climate Change—a trade body for 137 institutional investors—with AUM of $16 trillion has signaled its members intend to invest in low-carbon assets.("IIGCC—The Institutional Investors Group on Climate Change," n.d.) Likewise, the US-based Investment Network on Climate Risk—encompassing 120 institutional investors— with AUM of $15 trillion aim to increase investments into green asset classes. (Ceres Investor Network, n.d.).

Figure 13: Interest in 'asset stranding' over time



Source: Calculated using Google Trends software and looking for the words "stranded assets. "

Figure 14: Interest in "asset stranding" by region

Source: Calculated using Google Trends software and looking for the words "stranded assets."

Note: Numbers represent search interest relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. A score of 0 means that there was not enough data for this term.

While the issue of asset stranding has been examined extensively in the context of private investors and listed companies in Western countries, less has been done in terms of sovereign assets, such as stakes in national oil companies.[175] Only very recently, a new stream of work highlights the fact that states themselves have a huge exposure to changes in the global energy mix and that the wealth of nations may become stranded.[176]

In this context, GCC countries have also started to invest in renewable technology on a domestic and an international basis. Even oil giants, such as Saudi Aramco, the Kuwait Oil Company, and the Kuwait Petroleum Corporation, have started investing in renewables.[177] Together with other

175 Carbon Tracker Initiative, n.d.; LSE Grantham Research Institute, n.d.; Oxford Sustainable Finance Programme, n.d..

176 Cust et al., 2017a; Tagliapietra, 2017a, 2017b; Zenghelis et al., 2017; Bradley et al., 2018.

177 Aramco, 2017.

global oil producers, Saudi Aramco has set up the Oil and Gas Climate Initiative—a CEO-led organization, with 150 experts and a $1.3bn fund, with the aim of reducing their carbon footprint.[178] Another initiative, the "One Planet Sovereign Wealth Fund Working Group"—a group that collectively manages $3 trillion—was created in December 2017 by Saudi Arabia, Norway, Qatar, Abu Dhabi, and Kuwait with the aim of accelerating low-carbon transition and addressing climate risks in the management of large pools of capital.[179] Saudi Aramco Energy Ventures has started to invest in a wide range of companies, such as a Silicon Valley startup that converts gas to chemicals and a German firm that creates parts of solar panels.[180] Similarly, the Kuwait Oil Company, together with the Kuwait Oil Corporation, launched in September 2018 a tender for a 1.5GW solar plant.[181] Also, a number of sovereign wealth funds from oil-producing countries have been at the forefront in investing in the EV sector. For example, Qatar's sovereign wealth fund invested in the Spanish solar company Iberdrola and EV producer Fisker Automotive, whereas the Abu Dhabi Investment Authority made investments in green power generation in India. Likewise, Abu Dhabi's Mubadala invested nearly $1bn in UK's Dugeon Offshore Wind Farm,[182] and in the Jordan Wind project company.[183] The Kuwait Investment Authority formed a joint venture with Helioscentrie Snergy Solution Germany. Saudi Arabia's Public Investment Fund has agreed to invest more than $1bn in Lucid Motors in addition to its $2bn stake in Tesla.[184]

An evaluation of asset stranding risks is based on two parameters: the average production costs of oil/gas, and the product lifespan (i.e., reserves under the ground under current production). The risk of having a significant amount of carbon assets remaining unburned is highest for countries and firms with high production costs. A statement by economist Jeffrey Sachs that "if you are going to strand assets, strand the high-cost [hydrocarbon] assets, not the low-cost assets" suggests that asset stranding is primarily a problem for high-cost producers, such as the UK and Canada, and not for

178 Nasser, 2018.

179 One Planet SWF, 2018.

180 Jones and Said, 2018.

181 Parnell, 2018.

182 Masdar, 2014.

183 *Business Intelligence Middle East*, 2013.

184 Arnold, 2018.

low-cost producers, such as the Gulf countries.[185] According to this logic, countries with a long lifespan of their reserves, combined with high production costs per barrel, such as Canada and Venezuela, have the highest risks of asset stranding. At the current rate of production, Canada has oil for more than 150 years and Venezuela has oil for more than 350 years (see Figure 15).

In contrast to Western countries, the production of oil is very cheap among GCC countries. This allows them to outcompete other producers for decades and thereby marginalizes everybody else.[186] Industry leaders, notably Saudi Aramco's CEO Nasser, contend that there is no risk of asset stranding for GCC oil producers over the coming decades.[187] That is further supported by the fact that large GCC oil companies, such as Saudi Aramco, have made significant investments in new energy technology, such as the development of highly efficient engines.[188] Out of Aramco's nine technology centers, one is based in Detroit and one in Paris and both of them are dedicated to working with the car manufacturers in Europe and the US with the goal of increasing efficiency and reducing carbon footprint.[189] Saudi Aramco also cooperates with the Japanese auto manufacturer Mazda to develop more efficient engines and gasoline with the aim of reducing emissions from the transport sector.[190]

Although more efficient combustion engines seem to be bad news for oil exporters, Jamal Jaffer—the CEO of the Kuwait Oil Company—highlights the fact that a massive demand for cheaper and more efficient cars connecting remote areas of Asia and Africa will also ensure the demand for oil in the future.[191] Thanks to low average production costs, GCC countries could even see their market share increasing in a low-carbon environment over the long term. Energy experts from the King Abdullah Petroleum Studies and Research Center (KAPSARC) and the Institute of Energy

185 Bouyamourn, 2016.

186 Sultan, 2018; Ward, 2017.

187 Clark, 2015; Reed, 2017.

188 The idea behind hybrid cars is to replace the large expensive battery of electric cars by smaller batteries in combination with a smaller combustion engine, which is lighter. Then you will have a battery with 400 horsepower and an engine with 50 horsepower. The combustion engine will keep the battery topped up and when you need the power, you get it.(Al-Khowaiter, 2018)

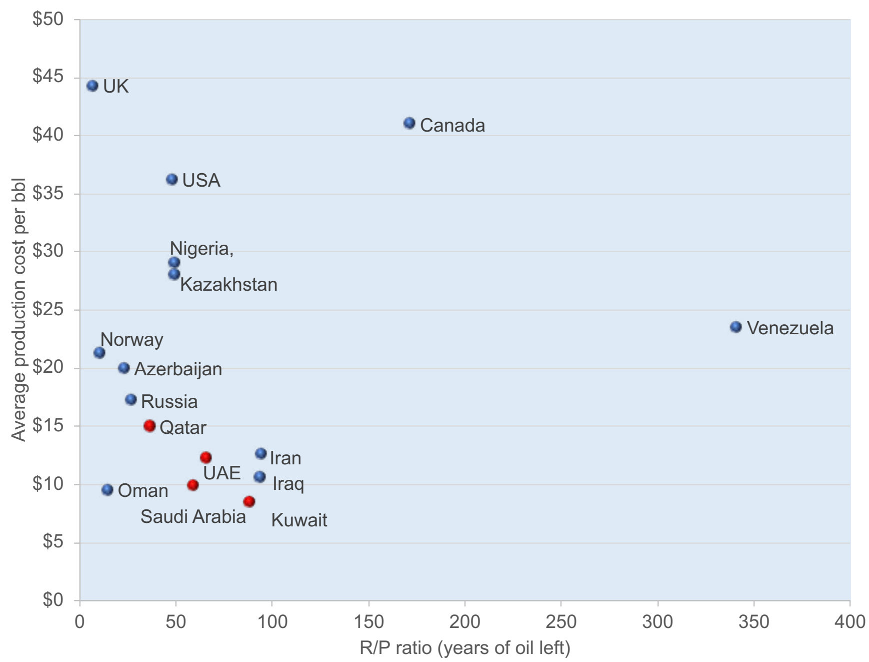
189 Nasser, 2018.

