RICE UNIVERSITY'S
Baker Institute for Public Policy

Economic Ramifications of Energy Transition Investments in the Arab Gulf States

Working Paper

Economic Ramifications of Energy Transition Investments in the Arab Gulf States

Osamah Alsayegh, Ph.D.
Visiting Research Scholar

This publication was produced in collaboration with Rice University's Baker Institute for Public Policy. Wherever feasible, this research was reviewed by outside experts before it was released. Any errors are the author's alone.

This paper is a work in progress and has not been through editorial review.

Economic Ramifications of Energy Transition Investments in the Arab Gulf States

Summary
The energy transition process highly depends on investments in clean technologies to cut down carbon emissions in various sectors of the economy. Such investments in clean technologies do not usually increase the productivity of the economic sectors, they may even lower it down. Thus, the energy transition process might lead to a decline in energy return on investment, increasing energy prices, and a fall in economic growth. Unlike advanced economy nations, economic growth is central to developing countries to sustain their basic socioeconomic needs. Hence, taking steps toward energy transition by developing nations may require more time, compared to developed nations.

In reality, funds are limited, and hence, increasing investments in certain sectors results in reducing investments and consumption in other sectors. Building on this reality assumption, a quantitative analysis is carried out to assess the impact of the energy transition process on economic sectors. This paper focuses on the Arab Gulf states – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) – as a case study. All economic industries of each Gulf state were aggregated into eleven sectors. The input-output data tables of the Arab Gulf states were used, and the analysis was carried out using Leontief and Ghosh models to assess exogenous demand and supply change impacts. The analysis was performed by increasing the investments and value added – required for the energy transition – in the oil, gas, petrochemical, and power sectors to assess the macroeconomic impact on the remaining sectors. Results implied that the most vulnerable and exposed sectors to the transition were education and health, finance and businesses, and services sectors. Moreover, policies were proposed to mitigate the negative impact of the transition process on the affected sectors.

Introduction
Many studies pointed out the positive opportunities and benefits of the energy transition to net zero carbon emission on both global and regional economies. The commonly suggested benefits of the energy transition would involve the gross domestic product (GDP) growth through raised investments in clean technologies, increased consumer expenditure due to tax rate changes, and the creation of new businesses and job opportunities.[1]

On the other hand, some reports noted the high cost of the energy transition to net zero, which could be a burden on the economy rather than an advantage. Reports have different assessments of the transition to net zero cost. For example, the BloombergNEF expected that the transition will require U.S. $200 trillion by 2050 – i.e., nearly U.S. $7 trillion a year from the year 2022 to 2050.[2] McKinsey Global Institute anticipated that the capital spending on physical assets for energy and land-use systems in the net-zero transition between 2021 and 2050 will amount to about U.S. $275 trillion, or U.S. $9.2 trillion per year on average.[3] The International

Energy Agency (IEA) estimated that reaching the goal of net zero will cost about U.S. $4 trillion a year over the next 30 years.[4]

Both narratives of the energy transition arguments – i.e., benefits and burden of the energy transition to net zero – have a common ground that the transition is an intensive investment process. The investment in the transition would have more impact in hampering the economic growth of developing countries, and hence, it is highly challenging to meet. Developing countries are either in a starting or in a middle position in their economic growth process. It is a crucial need for developing nations to develop their education, healthcare, and infrastructure sectors. Thus, the priority is to allocate resources to economic development and growth processes, which may not be of primacy to developed countries since they have already achieved a high standard of living, well-developed infrastructure, advanced technology, and strong institutions. Developed nations generally experience steady, moderate economic growth due to their mature economies. Hence, the energy transition impact is more of a concern to developing countries.

The degree of a country's economic growth is typically measured by the GDP which quantifies the total value of all goods and services produced within a country's borders during a specific time frame. It is important to note that GDP is not the only indicator of a nation's well-being. Factors like income distribution, quality of life, social services, and environmental sustainability also play critical roles in assessing a country's overall development and prosperity. However, GDP is used in this study since it serves as a comprehensive measure of a nation's economic activity and output and helps identify where resources are being allocated for the study.

As mentioned earlier, the economic impact of an energy transition is reflected in the allocation of income to investment rather than consumption, and the implications for value-added concerning the distribution of income: wages versus profits, and taxes versus subsidies. The cost of adopting new technologies results in reduced value added. This outcome arises because, under constant conditions, the additional cost raises the overall production expenses. Since energy is a component in the production of all commodities, this implies that all productive endeavors will encounter heightened production costs.[5]

The energy transition impact was examined through the assessment of forms of the GDP calculations[5] – i.e., a sum of consumption, investment, and net export, or a sum of total inputs into production sectors, and gross value added. It is noted that in the absence of a carbon emission price charge, the investment in clean technologies does not necessarily increase and enhance useful energy production.[5] It is an additional cost to provide the same energy outcome or even downgrade the energy quantity and quality. For instance, investing in carbon capture technology in the power sector does not enhance the sector's electric energy production. It reduces the available energy quantity because part of the produced energy goes to the emission capture process. Investing in solar and wind technologies – which are intermittent and non-dispatchable systems – undermines the power grid stability to meet the changing demand profiles – which is not always in synch with solar and wind resources availability. Moreover, the argument of job creation as an outcome of the energy transition does not fully hold.

Substituting fossil-fired power plants' labor with renewable energy plants' labor challenges such an argument. Besides, renewable energy power plants have an inefficient labor-to-production ratio relative to other conventional plants. According to the American Enterprise Institute, about 20% of electric power payrolls were in solar workers who's their sector produced less than 1% of the electric power generated in the United States in 2016.[6]

This paper examines by quantifying the impact of investments in the energy transition process on developing nations' economic sectors. The six Arab Gulf states' economic sectors are analyzed to identify the most vulnerable sectors in these states to the energy transition process. Despite their overall wealthy economic status due to the abundance of oil and gas resources, however, the pace, stability, and continuity of investments are critical for the success and effectiveness of the energy transition process.

Macroeconomic Overview

The Arab Gulf states are spread over an area of about 2.57 million square kilometers (about 1.0 million square miles). As of 2022, the Gulf states had a total population of about 59 million, total GDP (current prices) U.S. $2.1 trillion, and this made their overall GDP per capita U.S. $35,600 compared to the world average GDP per capita of U.S. $12,650 (Table 1 presents the Gulf per country information breakdown).[7]

