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ENERGY SECURITY IN PAKISTAN: A QUANTITATIVE APPROACH TO A SUSTAINABLE ENERGY POLICY

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Abstract

Pakistan imports nearly a third of its energy resources in the form of oil, coal, and liquefied natural gas (LNG). An import-driven energy policy is not sustainable for Pakistan, making it energy insecure in the long term. Besides being a drain on its foreign exchange reserves, it exposes the economy to international energy price shocks, putting the entire economy at risk through inflation. Inflationary pressures reduce the competitiveness of the country's exports, further constraining the economy's capacity to pay for energy imports. This paper analyzes Pakistan's energy security under the 4As framework over the 6-year period of 2011–2017. The 4A methodology attempts to measure and illustrate graphically the change in the energy security of a region by mapping it onto four dimensions: availability, applicability, acceptability, and affordability. The analysis indicates that Pakistan's energy security improved initially over the first 3 years but then deteriorated over the next 3 years. Despite significant investments in the energy infrastructure over the last 5 years, Pakistan continues to be energy insecure. This paper recommends the immediate and rapid adoption of green energy solutions, like distributed solar and smart metering, and increased conservation efforts, like developing and implementing building insulation standards to mitigate energy insecurity.

Keywords: energy security, Pakistan, renewable energy, 4As framework

JEL Classification: O13, Q4

Contents

1. INTRODUCTION

Imports satisfy nearly a third of Pakistan's energy demand. In the year 2017–18, its energy imports were around $14.4 billion as compared with $10.9 billion in the previous year (State Bank of Pakistan 2018). Almost 75% of the $3.5 billion increase in energy imports was due to higher energy prices, and only about 25% of the increase was due to the increase in energy import volumes. This kind of "price shock" moves down the entire energy supply chain and translates into higher costs of conducting business and higher costs of living in Pakistan.

Relying heavily on imported energy is not sustainable for Pakistan's economy, which has been running a current account deficit for over 2 decades (with the exception of 1 or 2 years). Borrowing (from friendly nations, international sovereign bonds, and multilateral banks) funds these deficits almost by default, as bureaucratic inertia and the absence of an enabling political and regulatory environment typically limit the foreign direct investments flowing into the country. As Pakistan's external liabilities build up and it diverts an increasing share of its foreign exchange earnings toward external debt servicing, it is simply not left with the financial means to import energy continuously. It is important for the country to rethink its energy design to achieve not just energy sufficiency but also energy security.

Energy security is a multidimensional concept and is a measure of a unique nexus that encompasses economic, political, geopolitical, and institutional, legal, and regulatory aspects of a country or region. The first dimension is the economics of energy security, which covers the consequences of import dependence in relation to instable energy markets, the diversification of the primary energy mix and the use of indigenous resources, and the circular flow of energy. The second dimension is the political economy of energy security, which examines the interrelations between crude and natural gas exporting and importing countries. The third dimension is the geopolitics of international relations, which explores how geopolitics influences and shapes coalition, cooperation, or unilateral action for energy security. The fourth dimension consists of the aspects of energy security in institutional, legal, and regulatory frameworks in the local, regional, and international context (Taghizadeh-Hesary et al. 2019).

Other aspects of energy security include differences in the perceptions of energy security between developed and developing countries, infrastructure and technological aspects that can impede or accelerate energy security, different time dimensions of energy security, the risk perception of energy security, the role of the government, the nature of the threat, such as physical and cyber-attacks on the infrastructure, and climate change.

Studies have also defined energy security as an adequate and reliable supply of energy resources at a reasonable price (Bielecki 2002; Bohi and Toman 1996). Yergin (1988) originally cited this definition during the crises of the 1970s and 1980s when oil embargoes globally disrupted the supply of cheap and reliable oil from the Gulf region. The contemporary discussion on energy security in the literature, in general or in a broader sense, has implied the availability of energy resources, which are further measurable under the concept of "diversification" (or hedging). There are three aspects of the interpretation of diversification—variety, balance, and disparity (Stirling 2010). Variety measures the economically available primary energy resources, and balance measures the reliance or dominance of these various options in the overall energy mix. Disparity examines the differences among these various options in terms of delivery modes or characteristics.

This paper provides a quantitative evaluation of the energy security of Pakistan for the period 2011–2017. It constructs a set of indicators to quantify Pakistan's energy security in four areas—availability, applicability, acceptability, and affordability—and tracks the trends of each indicator between 2011 and 2017. Further, it uses rhombus plots to measure changes in Pakistan's overall energy security and on each energy security dimension between 2011 and 2017.

This paper is divided into five sections. Section one begins with an introduction to the paper. Section two contains a literature review of energy security. Section three provides an overview of Pakistan's current energy mix and the challenges that it is facing. Section four describes the 4As methodology and its application to the Pakistani context. Finally, section five concludes and provides policy recommendations.