190 Krane, 2018.

191 Personal conversation with Jaffer, 2018.

Economics, Japan (IEEJ) agree that in a peak oil demand scenario with an oil price of $50/bbl, low-cost producers, notably GCC countries, will be the only ones with a potential to increase their market share.[192] According to calculations by the IEEJ, in a peak oil demand scenario with oil prices of $50/bbl, as well as in the reference scenario with oil prices of $125/bbl, all countries will be supplying less oil by 2050, with the only exception being the Middle East.[193] In 2030, tight oil production in the US is expected to plateau and OPEC production is expected to increase thereafter. Moreover, the IEA and OPEC expect that low-cost producers will see an increase in their market share over the long run.[194]

Figure 15: Average production cost per barrel of oil in USD and Reserve/Production ratio across oil exporting countries



R/P ratio Reserves-to-production (R/P) ratio: If the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.

Sources: Calculated with data from British Petrol, 2018; Rystad Energy, 2018.

Although GCC countries achieve a relative gain in a low oil price environment, in terms of market shares, their overall income will be severely

192 Pierru, 2019a; Yamashita and et al., 2017. See Appendix 4.

193 Yamashita and et al., 2017. See Appendix 4.

194 See Appendix 4.

affected by the reduction in oil prices. Under a peak oil demand scenario with oil prices at $50/bbl, the trade income of these countries would be decreased by about $1.6 trillion—representing a drop of 13 percent of their nominal GDP.[195] According to the IEEJ, the decreasing oil prices account for the most of this decrease.[196]

Investments in renewables can be seen as an effort toward diversification of income revenue streams to sectors whose prospects are negatively correlated with the prices and the business cycles of fossil fuels.[197] GCC countries, such as Saudi Arabia, have the potential to "become a major solar power exporter"[198] by harnessing solar power from a region that is abundantly endowed with sun and transferring it through high voltage lines to consumption centers.[199] That was the original idea of Desertec—a giant solar power plant in the Sahara desert—which was planned to power more than five million homes in Europe.[200]

As such, it seems reasonable to invest in renewables as a hedge against lower oil income in a low- oil price environment. This is so, even though the proceeds from the export of renewables would by no means replace oil revenues even if all the ambitious renewable projects are implemented. Exporting renewable energy requires huge upfront infrastructure investments. If the Gulf countries want to export meaningful quantities of renewable energy, they need to use ultra-high voltage (UHV) technology. The cost of long distance transmission is coming down, thanks to China. For example, China has a 10 Gigawatt UHV line with estimated costs of $5bn per line.[201] If Saudi Arabia goes ahead with its 40 GW capacity target, they would need to build one of these 10 GW UHV lines. If this UHV line is used for around 3,500 hours per year, this would be a 35ml MWhours target.[202] Selling the renewable energy electricity for $100 per

195 Yamashita and et al., 2017.

196 See Appendix 4.

197 Cust et al., 2017b.

198 *Arab News*, 2018.

199 Mayor, 2014.

200 Morgan, 2017.

201 With an estimated cost of 35 billion yuan ($5.25 billion), the 1,231-km long 800-KV link is designed with a transmission capacity of 10 GW, which is expected to deliver 55 TWh of power to the eastern provinces, according to the nation's top grid operator (Guo, 2017).

202 Weather and Climate, n.d.

MWhour—which is optimistic—would create around $3.5bn in export revenues per line per year. This would be equivalent to about 2.4 percent of Saudi Arabia's export revenues from mineral fuels and oil in 2017.[203] In similar fashion, under IRENA estimates the UAE with its 29.1 GW target, would have the potential to create $2.3bn in export revenues, which would be equivalent to 1.8 percent of the UAE's export revenues from mineral fuels and oil in 2017.[204] In the case of Kuwait and Qatar, renewable energy capacity targets (i.e., 5.1 GW and 4.9 GW respectively) would not lead to a meaningful export earnings.[205]

2.5 **Geopolitics**

In a world where renewables are becoming a major source of energy, investments in renewables are also a means of accruing geopolitical benefits. Building on the earlier insights of how the characteristics of fossil fuels have shaped interstate relations, scholars increasingly analyze how the energy transition gives rise to new conflict lines and disrupts long-established strategic realities.[206] A nascent scholarship has emerged that looks at the global energy transition and its geopolitical dimensions.[207] Major research themes in the geopolitics of renewable literature revolve around new critical materials supply chains, electric grids infrastructure, and energy security. While the geopolitical implications of some areas, such as finance, are in the early stages of research, other themes, notably renewables and energy security, have already been outlined empirically. The introduction of renewables in the energy mix has the potential to increase energy independence.[208] Other dimensions not yet mentioned in the debate but specific to the geopolitical realities of GCC countries, refer to the impact of renewable investments on spare oil capacity.

203 Center for International Development at Harvard University, 2018.

204 Ibid.

205 Kuwait's 5.1 GW capacity target would create $451 mill, whereas Qatar's 4.9 GW capacity target would create $431 mill of export revenues from the export of solar electricity.

206 Criekemans, 2011; Green, 2007; Koranyi, 2011; Wenger et al., 2009; Goldthau and Sovacool 2012.

207 Aklin and Urpelainen, 2018; O'Sullivan et al., 2017; Overland, 2019; Scholten et al., 2018.

208 O'Sullivan et al., 2017.

2.5.1 Renewable investments as a means of maximizing spare capacity

One of the key levers of the petro states' influence in world politics relates to their spare oil production capacity. Spare capacity refers to the volume of oil production that can be brought online within 30 days and sustained for at least 90 days.[209] Spare capacity serves as an indicator of the world oil market's ability to respond to potential crises. Increasing or maintaining spare capacity would add to global stability in the energy market, especially during periods of geopolitical tension.[210] Spare capacity helps in controlling oil prices in order to keep these prices from rising too high or falling too low.[211] Saudi Arabia, the largest oil producer within OPEC, historically has had the greatest volume of spare capacity.[212] According to Ed Morse, global head of commodities research at CITI, Saudi Arabia has frequently used its spare oil capacity as a means of keeping oil prices low and thereby preserving its influence in Washington, Brussels, Tokyo, and Beijing.[213]

But parallel to the stabilizing effect, Saudi Arabia's imposing spare capacity also promotes compliance among OPEC members through the ability to keep oil prices down. Via its spare capacity, Saudi Arabia has been able to put financial pressure on other exporting countries and curb their influence in the market and in the geopolitical arena.[214] For example, Saudi Arabia's overproduction in 1997 was designed to punish Venezuela, which did not comply with OPEC production quotas at that time.[215] Likewise, Saudi Arabia punished the USSR by flooding the world energy market with oil in the 1980s with the effect of oil prices plummeting as a response to the USSR's invasion of Afghanistan.[216]

209 US Energy Information Administration, n.d.

210 International Energy Agency, 2019b.

211 Maurer, 2008.

212 Saudi Arabia has usually kept between 1.5 - 2 million bbl of spare capacity.

213 Morse, 2009.

214 Ibid.

215 Ibid.

216 Ibid.

Introducing renewables into domestic electricity generation would free up additional oil for increasing or maintaining spare capacity. According to Majid Al-Moneef—former Saudi Governor to OPEC—renewable investments would allow oil exporters to free up more oil for exports without the need to spend more on developing spare capacity, which is very costly. In 2010, the costs of bringing on one additional barrel oil was estimated at between $5,000 and $7,000.[217] By 2018, these costs went up to $15,000 per barrel.[218] According to Saudi's former Energy Minister Khalid al-Falih, Saudi Arabia would need to invest $20 billion over the next several years in order to maintain and expand its spare oil production capacity (by 1 million bbl).[219]