Table 1 — General Socioeconomic Information of the Arab Gulf States As of 2022

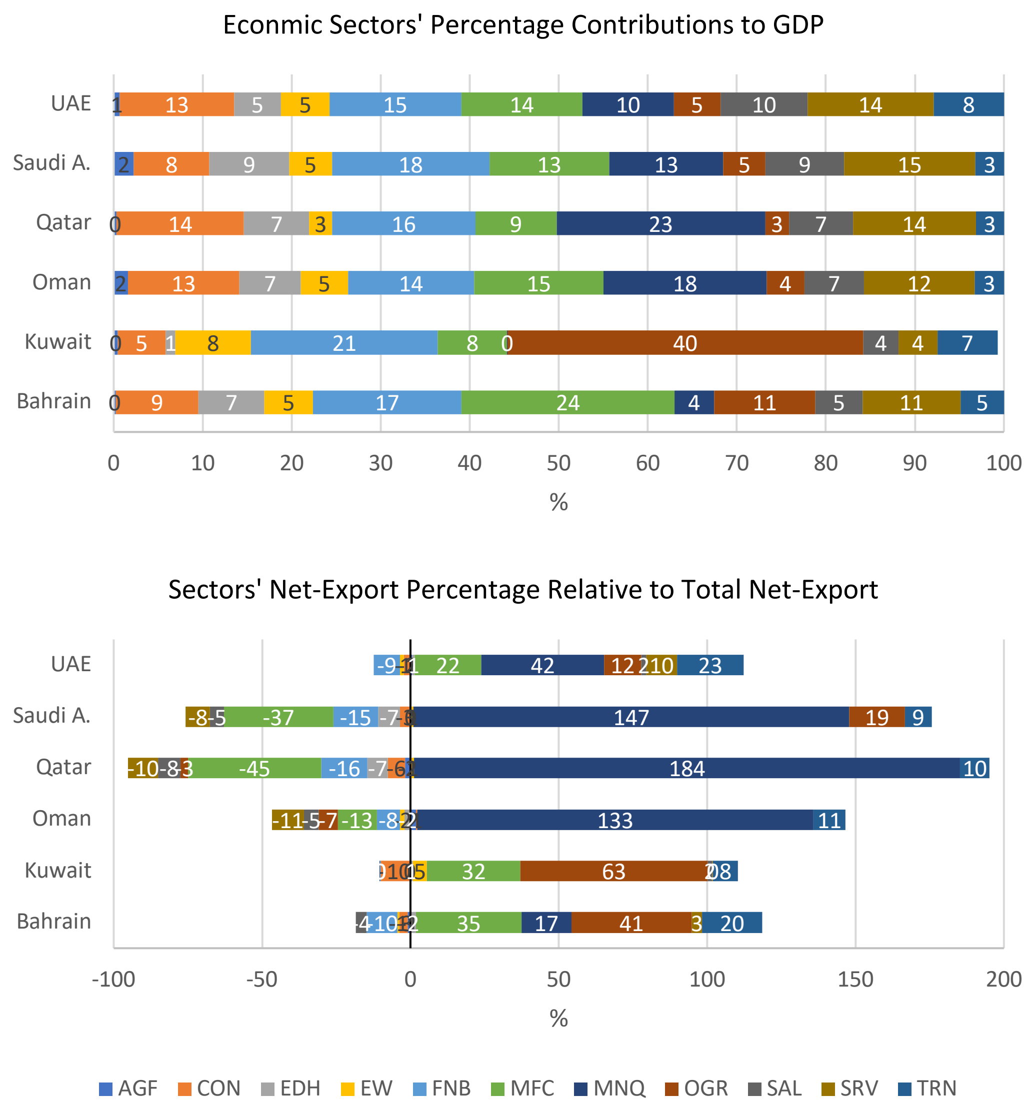
Country	Area (square kilometers)	Population (million)	GDP (U.S. $ billion)	GDP per capita (U.S. $)
Bahrain	778	1.5	44.4	29,600
Kuwait	17,818	4.3	184.6	42,930
Oman	309,500	4.6	114.7	24,934
Qatar	11,581	2.7	237.3	87,888
Saudi Arabia	2,149,690	36.4	1000.1	27,475
UAE	83,600	9.4	507.3	53,968
Total	**2,572,967**	**58.9**	**2088.4**	**Overall: 35,456**

The size of the economic sectors of the Gulf states varies from one country to another. In this paper, all sectors in each country are aggregated into eleven major economic industrial activities. The 2016 percentage contributions of the eleven sectors to GDP, and sectors' percentage net exports relative to total net exports are shown in Figure 1.

It is assumed that the present percentage shares of the sectors in GDP are similar or close to that of 2016 for the following reasons. The mining and quarrying (MNQ) and oil, gas and refining (OGR) sectors are the central pillars of the Gulf states' economies. Revenue-wise, the export of natural resources and their by-products is the anchor of the Gulf states economic prosperity.[8] Consequently, in general, the Gulf states do not have genuine productive economies across their sectors where technological development and knowledge creation values are produced locally and exported to international markets. Their internal structural imbalances and exposure to global markets constrain their economic performance. Accordingly, the dominance of oil and gas sectors in most of the Gulf states (mainly, Kuwait, Qatar, Saudi Arabia and UAE) has resulted in a large public sector and a small non-oil and -gas production base.[9] Most of the private sector highly depends on oil and gas revenues through government expenditure.[10]

Besides natural resources rent, the Gulf states' financial status is also strengthened by their sovereign wealth funds (SWFs) with total investments that are estimated at $2.3 trillion.[11] These financial assets are not directly counted in the GDP, however, their returns on investments have a positive impact on the Gulf states economic indicators. They provide resiliency and security that hedge against oil and gas market volatility.

Figure 1 — The Arab Gulf States' Major Economic Activity Sectors



AGF: Agriculture and Fishing; CON: Construction; EDH: Education and health; EW: Electricity and water; FNB: Finance and businesses; MFC: Manufacture; MNQ: Mining and quarrying; OGR: Oil, gas and refining; SAL: Whole and retail sales; SRV: Services; TRN: Transport.
Source: Author's calculations and Eora Global Supply Chain Database.

Energy Transition Endeavors Toward Net Zero

Despite continuing investments and development of their oil and gas sectors, the Arab Gulf states have set ambitious goals for mitigating carbon emissions (Table 2). Their strategy in combating climate change revolves around mitigating carbon emissions rather than abandoning the oil and gas energy industry. Gulf states' leaders call for a balanced approach that is a gradual and responsible transition to avoid exacerbating inflation, rising energy prices, and social and security unrest.[11]

The Arab Gulf states' strategy for mitigating carbon emissions is to integrate hydrocarbon-fired facilities with clean energy systems and diversify the energy mix, using renewables, hydrogen, nuclear power, plantations, and carbon capture, utilization and storage (CCUS). Although greenhouse gas emissions in the Gulf states are relatively low – 1.4 billion tons compared to China's 12.7 billion tons and the U.S.'s 6.0 billion tons in 2019 – they have already begun work to achieve their announced targets (Table 3).

There is no declared clear specification on the targeted type of emission group – Scope 1, 2 or 3 – that is (are) sought. Scope-1 encompasses emissions from establishments or entities that have direct control over fuel consumption, and hence, emission. For example, emissions from a power plant are categorized as Scope-1 since the plant has direct control of the burning fuels in its facility. Scope-2 involves emissions that a consumer causes indirectly and come from different sources. For instance, the emissions caused by the building sector in consuming electricity that is generated by a power plant are of Scope 2 type. Scope 3 covers all emissions not within the Scope 1 and 2 boundaries. It covers emissions in the value chain of goods and services but not from the supplier and consumer sides. Hence, this study assumes that the Gulf states are seeking carbon neutrality of Scope 1 type in controlling the emissions at the source. The major sectors that this study focused on and fall within Scope 1 emissions are the electricity and water (EW), mining and quarrying (MNQ), and oil, gas and refined oil products (OGR) sectors.

The expected energy sources and technologies to be invested in and integrated with Scope 1 type emission sectors – i.e., EW, MNQ, and OGR – include renewable energy, blue and green hydrogen, nuclear energy, carbon capture, storage and utilization (CCSU).

Table 2 — Arab Gulf States Carbon Emission Reduction Targets[11]

Country	Carbon Emission Reduction Target Relative to Business as Usual			
	2030	2035	2050	2060
Bahrain	-	-	-	Net zero
Kuwait	-	7.4%	Net zero in oil sector	Net zero in all sectors

Oman	7.0%	-	Net zero	-
Qatar	25%	-	-	-
Saudi Arabia	31%	-	-	Net zero
UAE	31%	-	Net zero	-

Source: NDC Registry.

Table 3 — Endeavors To Mitigate Emissions Among the Arab Gulf States[12]

	Technologies and Actions			
Country	**Renewable Energy (RE) and Nuclear Energy (NU)**	**Hydrogen (H2)**	**CCUS**	**Plantation**
Bahrain	- Total installed capacity as of 2021: RE 12 MW (0.1%). - Planning 10% RE of total installed capacity by 2035.	- Investigating the feasibility of H2 production plants.	- Announced carbon capture investment plan with 10 mt/y capacity.	- Planting more than 50,000 trees and shrubs through its National Initiative for Agricultural Development.
Kuwait	- Total installed capacity as of 2021: RE 106 MW (0.5%). - Planning 15% RE of total installed capacity by 2030.	- Developed a national strategy for H2 production (mainly blue H2).	- Piloting carbon capture systems with plans to expand CCUS for enhanced oil recovery application.	TBD.
Oman	- Total installed capacity as of 2021: RE 188 MW (1.6%). - Plans to meet 35% of energy demand from RE by 2040.	- Planning green H2 production: at least 1 mt/y by 2030, up to 3.75 mt/y by 2040, and up to 8.5 mt/y by 2050.	- Exploring CCUS for blue hydrogen production.	- Launched an initiative to plant 10 million trees in 2020.
Qatar	- Total installed capacity as of 2021: RE 43 MW (0.4%).	- Entering international consortium for the production of H2.	- Developing a national plan for carbon capture.	- Planting 10 million trees by 2030.
Saudi Arabia	- Total installed capacity as of 2021: RE 443 MW (0.5%). - Plans to meet 50% of energy demand from RE by 2030; 17 GW NU by 2040.	- Plans to produce 11 million tons (mt) of blue H2/ammonia by 2030. - Plans to produce 650 tons per day of green H2 and 1.2 mt/year green	- Has a CCUS hub with a capacity of 9 mt/y by 2027, expandable to 44 mt/y by 2035.	- Plans to plant 10 billion trees over several years, with more than 600 million trees and shrubs to be planted by 2030.

		ammonia by 2026.		
UAE	- Total installed capacity as of 2021: RE 2706 MW (7.0%) and NU 2690 MW (7.0%). - Plans to meet 50% of energy demand from RE and NU by 2050.	- More than seven planned projects with a capacity of 0.5 mt/y. - Production targeting 25% market share of low-carbon hydrogen and derivatives in key import markets by 2030. - Plans to produce 1.4 mt/y by 2031 and 15 mt/y by 2050.	- Al Reyadah carbon capture facility has a capacity of 0.8 mt/y, expandable to 5.0 mt/y by 2030. The captured carbon is utilized in enhanced oil recovery.	- Has pledged to plant 100 million mangrove trees by 2030.

Potential Implications of Net-Zero Emission on Economy Sectors

The fundamental nature of the energy transition toward net zero requires an increase in investment in clean technologies and eventually reduction in consumption. The investment in clean technologies does not necessarily imply an increase in production capacity. It only increases capital – e.g., investment in carbon capture and energy-efficient systems do not increase generation capacity – while the output remains almost the same or even lower. Hence, the general feature of the energy transition to net zero is having a low output-to-capital ratio. In general, in emerging economies, growth is driven by investments in assets that have a high output-to-capital ratio. In other words, emerging economies seek to maximize outcomes and benefits while making the minimum capital investment possible. Moreover, most developing countries would be net importers of energy transition technologies. Hence, an additional increase in imports would potentially degrade the trade position of these countries.

In the assumption of achieving the net zero goal of Scope 1 type in the considered sectors (EW, MNQ and OGR), potential disruption affects the intermediate transactions between the economic sectors and their associated value-added and final demands. This assumption would entail higher cost inputs from the EW, MNQ, and OGR sectors to all other sectors. These higher cost values are needed to compensate for the transition investment and operation costs in the EW, MNQ, and OGR sectors. Consequently, the remaining sectors would likely raise their product and service cost values, withhold their developmental plans, or decrease their value added.

The above narrative on the expected impact of the energy transition is quantitively estimated for the six Arab Gulf states using Leontief and Ghosh models through their input-output data tables. The goal is not to determine precise values, it is rather to analyze the energy transition measures shock on their economy sectors.

Methodology and Data

The Leontief and Ghosh models also both referred to as the input-output (IO) model, have been extensively used to examine economic sectors' responses and performances under various exogenous impact scenarios. The fundamental purpose of the IO framework is to analyze the interdependence of industries in an economy by specifying the inputs required by each industry to produce its outputs (Figure 2). These inputs are often categorized as intermediate inputs, z_{ij} (value inputs from sector i to sector j) and final demand of sector i (f_i). Intermediate inputs are the goods and services used by one industry as inputs from another industry, while final demand refers to the goods and services consumed by households, government, and other final users.

Figure 2 — A Typical Input-Output Table

		Intermediate Consumers					Final Demand			
		Sector-1	.	.	.	Sector-n	Consumption	Investments	Net-export	Other_Dmds
Producers	Sector-1	z_{11}	..	..	...	z_{1n}				
	.	...	...	..	..	...				
	.	..	..	...	..	..				
	.	.			.	.				
	Sector-n	z_{n1}	.	.	.	z_{nn}				
Value Added	Employee compensation									
	Capital consumption									
	Profit income									
	Taxes									
	Subsidies									
	Other_Inputs									

Given an economy with n sectors, the total output (production) of the sector, x_i, can be expressed as follows:

$$x_1 = z_{11} + \cdots + z_{1n} + f_1$$
$$\vdots$$
$$x_n = z_{n1} + \cdots + z_{nn} + f_n$$

In its matrix algebra notation,

$$\begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix},$$

or its compact representation,

$$\boldsymbol{x} = \boldsymbol{Zi} + \boldsymbol{f} \qquad (1)$$

Where $\boldsymbol{x}$ is a column vector of n sectors' productions, $\boldsymbol{Z}$ is n by n matrix, $\boldsymbol{i}$ is one vector of length n, and $\boldsymbol{f}$ is the final demand vector of length n (representing n sectors).

The components of the value added are payments by sectors for employee compensation (labor services), government services (received subsidies and paid for in taxes), capital (interest payments) land (rental payments), entrepreneurship (profit), and for all other value-added items.

In the IO model, a fundamental assumption is that z_{ij}, the interindustry flows from sector i to sector j within a period depends entirely on the total output x_j of sector j for that same period. Given z_{ij} and x_j, a direct input coefficient parameter ratio – referred to as the technical coefficient – is calculated as follows:

$a_{ij} = \frac{Input\ from\ sector\ i\ to\ sector\ j}{Total\ output\ of\ sector\ j} = \frac{z_{ij}}{x_j}$, hence, $z_{ij} = a_{ij}x_j$

Equation (1) can be rewritten as follows:

$$\begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix},$$

or its compact representation

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f} \qquad (2)$$

Where $\boldsymbol{A}$ is the technical coefficient n by n matrix. Equation (2) is solved for $\boldsymbol{x}$ – i.e., the total production of n sectors is as follows:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} = \boldsymbol{L}\boldsymbol{f} \qquad (3)$$

Where $\boldsymbol{I}$ is n by n identity matrix, $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the inverse of the matrix $(\boldsymbol{I} - \boldsymbol{A})$ and is known as the Leontief inverse matrix, $\boldsymbol{L}$. The Leontief inverse, $\boldsymbol{L}$, relates sectoral gross outputs to the amount of final product (final demand).

The alternative interpretation that relates sectoral gross production, $\boldsymbol{x}$, to the primary inputs and value added, can also be calculated using the following equation

$$\boldsymbol{x}' = \boldsymbol{i}'\boldsymbol{Z} + \boldsymbol{v}' \qquad (4)$$

Where $\boldsymbol{x}'$ is the transpose of $\boldsymbol{x}$, $\boldsymbol{i}'$ is the transpose of a vector of length n where all of its component values are ones, and $\boldsymbol{v}'$ is the transpose of the value added vector. A direct-output (or allocation) coefficient can be calculated as follows

$b_{ij} = \frac{Input\ from\ sector\ i\ to\ sector\ j}{Total\ inputs\ into\ sector\ i} = \frac{z_{ij}}{x_i}$, and z_{ij} can be expressed as $z_{ij} = b_{ij}x_i$,