Replacing oil through renewables as a feedstock for electricity generation would free between 600 and 900 mb/d. By comparison, developing an additional 900,000 bbl of oil in spare capacity would cost between $4.5bn and $13.5bn. Replacing the 600 to 900 mb/d of crude, which are burned daily for the generation of electricity through renewables, would increase Saudi Arabia's spare capacity accordingly. By comparison, in the UAE and Qatar, there is no room for increasing spare capacity through the introduction of renewables into the domestic energy mix, because oil plays a negligible role in electricity production in these countries. By contrast, Kuwait, with around 100,000 bbl of spare capacity,[220] has the potential to increase its spare capacity significantly by introducing renewables into the domestic mix.[221]

217 Maurer, 2008.

218 Personal conversation with Al-Moneef 2018a.

219 "Saudi Arabia to invest $20 billion in spare oil production capacity, Reuters," n.d.

220 The resumption of the Neutral Zone's oil fields could add up to 500,000 bpd of oil output capacity to Saudi Arabia and Kuwait (S&P Global, 2018).

221 "Saudi Arabia to invest $20 billion in spare oil production capacity," Reuters, n.d.

2.5.2 **Renewables as a means of maximizing energy security**

Investments in renewables also affect the strategic realities of oil producers in terms of their energy security. National energy security can be defined as a condition in which a state perceives that it has an adequate energy supply at affordable prices.[222] That is especially critical for the future economic and social planning of activities.[223] External factors, notably energy imports, pose the most immediate threat to national energy security.[224] The Russio/Ukrainian energy crisis in 2005/2006 is a good example illustrating the effect of interstate relations on energy security and the consequent efforts of states to increase their energy independence. Considerations of energy security have been a major driver behind the EU's push toward renewables.[225]

In turn, national energy security is closely linked to the feedstock profile and the import components of electricity generation, as well as their respective import components. The electricity generation feedstock profile varies across GCC countries. While a significant part of electricity in Kuwait and Saudi Arabia is produced by burning oil, in the UAE and Qatar almost 100 percent of the electricity is generated by burning gas (see Figure 16). Kuwait and the UAE need to import gas to cover increasing domestic energy consumption, whereas Qatar and Saudi Arabia produce enough energy to cover domestic electricity generation. As such, introducing renewables into the domestic energy mix has a different impact across GCC countries from an energy security standpoint.

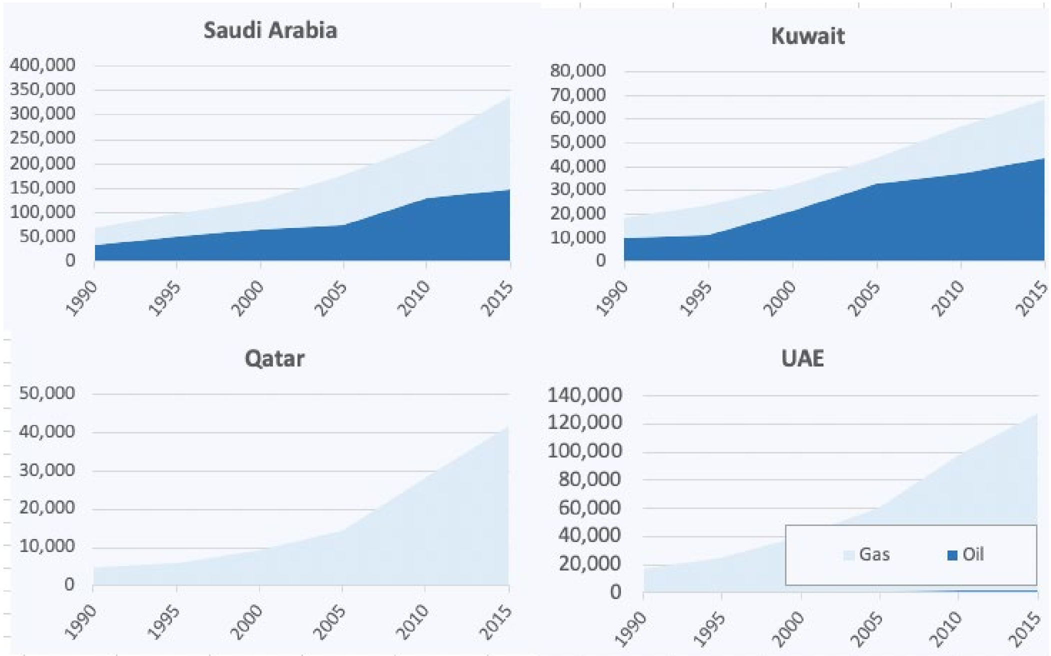
222 Deese, 1979.

223 Deese and Nye, 1981.

224 Deese, 1979.

225 Johansson, 2013.

Figure 16: Electricity generation in GWh by fuel across GCC countries between 1990 and 2015



Source: International Energy Agency, 2017e, 2017f, 2017g, 2017h

Although by 2019, Saudi Arabia had achieved the security of its energy supply through domestic production of oil and gas, it is sensible to invest in renewables, given Saudi Arabia's limited domestic gas resources. Gas shortfalls in electricity production were traditionally addressed by increasing the oil component of the domestic energy mix. For example, as Saudi Arabia experienced a bottleneck in its gas supply in the early 2000s, a Royal decree put a cap on the use of gas in the power sector and required all new power plants to use oil instead of burning gas for the production of electricity.[226] Although Saudi Arabia's total proved natural gas reserves amounted to 8 trillion cubic meters in 2017, making Saudi Arabia's reserves the world's sixth largest and the third largest in the Middle East, it will soon need to start importing gas.[227] Though the country has huge proved reserves, the extraction and production of natural gas remains technically challenging. Most of it is associated with oil; and is either sour (sometimes above 25 percent sulfur content) or tight gas (gas trapped in unusually impermeable hard rock or in a sandstone or limestone formation). Non-associated gas is geologically and technically challenging to extract in Saudi

226 Kombargi et al., 2010.

227 British Petrol, 2018.

Arabia.[228] These difficulties are increasing costs and project risks.[229] In addition to these challenges there are water shortages, which make shale gas fracking almost impossible.[230]

For more than a decade, Kuwait has been relying on gas imports (especially in form of LNG) to meet its increasing domestic demand.[231] The role of gas in Kuwait's energy mix has grown massively since the mid-1990s. When Kuwait was confronted with bottlenecks in the domestic gas supply in the 2000s, it started importing LNG to free up crude for export.[232] In June 2009, Kuwait signed a deal with Royal Dutch Shell to import LNG.[233] Previously, in the early 2000s, Kuwait tried to secure funding for a Qatari-Kuwaiti gas pipeline.[234] Yet this project was blocked by Saudi Arabia, which was concerned about Qatar's growing influence in the region.[235]