Equation (4) can be re-written as follows

$$\boldsymbol{x}' = \boldsymbol{x}'\boldsymbol{B} + \boldsymbol{v}' \ \Rightarrow \ \boldsymbol{x}' = \boldsymbol{v}'(\boldsymbol{I} - \boldsymbol{B})^{-1} = \boldsymbol{v}'\boldsymbol{G}$$

where $\boldsymbol{B}$ is the direct-output coefficients matrix, and $\boldsymbol{G}$ is the Ghosh inverse matrix $(\boldsymbol{I} - \boldsymbol{B})^{-1}$. Above equation – i.e. $\boldsymbol{x}' = \boldsymbol{v}'\boldsymbol{G}$ – can also be expressed as

$$\boldsymbol{x} = \boldsymbol{G}'\boldsymbol{v} \quad (5)$$

Where $\boldsymbol{G'}$ is the transpose of Ghosh inverse matrix, $\boldsymbol{G}$. From equations (3) and (5),

$\boldsymbol{x} = \boldsymbol{L}\boldsymbol{f} = \boldsymbol{G}'\boldsymbol{v}$, final demand and value added can be expressed as follows,

$$\boldsymbol{f} = \boldsymbol{L}^{-1}\boldsymbol{G}'\boldsymbol{v} \quad (6)$$

$$\boldsymbol{v} = \boldsymbol{G}'^{-1}\boldsymbol{L}\boldsymbol{f} \quad (7)$$

The work simulates the impact of energy transition in focusing on the electricity and water (EW), mining and quarrying (MNQ) and oil, gas and refineries (OGR) sectors. Their final demand and value added are altered (simulating energy transition investments), and the impacts on the remaining sectors and overall economy of each of the Gulf Arab states are assessed. Increasing investments to meet the energy transition requirements in these three sectors would eventually increase their final demands (since investment is one of the final demand components).

Issues to be investigated, under the case of final demand changes – i.e., increasing investments in the EW, MNQ and OGR sectors – how sectors' production, $\boldsymbol{x}$, and value added, $\boldsymbol{v}$, are affected? In a mathematical term using equations (3) and (7), this can be assessed by

$$\Delta\boldsymbol{x} = \boldsymbol{L}(\Delta\boldsymbol{f}) \quad (8)$$

$$\Delta\boldsymbol{v} = \boldsymbol{G}'^{-1}\boldsymbol{L}(\Delta\boldsymbol{f}) \quad (9)$$

Where $\Delta\boldsymbol{x}$ and $\Delta\boldsymbol{v}$ are the output production and value added changes in response to the variation in final demand, $\Delta\boldsymbol{f}$.

Similarly, given the alteration in value added, $\Delta\boldsymbol{v}$, of EW, MNQ and OGR, how the sectors' production and final demands are affected? These issues are addressed using equations (5) and (6) and they are expressed as follows,

$$\Delta x = \boldsymbol{G}'(\Delta\boldsymbol{v}) \quad (10)$$

$$\Delta\boldsymbol{f} = \boldsymbol{L}^{-1}\boldsymbol{G}'(\Delta\boldsymbol{v}) \quad (11)$$

In calculating equations (8) – (11), it is assumed that the technologies of the production sectors are unchanged – i.e., matrices $\boldsymbol{L}$ and $\boldsymbol{G}$ have fixed values.

The data of the year 2016 of Arab Gulf states' IO tables were sourced from the EORA-26.[13] The EORA-26 offers information for monetary input–output coefficients for 189 countries. For each country, IO coefficients table representing 26 industrial sectors is provided. It is worth noting that Kuwait and Saudi Arabia are the only Gulf countries that officially publish their IO tables. For the other countries, for which there is no official IO table, EORA estimates their IO tables in processing a 26-sector proxy IO table combining diverse industries and products from the Australian, US, UK and Japanese economies, then scales it to match the available data for that country, such as GDP, imports, exports, etc.[14]

The Gulf states' 26-sector industries data were aggregated into 11-sector industries (Table 4). The analysis is carried out by changing the final demands or value added to simulate final demand (e.g., investments) and value added (e.g., wages, taxes, profits, etc.) requirements for the energy transition. In this study, it is assumed that the Gulf states would funnel energy transition investments in electricity and water (EW), mining and quarrying (MNQ), and oil, gas, petrochemical and refinery (OGR) to achieve Scope 1 carbon neutrality in these sectors.

Table 4 — The Considered Sectors in the Analysis for the Arab Gulf States

No.	Sector	Sub-sector
1	AGF – Agriculture & Fishing	- Agriculture - Fishing
2	CON – Construction	Construction
3	EDH – Education & Health	Education, health and other services
4	EW – Electricity & Water	Electricity, gas and water
5	FNB – Financing & Business Activities	- Financial intermediation and business activities - Re-export and re-import
6	MFC – Manufacturing	- Electrical and machinery - Food and beverages - Metal products - Recycling - Textiles and wearing apparel - Transport equipment - Wood and paper - Others
7	MNQ – Mining and Quarrying	Mining and quarrying
8	OGR – Oil, Gas & Refining	Petroleum, gas, petrochemical, refining products
9	SAL – Wholesale & Retail Trades	- Wholesale trade - Retail trade
10	SRV – Services	- Hotels and restaurants - Maintenance and repair - Post and telecommunications - Private households - Public administration - Others
11	TRN - Transport	Transport

Results and Discussion

Effects of Exogenous Changes

It is worth recognizing the effects of exogenous changes – i.e., final demand and value added – on sectors' outputs. This information is useful to clarify and rationalize the impact of energy transition investments in the sectors of Electricity and water (EW), Mining and Quarrying (MNQ), and Oil, Gas and refining on the remaining eight sectors in the analysis in a later section. Output and input multipliers are used to examine the difference between the initial effect of an exogenous change and the total effects of that change. An output multiplier for sector j is defined as the total value of production in all sectors of the economy that is necessary in order to satisfy a dollar's worth of final demand for sector j's output. In the view of demand-side, one can identify sectors of large output multipliers to guide investments (or final demand) for the most benefits of the overall economy.[15]

An input multiplier for sector j is defined as the total value of production in all sectors of the economy for a dollar's worth of value added for sector j's input. In this view of the supply-side model, one might use these input multiplier figures to decide where an additional dollar's worth of provision of primary resources (labor, etc.) would be most beneficial to the total economy, in terms of potential for supporting expanded output.

Per unit monetory value – e.g., per U.S. $1 – the output and input multipliers of a sector, j, OM_j and IM_j, respectively, are determined using the Leontief and Ghosh inverse matrices, $\boldsymbol{L}$, $\boldsymbol{G}$, as follows,

$OM_j = \sum_{i=1}^{n} l_{ij}$,and $IM_j = \sum_{i=1}^{n} g_{ji}$,

Where l_{ij} is the element in the i-th row and j-th column of the $\boldsymbol{L}$ matrix, and g_{ji} is the element in the j-th row and i-th column in the $\boldsymbol{G}$ matrix.

Figure 3 presents the output and input multipliers of the Gulf states' economic sectors. The largest and smallest multipliers of all countries are shaded in green and yellow, respectively. For example, Kuwait's construction (CON) sector is the largest output multiplier in the country's economy. This suggests that investing an additional dollar in the CON sector would have the greatest impact on the total dollar value of output generated throughout the economy with growth of 2.3-fold. On the other hand, Kuwait's education and health (EDH) sector's impact is the smallest on the output growth of 1.1-fold. In the case of input multipliers, Kuwait's transportation (TRN) sector has the largest input multiplier. It implies that an additional dollar's worth of provision of primary resources – e.g., labor – would be most advantageous to the total economy, in terms of potential for supporting expanded output by double. While the electricity and water (EW) sector has the smallest input multiplier with no effect on the economy's output. This is most likely due to the high subsidy offered by the EW sector to domestic consumers.

Concerning the three sectors – i.e., EW. MNQ and OGR – under investigation, the EW sector leans toward a lower output multiplier effect in all of the Gulf states. Hence, investments in renewable energy, CCSU, and blue/green hydrogen – which do not necessarily increase the sector's production output – are expected to have zero or negative returns on investment. However, the EW input multiplier has a moderate positive effect across the Gulf states' economies – except for Kuwait and UAE which have the smallest and largest values, respectively.

The MNQ sector includes oil and gas – besides other minerals and materials – extractions in all Gulf states except for Kuwait where its oil and gas extraction is included in the OGR sector. Overall, the MNQ has a low to moderate output multiplier effect on the Gulf states' economies. As for its input multiplier, MNQ is at its low-end effect. Except for Bahrain and Kuwait where the former has negligible oil and gas production and the latter has its oil/gas extraction in the OGR.

The OGR sector is the heart of the Gulf states' economy. It mainly includes the mid and downstream of oil and gas industries and makes the most export revenue. In all Gulf states, OGR sector has medium to high output and input multiplier effects. Increasing green technology investments in OGR sector might not increase its production; however, it could maintain its export level in international markets where products' environmental specifications are required. Raising the sector's value added – e.g., labor – it may reflect on the enhancement of its product quantity and quality.

Figure 3 — Output and Input Multipliers of the Arab Gulf States' Economic Sectors

Output Multipliers						
Sector	**Country**					
	Bahrain	**Kuwait**	**Oman**	**Qatar**	**Saudi A.**	**UAE**
AGF	1.3	1.5	1.3	1.7	1.4	1.7
CON	2.1	2.3	2.2	1.4	1.8	2.2
EDH	1.4	1.1	1.3	1.2	1.8	1.3
EW	1.3	2.1	1.5	1.2	1.2	1.5
FNB	1.2	1.6	1.2	1.1	1.1	1.4
MFC	2.5	1.5	2.3	1.7	1.8	2.3
MNQ	1.4	1.7	1.3	1.1	1.1	1.2
OGR	2.3	1.4	2.3	1.4	1.7	2.3
SAL	1.7	1.5	1.5	1.4	1.5	1.6
SRV	1.5	1.4	1.8	1.5	1.8	1.9
TRN	1.8	2.0	1.7	1.3	1.5	2.1
Average	**1.7**	**1.7**	**1.7**	**1.4**	**1.5**	**1.8**

Input Multipliers						
Sector	**Country**					
	Bahrain	**Kuwait**	**Oman**	**Qatar**	**Saudi A.**	**UAE**
AGF	3.4	1.2	2.1	2.6	1.9	2.0
CON	1.9	1.5	1.2	1.0	1.2	2.1
EDH	1.1	1.2	1.1	1.0	1.1	1.3
EW	2.5	1.0	2.7	1.4	1.3	2.6
FNB	2.2	1.7	2.1	1.8	2.2	2.5
MFC	2.1	1.7	2.3	1.5	1.8	1.7

MNQ	1.6	1.7	1.0	1.0	1.0	1.0
OGR	1.6	1.7	3.2	1.8	1.7	1.7
SAL	2.0	1.2	1.9	1.3	1.5	2.0
SRV	1.3	1.2	1.2	1.2	1.3	1.5
TRN	1.5	2.0	1.5	1.5	1.8	1.5
Average	**1.9**	**1.5**	**1.8**	**1.5**	**1.5**	**1.8**

Largest multiplier
Smallest multiplier

Impact Analysis

Given the reality of limited resources, the analysis is carried out under the assumption of final demands ($\Delta \boldsymbol{f}$) or value added ($\Delta \boldsymbol{v}$) increase change in the three sectors – EW, MNQ and OGR. This increase is compensated by diverting resources from the remaining sectors to these three sectors. Eventually, it is a zero-sum process where the gain of some sectors is sourced from the remaining sectors. The author is aware that such a process in funding the energy transition in EW, MNQ and OGR is unlikely to happen in reality. However, the purpose is to introduce a shock in the economy to perceive the level of impact. The goal is not to attain precise figure results but rather to perceive ripple effects on sectors of the economy or the most impacted ones.

In simulating this shock, the final demands of EW, MNQ and OGR sectors are increased by 1% representing energy transition investments. The sum of 1% investment increase in the three sectors is sourced at the expense of the remaining sectors relatively according to their final demand figures – i.e., the contribution of each sector to this sum of investment is proportional to its final demand value. A similar simulation is carried out concerning the value added of these three sectors. The increase of 1% in the three sectors' value added is sourced at the expense of the remaining sectors relatively according to their value added figures.

Using equations (8) – (11), the results include four indicators per country representing percentage impact changes on (i) economy sectors' outputs ($\Delta \boldsymbol{x}$) and (ii) value added ($\Delta \boldsymbol{v}$) per 1% change in final demand; and (iii) economy sectors' outputs ($\Delta \boldsymbol{x}$) and (iv) final demand ($\Delta \boldsymbol{f}$) per 1% change in value added. Figure 4 illustrates the calculated results of these four indicators. Accordingly, all Gulf states economic sectors – except for EW, MNQ and OGR where investments and added value were increased – show contraction in their production outputs, final demand, and value added. One should note that these contraction percentage values (shown in Figure 4) are relative to the sector's final demand, value added and production output.

It is worth noting that the agriculture and fisheries (AGF) in the Gulf states have negligible to low contributions to their GDPs ranging from 0.0% to 2.0% (Figure 1). Therefore, the impact on its production, final demand, and value added are not addressed.

In the case of Bahrain, with the 1% investment increase in final demands in these three sectors, the most impacted value added sector was manufacturing (MFC). MFC sector has the highest contribution to the country's GDP (Figure 1) making about 25% of the GDP. Moreover, it has the largest output multiplier (Figure 3), hence, decreasing investment or decapitalizing in MFC sector in Bahrain would logically reflect negatively on its value added. Though its GDP contribution about 7.0%, the most impacted sector's production output in Bahrain was the education and health (EDH) sector. Under the 1% increase in value added in EW, MNQ and OGR sectors, the finance and businesses (FNB) was the most affected sector. It is worth mentioning that FNB has relatively high output multiplier and the least input multiplier in the Bahraini economy. Unlike most Gulf states, Bahrain is hydrocarbon poor resource country. Its economy highly depends on the finance sector. Cutting FNB's value added – i.e., labor, profits, etc. – would most likely reflect on its final demand – i.e., investments, consumption, etc. Eventually, its production outcome is most impacted.

Kuwait's transportation (TRN) sector has the highest input multiplier and relatively high output multiplier (third highest) within the economy (Figure 3), and it contributes about 10% to the GDP. Obstructing the sector's investment by diverting resources to EW, MNQ and OGR sectors' final demands – as a result of 1% increase in the three sectors' final demands – makes the TRN the most affected sector with regard to its value added (Figure 4). In addition to TRN, the construction (CON) sector has close de-growth value to TRN as a result of this investment. The output production of the whole- and retail-sales (SAL) sector experiences the most contraction percentage value. Moreover, the FNB – which contributes about 20% to the country's GDP – and services (SRV) sectors have close contraction percentage values as the SAL sector (Figure 4). Though education and health (EDH) sector's low output multiplier, the 1% increase in value added in these three sectors stems most negative impact on Kuwait's education and health (EDH) sector's final demand – which might include reduced investments – and its overall output. In addition to EDH, FNB's output production is stressed as a result of this value added increase in EW, MNQ and OGR sectors.

In Oman, the most exposed sectors to the investments increase in above-mentioned three sectors include value added of SRV and CON sectors (Figure 4) – which they make about 12% and 13% of the country's GDP. In output production-wise, the most affected sector is the EDH followed by SRV sector. The SRV sector has relatively large output multiplier (Figure 3). Such negative effect would be reflected on the economy. Incentive provision to EW, MNQ and OGR sectors' value added by 1% increase would have negative effect mostly on CON and TRN sectors' final demands. With respect to output production, EDH and CON are the most impacted. Both sectors have relatively low input multipliers suggesting that their expansion doesn't necessitate a significant increase in inputs from other sectors.