One way of ensuring energy security in Kuwait is to replace the import gas component of electricity production with renewables, notably solar (see Figure 17). To assess the adequacy of Kuwait's renewable targets for energy independence, we need to calculate the equivalent of the gas import component in GW solar capacity.[236] We know that Kuwait imported 4.5 mtoe of gas in 2016.[237] We also know that 6.15 mtoe of gas was used for electricity production (i.e. 25,016 GWh).[238] Replacing the entire gas component of electricity production would require the installation of 11.4 GW solar PV, whereas replacing the imported gas component (i.e. 4.5mtoe) would require an installed capacity of 8.8 GW of solar PV.[239] While the 8.8 GW needed for replacing the import gas component are beyond the 5.1 GW in our calculation, they are within the more generous estimates of KAPSARC (i.e. 10.7

228 Griffiths and Orkoubi, 2018.

229 Kombargi et al., 2010.

230 Al-Moneef, 2018.

231 Central Intelligence Agency, 2018c.

232 Kombargi et al., 2010.

233 US Energy Information Administration, 2013.

234 Seznec, 2018.

235 Ibid.

236 We assume that all the imported gas flows to electricity generation.

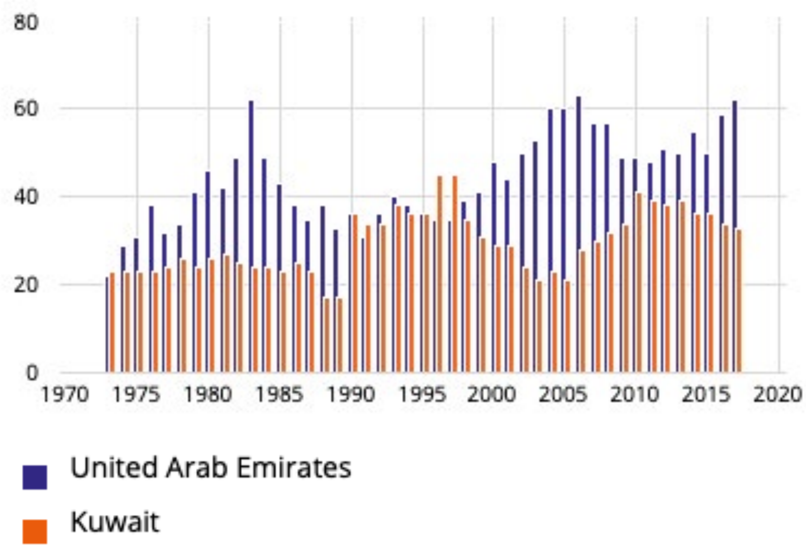
237 International Energy Agency, 2019a, 2016b.

238 International Energy Agency, 2016b.

239 Calculated: GWh/hours per year*0.25 (capacity factor).

GW). Using the latter estimate Kuwait would be able to fully secure the independence from gas imports required for the electricity sector.

Figure 17: Share of natural gas used for electricity production in total natural gas consumption (%)



Source: International Energy Agency, n.d.

Unlike Kuwait, the UAE produces almost all of its electricity by burning gas, and the UAE is the world's 13th largest consumer of natural gas.[240] With a small population of 9.5 million, the UAE uses more gas than countries like India or Italy.[241] The UAE's massive gas consumption is due to two factors: (a) the dramatic increase in electricity usage, and, (b) the UAE's injection of about one-quarter of its gas into oil fields as a part of enhanced oil recovery techniques.[242] The UAE has started to import gas—mainly from Qatar. Both countries jointly built and own the Dolphin Gas pipeline, which transports around 2bn cubic feet of gas every day from Qatar to the UAE.[243] The 2017 diplomatic dispute between the Saudi Arabia, the UAE, and Qatar has illustrated the UAE's vulnerability to Qatar's gas exports.[244] A commentator's note that "[w]ithout this energy artery, Dubai's glittering skyscrapers would go dark" pointed to

240 Central Intelligence Agency, n.d.

241 Central Intelligence Agency, 2018b.

242 US Energy Information Administration, 2017.

243 Seznec, 2018.

244 *Aljazeera*, 2017.

this vulnerability of UAE to Qatar's gas exports.[245] By contrast, there is no gas exchange between Qatar and Saudi Arabia and as such, political tensions between Saudi Arabia and Qatar has little impact on their energy policies.[246]

From an energy security standpoint, adding more renewables into the UAE's domestic energy mix would mean more energy independence from Qatar.[247] As in the case of Kuwait, one possibility to ensure energy security in the UAE is to replace the import gas component of electricity production with renewable energy. For 2017, we know total UAE gas imports (i.e., 14.99 mtoe) and we know that 36.92 mtoe of gas was used in the electricity sector to produce 131,231 GWh.[248] Replacing the entire 36.92 mtoe through renewables would require an installed renewable capacity of 60GW of solar PV.[249] Accordingly, replacing only the imported gas component, i.e., 14.99 mtoe,would require around 24GW. In our calculation, the UAE, with its 25 percent generation target, is not able to fully secure the independence from gas imports required for the electricity sector. Using more optimistic target estimates, such as the 29.1 GW from IRENA, the UAE would be able to fully secure independence from gas in generating electricity.

By contrast, Qatar has achieved energy security of its supply for the foreseeable future. Qatar has no import component in its energy mix for producing electricity, and natural gas meets all of Qatar's energy demand.[250] Qatar is the world's largest exporter of natural gas and has the third-largest proved reserves of natural gas. The introduction of renewables into the domestic energy mix would only free additional gas for net exports and would not contribute to the security of the domestic energy supply.

245 DiPaola, 2017.

246 Seznec, 2018.

247 Assuming that the renewables being added could offer 'firm' generation, which includes some form of storage.

248 International Energy Agency, 2016c.

249 Calculated: GWh/hours per year*0.25 (capacity factor).

250 US Energy Information Administration, 2015.

	Are renewable investments in line with a spare Capacity argument?	Are renewable targets large enough to make a Difference in spare capacity?	Are renewable investments in line with an energy Security argument?	Are renewable targets large enough for Securing energy independence?
Saudi Arabia	Yes	Yes	Depends	N/A
UAE	No	N/A	Yes	Depends
Kuwait	Yes	Depends	Yes	Depends
Qatar	No	N/A	No	N/A

3. Conclusion

This report has examined the question of whether it makes sense for Gulf Cooperation Council (GCC) countries to invest in renewables from the four broad strategic rationales. Although the GCC countries are blessed with huge reserves of hydrocarbons, they have announced ambitious goals in the renewable energy sector. The sheer magnitude of such investments involves the mobilization of significant public resources. Therefore, an assessment of the rationales behind such investments requires a more strategic perspective that goes beyond the GCC countries' nationally determined contributions to climate change mitigation or perceived constructive engagement in the global energy transition.

This report has evaluated national renewable energy targets in terms of which strategies make sense under which circumstances and to whom. Although there are many potential rationales, ranging from mitigating climate change, improving public health, fulfilling the Paris Climate agreement, and increasing countries' soft power, this report has focused on: geopolitics (energy security and spare oil capacity), revenue maximization, hedging, and job creation.

Out of the potential rationales outlined, only energy security and hedging against low oil prices as a driving rationale behind renewable investments make sense for the smaller Gulf economies, notably the UAE and Kuwait. By contrast, for Saudi Arabia the revenue maximization-, hedging- and spare oil capacity arguments are much stronger in justifying large renewable investments. For Qatar, all of the potential geopolitical rationales for renewable investments are weaker than in their GCC peers.

3.1 Findings and implications

Job creation: it is not clear whether renewables have the desired job creation impact, mainly due to the increasing automation and the nature of deployment. While there is some potential in the manufacturing construction and deployment phase, there is less in the operation and maintenance phase.