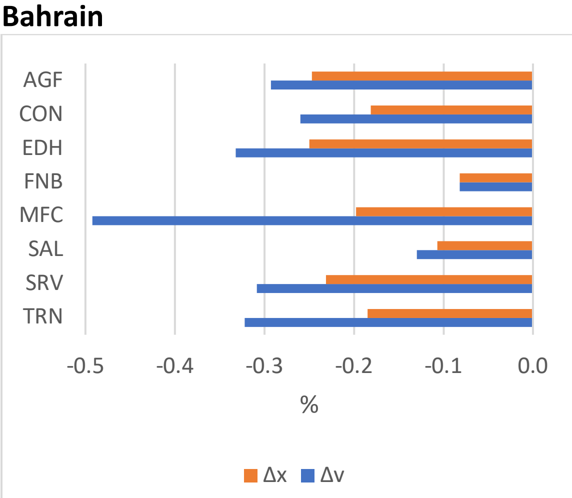
One should note that Qatar is the largest gas producer among the Gulf states. Its gas production makes about 40% of the Gulf states' total gas production. Consequently, gas-related infrastructure and facilities are relatively large, and energy transition investments in their systems would be significant. The 1% energy transition investment increase in final demands in EW, MNQ and OGR sectors would impact the value added of the services (SRV) and manufacturing (MFC) sectors the most. Furthermore, it would negatively affect the output production of EDH and SRV sectors where both sectors have low to moderate output multipliers. With the 1% value added increase in these mentioned sectors, the finance and businesses (FNB) sector bears the most impact on its final demand and output production. It is worth noting that FNB is among the largest input multipliers in Qatar's economy. Though AGF shows high reaction to energy transition investments; however, as mentioned earlier, AGF sector has negligible contribution to the Gulf states' GDP, including Qatar, hence, this sector is not addressed.

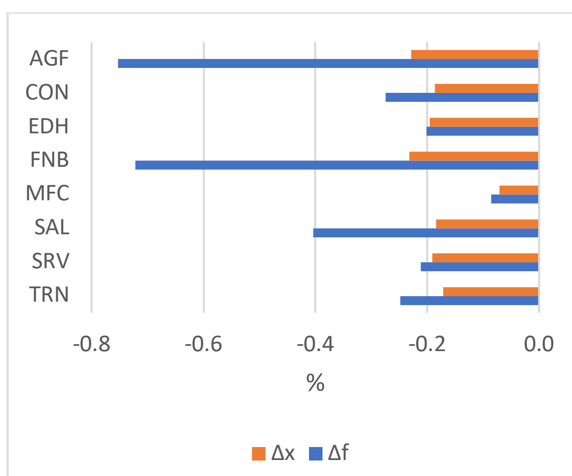
Saudi Arabia is the largest oil producer not only among the Gulf states but in the world and comes second after the U.S., and therefore, energy transition in related oil infrastructure and facilities would require significant investments. The impact of 1% final demands increase in the EW, MNQ and OGR sectors is noticed the most on the value added and output production of EDH sector. Such impact is due to the sector's large output multiplier – which is the largest multiplier in addition to the MFC sector. On the other hand, the 1% value added increase in these three sectors would mostly affect the FNB sector's final demand and output production. The FNB has the largest input multiplier within the Saudi's economy, and hence, it is sensitive in altering its value added inputs.

The UAE has the most diverse economy among the Arab Gulf states. Investing additional 1% in energy transition in EW, MNQ and OGR sectors, the MFC sector bears the most impact in its value added. It is noticed that MFC has the largest output multiplier beside the OGR sector (Figure 3). However, EDH sector output production is the most affected as a result of this additional investment. In the case of 1% rise in value added in above mentioned three sectors to fulfill the transition goals, the final demand of FNB sector is the most impacted. Moreover, beside the EDH sector, the FNB output production would also undergo the most de-growth.

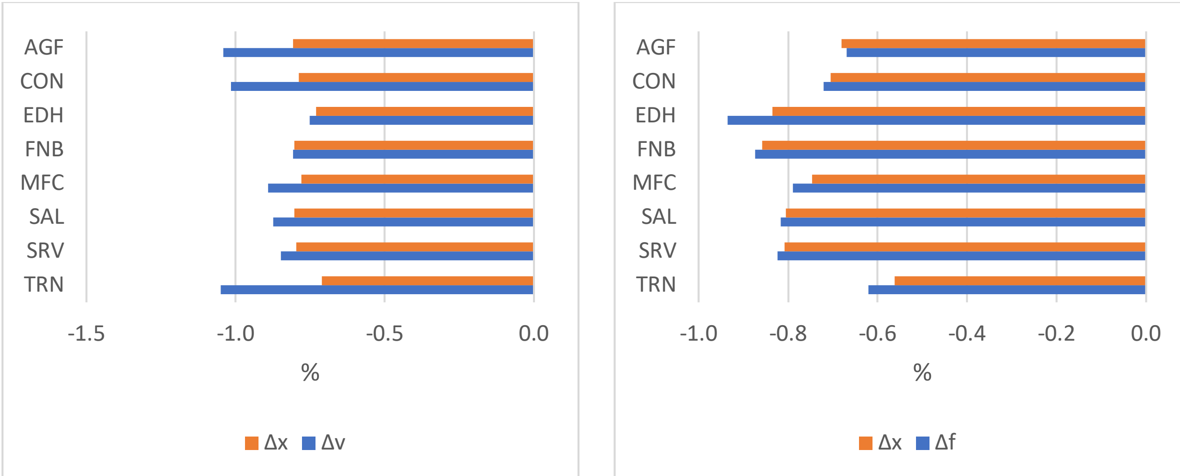
Figure 4 — Left side: Impact of 1% investment (final demand) increase in EW, MNQ and OGR sectors. Right side: Impact of 1% value added increase in EW, MNQ and OGR sectors. Δf, Δv, and Δx: impacted demand, value added and production output, respectively. Indicators are in percentage values.