Distributed solar deployment seems to yield jobs at a rate appreciably ahead of centralized solar. In the GCC context, deployments will be very large and these plants will yield the lowest number of jobs in relative terms, both during construction and operation. As such, from a national strategic perspective, job creation should not be the key driving rationale behind large renewable investments.

Revenue maximization: Investing in renewables is one potential avenue to maximize the return on fossil fuel exports. However, the potential of maximizing the revenue from oil exports through the introduction of renewables varies across GCC countries. That is because of differences in the domestic energy mix.

For Qatar and the UAE, adding renewables to the domestic electricity production has no effect on their oil export capacity and oil revenues, due to their energy mix for generating electricity, which consists almost fully of natural gas. The effect of introducing renewables on additional revenues from gas exports is minimal in Qatar—due to Qatar's small size and its position as a gas net exporter with large reserves and production capacity. In contrast to Qatar, the UAE is a net gas importer. In the UAE, renewables could replace part of the gas in the electricity mix, which is sourced at the international market.

For Kuwait, the scope for adding large amounts of renewables into the electricity feedstock with the purpose of maximizing oil revenues is much smaller in absolute terms than in Saudi Arabia—partly due to slower growth in electricity consumption, and larger oil reserves and production capacity per capita. However, if Kuwait is not able to increase domestic oil production, oil consumption growth for electricity generation could affect the country's oil export capacity over the long run.

There is a lot of scope for Saudi Arabia to substitute oil in the domestic energy mix with renewables in order to maximize revenues from the export of oil. However, the interesting detail is that the 2019 announced renewable targets of Saudi Arabia (i.e., 60 GW, of which 40 GW are dedicated to solar PV and CSP) would not come close to that goal, even under a moderate growth scenario of oil consumption for electricity production. Only if Saudi Arabia is successful in curbing domestic oil consumption growth to zero will the 40 GW solar target allow Saudi Arabia to replace around 4/5 of the crude component used in the oil mix (i.e. HFO, crude, diesel) for generating electricity.

Hedging rationale: Investing in renewables as a means of hedging against stranded assets makes sense for high-cost producers, such as Canada, but not for low-cost producers, such as the GCC countries. The latter group of countries could even see their share in global oil markets expanding in a low oil price environment.

While low-cost oil producers of the GCC could see their market shares expand in a low oil price environment, they are nevertheless exposed to the risk of reduced revenues due to the lower oil price. Investing in renewables could be a means of diversifying their revenue streams in a such an environment, particularly given that renewables are negatively correlated to the price of oil.

Although renewables can contribute to some diversification of GCC national income streams, the announced targets among the four countries come nowhere near replacing the carbon revenue streams.

Geopolitical rationale: Geopolitical opportunities for GCC countries arising from investing in renewables differ among GCC countries. Due to the differences in electricity feedstock profiles, the introduction of renewables into the domestic energy mix has differing effects on energy security among GCC countries.

As noted earlier, the UAE and Qatar generate almost 100 percent of their electricity by burning gas. Qatar covers all domestic energy consumption by its production, whereas the UAE is highly dependent on gas imports from Qatar. Therefore, replacing the import gas component through renewables would enhance the UAE's energy security supply. Moreover, there is scope for Kuwait to invest in renewables to increase the security of their energy supply for the generation of electricity. Of all the GCC countries, the rationale for investing in renewables as a way of increasing spare oil capacity is strongest for Saudi Arabia.

In Brief:

Renewables play a prominent role in the national development goals of the GCC member countries. The drive for developing solar PV and CSP capacity forms a central part of an overall strategic push to transform their economies (see Saudi Vision 2030, Kuwait's National Development Plan, Qatar's National Vision 2030 and Abu Dhabi's Economic Vision 2030).

However, investors need to assess the extent to which renewable energy development is driving GCC national economic transformation programs. To do this, it is important to identify the strategic reasons that GCC members cite in their pursuit of renewables (i.e. job creation, hedging, energy security, revenue maximization). Investors can then apply this knowledge as they assess the justifications used in public debates to encourage massive renewable infrastructure investments.

The primary takeaway from this report is that ongoing renewable energy projects fall short of the ambitions outlined in the national "Visions" of GCC leaders. Moreover, even if GCC nations attained the goals set forth in their formal visions, the renewable energy production in these countries would still be too low to justify the arguments they have made for investing in their countries.

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Appendix 1: Solar PV and CSP projects in the UAE, Saudi Arabia, Qatar, and Kuwait until 2018

Project Nation	Project Name	Year Announced	Project Status (2018)	MW	Project Cost in millions (US$)
UAE	Masdar Solar Scheme Shams 1 Project	2008	Completed	100	765
UAE	Masdar City Solar PV park ADFEC 10MW	2009	Completed	10	50
UAE	Mohammed bin Rashid Al Maktoum 1, 13 MW	2009	Completed	13	
UAE	Masdar Solar Scheme Shams 2 Project	2010	Completed	100	635
UAE	Mohammed bin Rashid Al Maktoum Solar Power Complex Phase I	2012	Completed	13	
UAE	Mohammed bin Rashid Al Maktoum Solar Power Complex Phase II (trans-action 1)	2012	Completed	200	350
UAE	Mohammed bin Rashid Al Maktoum Solar Power Complex (remaining)	2012	In process	3,287	14,000
UAE	Solar power plant, Utico, RAK 40 MW	2014	Completed	40	450
UAE	Sweihan Solar Photovoltaic Project	2015	In process	350	870
UAE	DEWA Mega Solar (Mohammed bin Rashid Al Maktoum) Third Phase Scheme	2015	Completed	800	1,000
UAE	Mohammed bin Rashid Al Maktoum Concentrated Solar Park	2016	In process	1,000	4,000
UAE	DEWA Concentrated Solar Power Project	2016	In process	200	4,000
UAE	Mohammed bin Rashid Al Maktoum Solar Power Complex Phase III	2016	In process	800	
UAE	Dubai Solar and Coal-Fired Power Scheme	2017	Announced	300	
UAE	Sweihan	2017	In process	1,177	870
UAE	DEWA Solar PV Phase 5 Project	2018	Announced	800	
UAE	Mohammed bin Rashid Al Maktoum Solar Power Complex Phase IV	2018	Announced	700	390
Qatar	Kahramaa Solar Scheme	2012	In process	220	
Qatar	KAHRAMAA-Solaar Power Plant 230MW	2014	Announced	230	
Qatar	Al Duhail Solar PV Park 10 MV	2014	Announced	10	
Qatar	Siraji Power 200	2017	In process	200	500
Qatar	Al Kharsaa Solar PV Project	2018	Announced	500	500
Kuwait	Al Abdaliyah Integrated Solar Com-bined Cycle Project	2012	Announced	60	3,000
Kuwait	MEW/KISR-Shagaya Solar Thermal 50 MW	2015	Completed	50	385
Kuwait	MEW/KISR-Shagaya PV 10 MW	2015	Completed	10	
Kuwait	Al-Abdaliyah ISCC project 60 MW	2016	Cancelled	60	

Project Nation	Project Name	Year Announced	Project Status (2018)	MW	Project Cost in millions (US$)
Kuwait	KPC/KNPC Shagaya Phase II (Dibdibah Project)	2017	In process	1,500	
Saudi Arabia	KAUST Rooftop PV panels 2MV	2010	Completed	2	
Saudi	Princess Nora University Solar Water Heating 17MW	2010	Completed	17	
Saudi	Saudi Aramco North Park PV Project 10.5MV	2011	Completed	11	
Saudi	KA-CARE Solar Project	2012	Announced	40,450	112,000
Saudi	Mecca Solar Scheme [Makkah]	2012	In process	100	240
Saudi	KAPSARC PV Phase 1-3.5MW	2012	Completed	4	
Saudi	KAPSARC PV Phase 2-1.8MW	2013	Completed	2	
Saudi	K.A.CARE, 500 MW PV plants around the Kingdom	2013	In process	500	
Saudi	Duba 1 ISCC Power Plant	2014	In process	550	600
Saudi	SEC - Duba ISCC Power plant phase 1 CSP 50MW	2015	Completed	50	
Saudi	Waad Al-Shamsal ISCC Project 50 MW	2015	Completed	50	
Saudi	Al-Aflaj Solar PV Park 50 MW	2015	In process	50	
Saudi	K.A.CARE, Royal Commission for Jubail and Yanbu 50 MW PV	2015	In process	50	
Saudi	KACST Al Khafiji PV desal Plant 10 MW	2016	In process	10	
Saudi	Taiba Integrated Solar Combined Cycle Scheme	2016	Announced	3,800	4,000
Saudi	Al Khafji Solar PV Powered Desalination Project	2016	Announced	40	130
Saudi	Sakakah Solar PV Plant Project	2017	In process	700	250
Saudi	Saudi Arabia Rooftop and Car-port-Mounted Solar PV Project	2017	Announced	150	
Saudi	Saudi Arabia Mega Solar Project (Phase 1)	2018	Announced	7,200	5,000
Saudi	Medina Solar Power Project	2018	Announced	250	
Saudi	Rafha Solar Power Project	2018	Announced	250	
Saudi	Qurayyat Solar Power Project	2018	Announced	200	
TOTAL				**68,014**	**155,608**

Sources: (Arabian Business, 2017; Climate Action, 2017; Dubai Electricity And Water Authority, 2018a, 2018b; Gifford, 2017; International Renewable Energy Agency, 2016; Thomson Reuters, n.d.)

Notes: Excluding wind projects and announcements after 2018, such as Shegaya Phase III 1400 MW (1200 MW PV, 200 MW CSP) Kuwait Authority for Public and Private Partnership are not included.

Appendix 2: Renewable Solar Capacity Targets of GCC countries

Country		Estimates/ targets by	GW (in PV, CSP)		Reference
Kuwait	KAPSARC	2030	10.3	CSP = 5.7 GW Solar PV =4.6 GW	Wogan et al., 2017, p. 22
	IRENA	2030	7.8	CSP= 1 GW Solar PV = 6.8 GW	International Renewable Energy Agency, 2019a, p. 102
	Author's calculation	2030	*5.1	Official generation target: 15%	KFAS, n.d.
		2030	6.7	Scenario with overall consumption ćby 30% and 15% renewables	International Renewable Energy Agency, 2019a, p. 49
Qatar	KAPSARC	2030	1.8	1.8 GW solar	Wogan et al., 2017
	IRENA	2030	1.8	1.8 GW solar	International Renewable Energy Agency, 2016, p. 12
		2030 (update)	3.0	CSP = 0.6GW Solar PV = 2.4GW	International Renewable Energy Agency, 2019a, pp. 49,102
	Author's calculation	2030	*4.9	Official generation target: 20%	Economist Intelligence Unit, 2016; The Peninsular Qatar, 2019
		2030	4.69	Scenario with overall consumption ćby 30% and 20% of remaining electricity by renewables	Hypothetical assumption of a 30% overall reduction in the electricity consumption
Saudi Arabia	IRENA	2030	20.7	CSP = 9.5 GW Solar PV = 11.2GW	International Renewable Energy Agency, 2019a, p. 102
	Official announcement	2023	9.5	9.5 GW consisting mainly of solar	Council of Economic and Development Affairs, 2016
		2030	40.0	Announced capacity target CSP and PV	Gulf Business, 2019; PVTech, 2019
United Arab Emirates	IRENA	2030	29.1	CSP = 6 GW Solar PV = 23.1 GW	International Renewable Energy Agency, 2019a, p. 102
	Author's calculation	2030	*15.9	Official generation target: 25%	UAE Government, 2019
		2050	45.0	44% of capacity	(International Renewable Energy Agency, 2019a, p. 49)
		2050	25.0	Scenario with overall consumption ćby 40% and 44% of remaining electricity by renewables	International Renewable Energy Agency, 2019a, p. 49

* Calculated by the author.

Calculation of GW needed based on official targets for RES generation (Kuwait, Qatar, UAE)

Kuwait	Electricty consumption per capita (ECpC)	15.68	MWh	
	Population (2030 UN estimate)	4.747	million	(Population*ECpC)
	Electricity consumption (EC)	74.43296	TWh	
	Target for RES generation (Target)	15%		
	Renewable electricity consumptoin (REC)	11.16494	TWh	(EC*Target)
	Average renewable generation (ARG)	1.274537	GWh	(REC/8760*1000)
	Capacity factor	0.25	%	
		5.1	GW	(ARG/Capacity factor)
Qatar	Electricty consumption per capita	16.24	MWh	
	Population 2030 (UN estimate)	3.327	million	(Population*ECpC)
	Electricity consumption	54.03048	TWh	
	Target for RES generation	20%		
	Renewable electricity consumptoin	10.8061	TWh	(EC*Target)
	Average renewable generation	1.233573	GWh	(REC/8760*1000)
	Capacity factor	0.25	%	
		4.9	GW	(ARG/Capacity factor)
UAE	Electricty consumption per capita	13.06	MWh	
	Population (2030 UN estimate)	10.661	million	(Population*ECpC)
	Electricity consumption	139.2327	TWh	
	Target for RES generation	25%		
	Renewable electricity consumptoin	34.80817	TWh	(EC*Target)
	Average renewable generation	3.973535	GWh	(REC/8760*1000)
	Capacity factor	0.25	%	
		15.9	GW	(ARG/Capacity factor)

Appendix 3: Assumptions for Saudi Arabia and Kuwait simulation

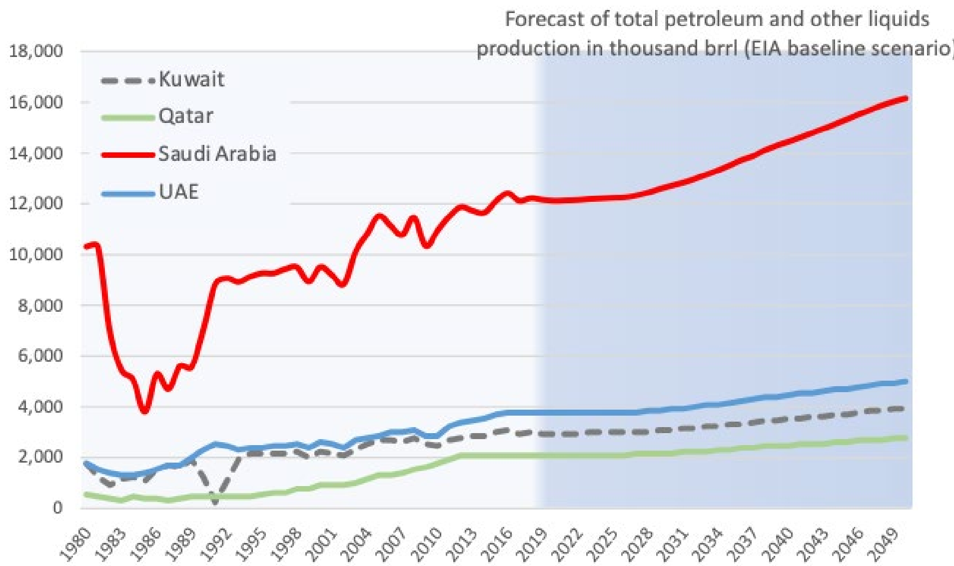
This model aims to address the question of how much MW solar capacity would be needed to replace oil consumption growth in the electricity sector. To answer the question, we have calculated the additional oil required—over the period 2018-2050—under different scenarios to maintain oil export at 2017 levels, and the corresponding MW/GW solar capacity needed. We have divided the key assumptions of our model:

Growth in oil production (EIA baseline scenario)

For growth in oil production we simply use the EIA baseline scenario. In this scenario world petroleum and other liquid fuels consumption is expected to grow by 18% between 2015 and 2040 with world oil consumption increasing to 113 mmb/d in 2040. In this scenario OPEC members are expected to increase their market share of crude production.[251] World liquid fuels production rises by 16.1 mmb/d from 2015 to 2040 and 10.3 mmb/d of the increase in crude and lease condensate is expected to come from OPEC members.[252] The graphic below was created using the categories of "Total Petroleum and Other Liquids" production and consumption from the EIA's Annual Energy Outlook 2018 and International Energy Statistics. Production and consumption forecasts for 2018-2050 were aggregated and reported together as the Middle East and OPEC. Since historically the relevant shares of Kuwait, Qatar, Saudi Arabia, and the UAE have remained stable (i.e., over the period 1980-2017), the table below transforms the production and consumption forecasts assigned respectively to OPEC: Middle East and Non-OECD: Middle East using the relative weights of the four countries in the aggregated value recorded respectively for 2017 and 2015 in EIA's International Energy Statistics.

251 EIA 2017 Outlook

252 Ibid.



Growth in overall domestic oil consumption (incl. chemicals, industry, transport, electricity)

Growth in overall domestic oil consumption is closely linked to GDP growth rates. GDP growth rates assumption for members of the GCC are between 2 and 3 percent between 2019 and 2021. We assuming a conservative 2% growth in oil consumption for Saudi Arabia, Qatar and the UAE which is a conservative estimate compared to previous average growth data from BP (2006-16). For Kuwait we assuming a 1.8% growth in overall domestic oil consumption which reflects average growth date between 2006-2016.

Oil as a fuel share in the energy mix[253]

The share of oil and gas in the production mix of electricity varies considerably across members of the GCC. In Qatar and the UAE, electricity is generated almost 100 percent by natural gas. This means that in Qatar and the UAE, the consumption growth in oil comes exclusively from the transport and petro-chemical sectors. By contrast, in Kuwait and Saudi Arabia, a significant amount of domestic consumption growth in oil also

253 (International Energy Agency, 2017g, 2017b, 2017c, 2017h)

comes from the generation of electricity because around half of the electricity in Saudi Arabia and Kuwait is generated by burning oil. We use IEA data and country specific data, such as from the Saudi Arabian Electricity and Cogeneration Regulatory Authority, for estimating oil as a fuel share in the energy mix. This share has remained similar over the last several years. As such, for simplicity reasons we assume that the fuel share in energy remains constant.

- Kuwait: 60%
- Qatar: 0%
- Saudi Arabia: 40%
- UAE: >1%

Linear electricity consumption growth

This is a simple extrapolation of past consumption and production growth rates and its impact on the capacity to export oil.[254] That is based on the assumption of no or only moderate progress in domestic price reform as well as regulatory efforts to curb consumption, as well as dynamic population growth under UN population forecasts. Based on BP average growth data (2006-16), we assume an average annual growth in consumption:

- Kuwait: 3.9%
- Qatar: 10.7%
- Saudi Arabia: 6.6 %
- UAE: 6.9 %

254 Thereby we follow the Lahn 2011(Lahn and Stevens, 2011)

Moderate electricity consumption growth[255]

The moderate growth scenario draws on the assumption of the Siemens Middle East Outlook, which expects a power demand growth rate of 3.3% over the coming decades.

Oil available for export under different scenarios

We have calculated oil available for export as the difference between growth of oil and other liquids production and growth of overall domestic oil consumption.

Additional oil required to maintain oil exports at 2017 levels

We have calculated additional oil required to maintain oil exports by using the differences between growth of oil and other liquids production and growth of overall domestic oil consumption over time.

Saudi Arabia additional oil required to maintain oil exports at 2017 levels (i.e 8,172mb/d) under moderate and linear growth assumptions
(opposite page):

255 In the moderate growth scenario we have not separated out energy and non-energy consumption of oil (i.e. oil as electricity or fuel for transport as well as petro-chemical feedstock).

			Assumption of moderate growth of electricity consumption (3.3%)			Assumption of linear growth of electricity consumption (6.6%)		
Year	Growth of oil and other liquids production (EIA baseline scenario)	Domestic oil consumption (transport, chemicals) 2% growth	oil consumption to generate electricity *	oil available for export = domestic oil production minus total domestic oil consumption	additional oil required to maintain oil exports at 2017 levels (in mb/d)	oil consumption to generate electricity (in mb/d) *	oil available for export = domestic oil production minus total domestic oil consumption	additional oil required to maintain oil exports at 2017 levels (in mb/d)
2019	12127	3,056.44	1,044.95	8,025.22	147.37	1,112.78	7,957.39	215.20
2020	12089	3,117.56	1,079.43	7,891.63	280.96	1,186.22	7,784.84	387.75
2021	12103	3,179.92	1,115.05	7,807.94	364.65	1,264.51	7,658.48	514.11
2022	12121	3,243.51	1,151.85	7,725.85	446.74	1,347.97	7,529.73	642.86
2023	12160	3,308.38	1,189.86	7,661.27	511.32	1,436.93	7,414.19	758.40
2024	12184	3,374.55	1,229.12	7,580.07	592.52	1,531.77	7,277.42	895.17
2025	12211	3,442.04	1,269.69	7,499.68	672.91	1,632.87	7,136.50	1,036.09
2026	12230	3,510.88	1,311.59	7,407.36	765.23	1,740.64	6,978.30	1,194.29
2027	12303	3,581.10	1,354.87	7,367.48	805.12	1,855.52	6,866.82	1,305.77
2028	12417	3,652.72	1,399.58	7,364.46	808.13	1,977.98	6,786.06	1,386.53
2029	12561	3,725.78	1,445.76	7,389.26	783.33	2,108.53	6,726.49	1,446.10
2030	12689	3,800.29	1,493.47	7,395.57	777.02	2,247.69	6,641.35	1,531.24
2031	12807	3,876.30	1,542.76	7,387.77	784.82	2,396.04	6,534.49	1,638.10
2032	12956	3,953.82	1,593.67	7,408.22	764.37	2,554.18	6,447.71	1,724.89
2033	13127	4,032.90	1,646.26	7,447.98	724.61	2,722.76	6,371.48	1,801.11
2034	13295	4,113.56	1,700.59	7,480.49	692.10	2,902.46	6,278.62	1,893.97
2035	13491	4,195.83	1,756.71	7,538.59	634.00	3,094.02	6,201.28	1,971.31
2036	13693	4,279.75	1,814.68	7,598.60	573.99	3,298.23	6,115.05	2,057.54
2037	13858	4,365.34	1,874.56	7,617.75	554.84	3,515.91	5,976.40	2,196.19
2038	14089	4,452.65	1,936.42	7,699.95	472.64	3,747.96	5,888.42	2,284.17
2039	14269	4,541.70	2,000.33	7,726.83	445.76	3,995.32	5,731.83	2,440.76
2040	14421	4,632.54	2,066.34	7,722.57	450.02	4,259.02	5,529.89	2,642.70
2041	14583	4,725.19	2,134.53	7,722.98	449.61	4,540.11	5,317.39	2,855.20
2042	14762	4,819.69	2,204.96	7,737.10	435.49	4,839.76	5,102.31	3,070.28
2043	14934	4,916.08	2,277.73	7,739.97	432.62	5,159.18	4,858.52	3,314.07
2044	15115	5,014.41	2,352.89	7,747.36	425.23	5,499.69	4,600.57	3,572.02
2045	15302	5,114.69	2,430.54	7,756.82	415.77	5,862.67	4,324.69	3,847.90
2046	15490	5,216.99	2,510.75	7,762.58	410.01	6,249.60	4,023.72	4,148.87
2047	15672	5,321.33	2,593.60	7,757.51	415.08	6,662.08	3,689.04	4,483.56
2048	15854	5,427.75	2,679.19	7,747.40	425.19	7,101.78	3,324.81	4,847.78
2049	16004	5,536.31	2,767.60	7,700.25	472.34	7,570.49	2,897.36	5,275.23
2050	16126	5,647.04	2,858.93	7,620.02	552.58	8,070.14	2,408.80	5,763.79