Bahrain

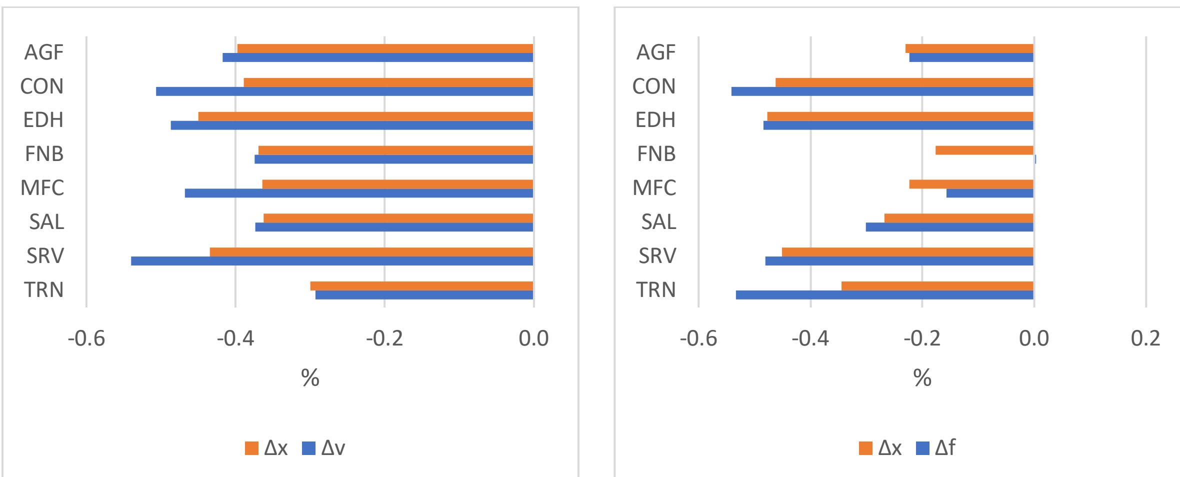




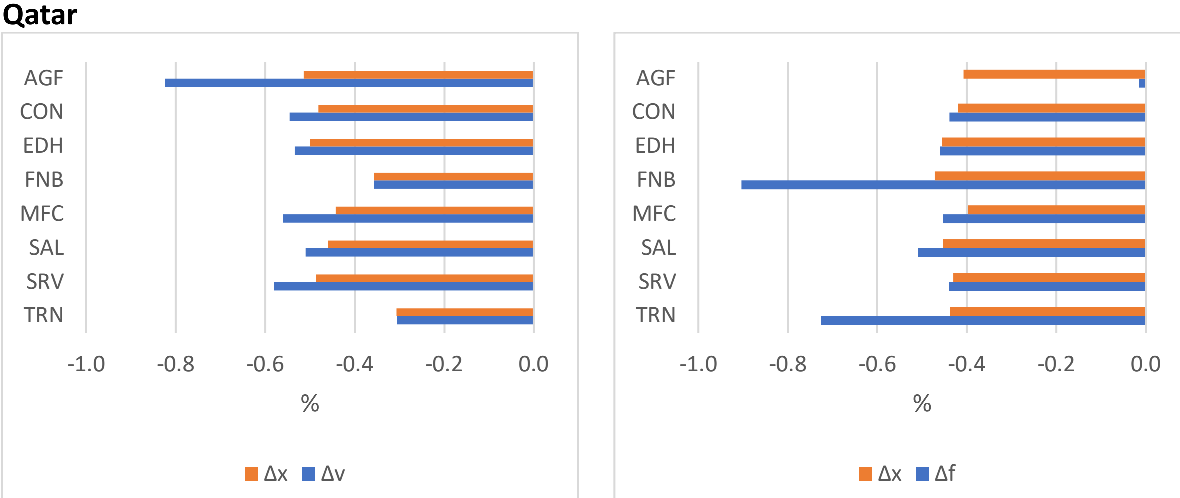
Kuwait



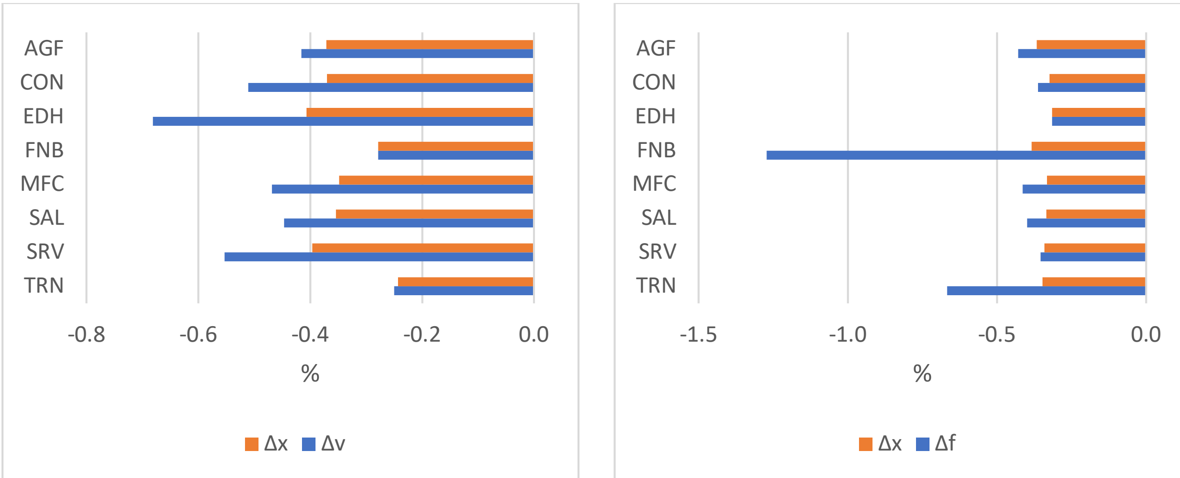
Oman



Qatar



Saudi Arabia



UAE

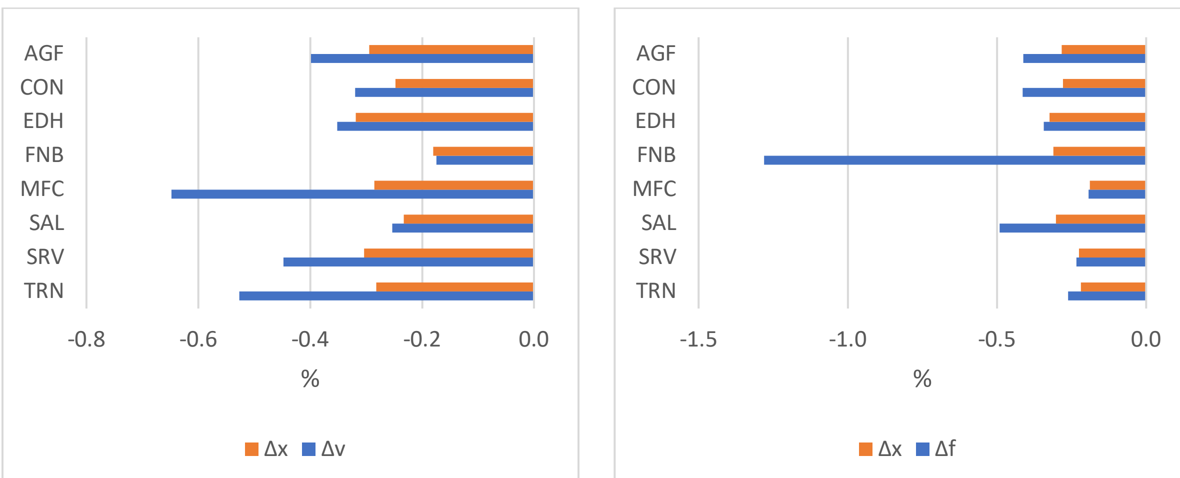


Table 5 — Most Impacted Sectors Under Energy Transition Investment in the Arab Gulf States

County	Most impacted sectors under 1% final demand increase in EW, MNQ, OGR sectors		Most impacted sectors under 1% value added increase in EW, MNQ, OGR sectors	
	Value Added	Production	Final Demand	Production
Bahrain	MFC	EDH	FNB	FNB
Kuwait	CON, TRN	FNB, SAL	EDH	FNB
Oman	CON, SRV	EDH, SRV	CON, TRN	CON, EDH
Qatar	MFC, SRV	EDH, SRV	FNB	EDH, FNB
Saudi Arabia	EDH	EDH, SRV	FNB	FNB, TRN
UAE	MFC	EDH, SRV	FNB	EDH, SAL

Table 5 summarizes the results concerning the most impacted sectors. Though they have different sizes of economies and industrial sectors' demand and supply values, overall, it is noticed that EDH is the most exposed sector to energy transition investments. The average GDP contribution of EDH across the Gulf states is about 6%. In almost all Gulf states, EDH has below-average values of output and input multipliers. This suggests that EDH has limited spillover effects on the rest of the economy in terms of output growth. Hence, the sector's expansion or contraction has a relatively contained impact on overall economic output. This could also indicate that the sector is less interconnected with the rest of the economy or that its production processes are relatively self-sufficient in terms of inputs.

The overall second most exposed sector in Gulf states is the FNB – which has below-average output multipliers and above-average input multipliers. A relatively low output multiplier implies that a change in demand or investment within FNB has a relatively small impact on overall economic output. However, being, a relatively, high input multiplier sector, FNB contraction would decrease inputs from other sectors. The SRV sector comes as the third most exposed to the transition process. Across all Gulf states, SRV has an average output multiplier and a below-average input multiplier.

Conclusions and Policy Implications

This work carried out a quantitative assessment study on the impact of energy transition development in the Arab Gulf states. The Gulf states' input-output tables of eleven industrial sectors were utilized and their respective Leontief and Ghosh models were developed to conduct the analysis. The models' exogenous changes – 1% final demand and value-added changes in EW, MNQ, and OGR – were applied to examine the impact on the remaining sectors. The three sectors mentioned above are the main sectors that the Gulf states are counting on to achieve Scope 1 type carbon neutrality.

The main shortcoming of the study is the use of 2016 input-output data tables – Saudi Arabia is the only Gulf state that has its official 2020 input-output publicly published. The work was counting on unchanged relative contributions of the industrial sectors to the GDP since most of the Gulf states' economies are dependent on hydrocarbon resources. However, the study needs to be revisited when updated data is made available. One should note that the input-output model – i.e., Leontief and Ghosh models – typically focuses on the interindustry flows of goods and services, which is most suitable for understanding the immediate impacts of changes within specific sectors and offers insights into the interdependencies within an economy. However, the model may not adequately capture the behavioral responses of consumers, firms, and policymakers. This limitation can restrict its ability to analyze the effects of changes in investment decisions, or government policies.

The goal of the analysis was not to reach precise values of the energy transition impacts but rather to identify the most affected sectors in terms of contraction in their final demands, value-added, and production. Simulation results showed most of the Gulf states' EDH, FNB and SRV would be the most impacted sectors by the energy transition process.

National policies are needed to smooth energy transition progress in the Gulf states, and particularly, to mitigate the impact on their EDH, FNB and SRV sectors. Mitigating such impacts can be managed by linking these sectors with the energy transition process. In other words, a strategy is needed to strengthen the interdependence between these exposed sectors and those sectors undergoing the transition process. Policies that may advocate such a strategy include:

- **Promotion of Research and Development**. Encouraging research and development in science and technology that can lead to innovative solutions to the overall industrial sectors, and hence, enhance the economy's output productions. This encouragement is carried out through funding energy sustainability research programs in educational institutions.

- **Education and Outreach.** Launching education and outreach campaigns to raise awareness among the public and businesses.

- **Incorporation of Health Impacts in Energy Policy**. Mandating health impact assessment for proposed energy projects and implementing regulations to mitigate negative health effects to prioritize health in energy policy decisions, and hence, promote energy transition agenda.

- **Green Finance**. Incentivize investments in the energy transition process through tax credits, subsidies, or loan guarantees for businesses that invest in energy transition technologies and measures. Moreover, the Gulf states may consider offering green bonds or green investment funds, to channel private capital toward sustainable energy initiatives.

- **Corporate Sustainability Reporting**. Establishing sustainability reporting standards for businesses to disclose their environmental, social, and governance (ESG) performance. This measure would encourage businesses to work toward sustainability, thus, liking businesses with the energy transition agenda.

The goal of the above-mentioned policies is to maintain the EDH, FNB and SRV sectors' growth in line with the energy sectors' supply, demand and output.

Notes

[1] Ciarán Nevin, Jamie Pirie, Jon Stenning, Cutting Bills and Creating Jobs: The Economic Opportunities of the Clean Energy Transition, June 2022, Cambridge Econometrics, Cambridge, UK (https://www.wemeanbusinesscoalition.org/wp-content/uploads/2022/06/Fullreport_EconomicOpportunitiesCleanEnergy.pdf); IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, International Energy Agency, October 2021 (https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf); IRENA, Global energy transformation: A roadmap to 2050 (2019 edition), International Renewable Energy

Agency, Abu Dhabi (https://www.irena.org/-/media/Irena/Files/Macroeconomic-benefits/IRENA_Global_Energy_Transformation_2019.pdf?rev=12eb39be30f64c3d89140aabb78cbf71&hash=A9F4F6A5AE959ABA8BB8B167F7194317).

[2] BloombergNEF, The $7 Trillion a Year Needed to Hit Net-Zero Goal, December 7, 2022 (https://about.bnef.com/blog/the-7-trillion-a-year-needed-to-hit-net-zero-goal/#:~:text=Global%20investment%20needed%20for%20net%2Dzero%20goal&text=The%20economic%20transition%20scenario%20requires,to%20%246.7%20trillion%20per%20year).

[3] McKinsey Global Institute, The net-zero transition: What it would cost, what it could bring, January 2022 (https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20net%20zero%20transition%20what%20it%20would%20cost%20what%20it%20could%20bring/the-net-zero-transition-executive-summary.pdf).

[4] IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, International Energy Agency, October 2021 (https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf).

[5] Giacomo Luciani, The Impacts of the Energy Transition on Growth and Income Distribution, The Geopolitics of the Global Energy Transition, Manfred Hafner and Simone Tagliapietra (Editors), Springer, 2020.

[6] Mark J. Perry, Inconvenient Energy Fact: It Takes 79 Solar Workers to Produce Same Amount of Electric Power as One Coal Worker, American Enterprise Institute, Washington, DC, May 2017 (https://www.aei.org/carpe-diem/inconvenient-energy-fact-it-takes-79-solar-workers-to-produce-same-amount-of-electric-power-as-one-coal-worker/).

[7] World Bank Open Data (https://data.worldbank.org/).

[8] Osamah Alsayegh, How Economic and Political Factors Drive the Oil Strategy of Gulf Arab States, Rice's University Baker Institute for Public Policy, Houston Texas, January 9, 2023 (https://www.bakerinstitute.org/research/how-economic-and-political-factors-drive-oil-strategy-gulf-arab-states).

[9] Nader Kabbani, KNejla Ben Mimoune, Economic diversification in the Gulf: Time to redouble efforts, Brookings Institute, Washington D.C. January 31, 2021, (https://www.brookings.edu/articles/economic-diversification-in-the-gulf-time-to-redouble-efforts/); N.A. Burney, K. Mohaddes, A. Alawadhi, A. Al-Khayat, M. Al-Musallam, M. Al-Ali, A. Al-Jaber, M. Behbehani, Kuwait's Macroeconomic Performance in the Global Context: a Global Vector Auto-regressive Approach, Kuwait Institute for Scientific Research, Kuwait, Report No. KISR13814, 2016.

[10] Goran M. Muhamad, Almas Heshmati, Nabaz T. Khayyat, How to reduce the degree of dependency on natural resources? Resources Policy, Volume 72, 2021 (https://doi.org/10.1016/j.resourpol.2021.102047).

[11] Osamah Alsayegh, The Arab Gulf Helps Fuel the Global Economy. What It Means for the Energy Transition, Rice's University Baker Institute for Public Policy, Houston Texas, October 12, 2023 .(https://www.bakerinstitute.org/research/arab-gulf-helps-fuel-global-economy-what-it-means-energy-transition).

[12] United Arab Emirates Portal, "UAE Net Zero 2050," https://u.ae/en/information-and-services/environment-and-energy/climate-change/theuaesresponsetoclimatechange/uae-net-

zero-2050; "Bahrain announces intention to bring carbon emissions to net zero by 2060," Bahrain News Agency, October 24, 2021; Saudi and Middle East Green Initiatives, "Paving the way to net zero emissions by 2060," https://www.greeninitiatives.gov.sa/about-sgi/sgi-targets/reducing-emissions/reduce-carbon-emissions/ ; The Sultanate of Oman's National Strategy for an Orderly Transition to Net Zero, Oman's Vision 2040, November 2022; "Qatar targets 25% cut in greenhouse gas emissions by 2030 under climate plan," Reuters, October 28, 2021, https://www.reuters.com/business/cop/qatar-targets-25-cut-greenhouse-gas-emissions-by-2030-climate-change-plan-2021-10-28/ ; "Kuwait committed to reaching carbon neutrality by 2050," Kuwait News Agency, November 7, 2022, https://www.zawya.com/en/projects/industry/kuwait-committed-to-reaching-carbon-neutrality-by-2050-fm-r3dkoq4b.

[13] M. Lenzen, K. Kanemoto K, D. Moran and A. Geschke, Mapping the structure of the world economy. Environmental Science & Technology 46(15) pp 8374–8381, 2012, https://worldmrio.com/pdf/LenzenEtAl2012_EST_MappingTheStructure.pdf ; The Eora Global Supply Chain Database https://worldmrio.com/ .

[14] The Eora Global Supply Chain Database, Frequently Asked Questions (https://worldmrio.com/documentation/faq.jsp#faq_3).

[15] R. E. Miller and P. D. Blair, Input–Output Analysis Foundations and Extensions 2nd Edition, Cambridge University Press, Cambridge, UK, 2009.