*Oil refers here to the composite of crude, diesel and heavy fuel oil (HFO) for generating electricity (see Saudi Arabian Electricity and Cogeneration Regulatory Authority)

Kuwait additional oil required to maintain oil exports at 2017 levels (i.e 2,435mb/d) under increasing and stagnating oil production:

				Scenario: increasing domestic oil production (EIA baseline scenario)		Scenario: stagnating domestic oil production (2017 levels)	
Year	Growth of oil and other liquids production (EIA baseline scenario)	Domestic oil consumption (transport, chemicals) 1.8% growth	oil consumption to generate electricity under linear growth (3.9%)	oil available for export = domestic oil production minus total domestic oil consumption	additional oil required to maintain oil exports at 2017 levels (in mb/d)	oil available for export = domestic oil production minus total domestic oil consumption	additional oil required to maintain oil exports at 2017 levels (in mb/d)
2019	2,937	383	133	2,421	14	2,412	23
2020	2,927	390	138	2,399	36	2,400	35
2021	2,931	397	143	2,390	45	2,387	48
2022	2,935	405	149	2,382	53	2,375	60
2023	2,945	412	155	2,378	57	2,361	74
2024	2,950	419	161	2,370	65	2,348	87
2025	2,957	427	167	2,363	72	2,334	101
2026	2,962	434	174	2,354	81	2,320	115
2027	2,979	442	180	2,356	79	2,305	130
2028	3,007	450	187	2,369	66	2,290	145
2029	3,042	458	195	2,389	46	2,275	160
2030	3,073	467	202	2,404	31	2,259	176
2031	3,101	475	210	2,416	19	2,243	192
2032	3,137	484	218	2,435	0	2,226	209
2033	3,179	492	227	2,460	-25	2,209	226
2034	3,219	501	236	2,482	-47	2,191	244
2035	3,267	510	245	2,512	-77	2,173	262
2036	3,316	519	254	2,542	-107	2,154	281
2037	3,356	529	264	2,563	-128	2,135	300
2038	3,412	538	275	2,599	-164	2,115	320
2039	3,455	548	285	2,622	-187	2,095	340
2040	3,492	558	297	2,638	-203	2,074	361
2041	3,531	568	308	2,655	-220	2,052	383
2042	3,575	578	320	2,677	-242	2,030	405
2043	3,616	588	333	2,695	-260	2,007	428
2044	3,660	599	346	2,715	-280	1,983	452
2045	3,706	610	359	2,737	-302	1,959	476
2046	3,751	621	373	2,757	-322	1,934	501
2047	3,795	632	388	2,776	-341	1,909	526
2048	3,839	643	403	2,793	-358	1,882	553
2049	3,876	655	418	2,803	-368	1,855	580
2050	3,905	667	435	2,804	-369	1,827	608

Calculation Steps: Replacing additional oil required through renewables in GW (e.g. moderate growth scenario Saudi Arabia)

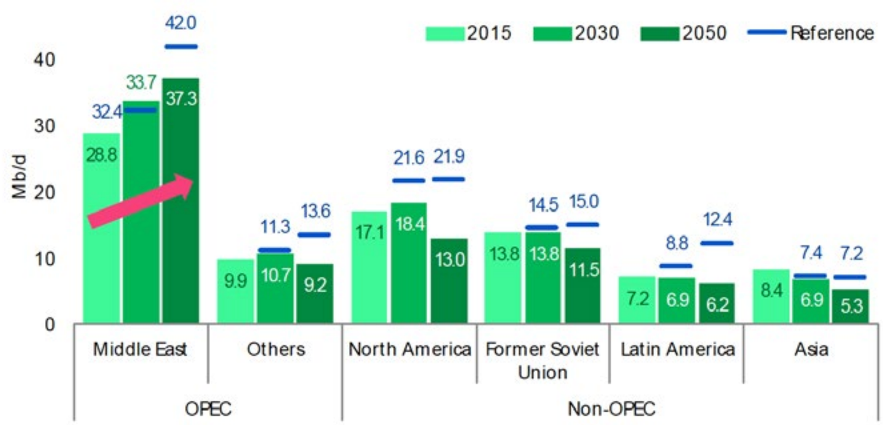
Calculating renewables needed (in GW) to replace additional oil required for electricity production

			Calculations
Additional oil required for electricty production (AOREP)	777,020.00	brl/day	
Oil electrictiy (OE)	38,851,000.00	ton oil equivalent	(AOREP/7.3*365)
Energy content/ton crude oil (ECTCO)	11,630.00	kwh	
Equivalent in kwh	451,837,130,000.00	kwh	(OE*ECTCO)
Equivalent in TWh	451.84	TWh	
Efficiecny power generation (EPG)	40%	Assuming a 40% standard efficiency for oil plant	
Electricity	180.73	TWh	(Equivalent in TWh/ EPG)
(Per day)	20.63	GWh	(Electricity/8760*1000)
Capacity factor	0.25 82.53	% GW	

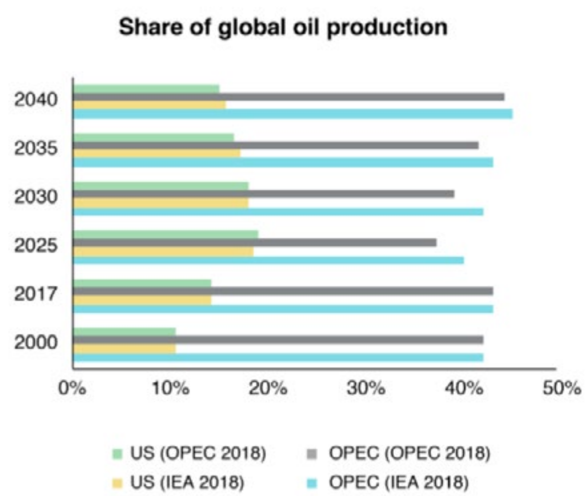
Note: the 777.02 mb/d refer to additional oil required in Saudi Arabia by 2030 under moderate growth of electricity consumption (3.3%).

Appendix 4: Effect of low oil prices (peak demand scenario) on the share of global oil production and income

Crude oil production (peak oil demand case) shift to low-cost regions:



Source: (Yamashita, 2018, p. 22)



Source: (Pierru, 2019b, p. 4)

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