2. LITERATURE REVIEW

Although the concept of energy security is as diverse as the number of disciplines involved, energy security could simply be the assurance of an energy supply both in times of abundance and in times of scarcity. Research can examine a disruption or less assurance of the energy supply in an economy to understand how and to what extent it affects the aggregate economic well-being of the economy.

In addition to the significant impact of the energy supply and energy prices on macroeconomic variables (Bohi 1991; Ferderer 1996; Hamilton 1996; Killian 2008; Taghizadeh-Hesary et al. 2016), the insecurity of the energy supply will have an impact on other commodities' prices and on food prices (Taghizadeh-Hesary, Rasoulinezhad, and Yoshino 2019).

To provide the end-user with energy security, it is necessary to meet four key conditions, as the 4As framework outlines: (1) the availability of an indigenous and sustainable supply of natural, extractable, or renewable energy resources; (2) the applicability of technologies and infrastructure economically to extract and harness the available energy resources; (3) the acceptability of the energy sources' environmental and social impacts; and (4) the affordability of the energy sources for the end-user (Yao and Chang 2014).

The contemporary energy security challenge extends beyond oil supplies to encompass a wider range of issues that are entangled with energy policy problems, such as equitable access to modern energy and addressing climate change (Cherp and Jewell 2014). The concept of energy security has evolved to address these wider issues by incorporating new dimensions, such as the environment, human security, international relations, foreign policy, energy efficiency, and capacity adequacy (Yao and Chang 2014). Regional and country-specific studies on energy security have discussed a wide variety of dimensions and frameworks, making the notion of contemporary energy security "multidimensional" (Yao and Chang 2014). In discussions about energy security, we should also take into consideration the "disruptive innovations" that can shape the future energy landscape (Proskuryakova 2018).

In a review of the available literature on the energy security of Pakistan, the researchers found that most studies have assessed the energy situation of Pakistan qualitatively in the context of policy review, energy supply and demand, generation capacity planning, and the primary energy mix (Aized et al. 2018; Mirjat et al. 2017; Nawaz and Alvi 2018). Few studies (Anwar 2014) have extended beyond the qualitative discussion to provide a quantitative analysis of the "impact" on energy security of factors such as the government's policy decisions, the continued primary energy import dependent pathway, and economic factors. None of these studies, however, have provided a base reference quantitative measure of the energy security of Pakistan.

Another study (Anwar 2016) has examined the impacts of reducing energy imports by 5%, 10%, and 15% on the energy system of Pakistan using MARKAL for the period 2005–2050 in 5-year incremental periods. The results show a marginal decrease in the primary energy supply and import fuel dependency for a comparatively larger addition of renewable energy to the mix. This diversification of resources reduces vulnerability to energy imports and improves energy security. The study, however, did not capture the individual impacts of liquefied natural gas (LNG) and coal imports, which will be a major part of Pakistan's energy mix in the future. Further, it did not consider the impact of changing the energy system's efficiency and more importantly the affordability for the end-user.

A meta-analytic review of 18 research studies identified five concerns—the economic burden, provincial conflicts, the security threat, project feasibility, and completion delays—that hinder the implementation of China–Pakistan Economic Corridor (CPEC) energy projects and adversely affect energy security in Pakistan. Spearman's rho correlation coefficients gave a strong negative correlation between energy security and these concerns, except project feasibility and completion delays (Ahmed et al. 2019). The economic burden here is the foreign debt that the execution of these projects will incur, and the negative correlation shows that this concern diminishes with increased energy security. However, the economic burden may dampen the energy security, and the extent of the impact needs quantitative assessment.

Studies have applied various energy modeling frameworks and techniques to analyze the energy and power planning policies in Pakistan. One paper (Mirjat et al. 2017) reviewed all of the existing power planning studies and energy and power planning policies that the Government of Pakistan has implemented since 1947. The paper broadly described the globally accepted energy modeling tools and suggested the use of the long-range energy alternative planning (LEAP) tool for integrated energy planning and policy formulation. However, it reached no conclusions about the state of energy security in Pakistan. Other researchers (Aized et al. 2018) have used the LEAP model to present four scenarios—the business-as-usual base case, green Pakistan, nuclear, and optimization—to analyze the renewable energy policy of Pakistan and suggest suitable options for securing energy supplies in the future.

Another study examined the relationship between energy security and economic growth by using the error correction model (ECM), which analyzes the causality between the energy gap and the economic growth (Mahmood and Ayaz 2018). The energy gap, a key metric for energy security, is the differential between the energy demand and the energy supply, and studies have shown that it has a statistically significant negative impact on economic growth and that reducing the reliance on imported fuel and improving the energy mix can reduce this energy gap and appears to improve energy security, paving the way to socio-economic and environmental sustainability (Nawaz and Alvi 2018). A study has also emphasized the need to diversify the energy mix through the utilization of indigenous resources and increased use of nuclear power (Khawaja and Rehman 2016). The paper proposed the expansion of electricity and gas trade, with Central Asia as a strategic option, leveraging its geographic position to meet its energy diversification and energy security goals.

Different energy demand forecasting methodologies have demonstrated continued heavy reliance on fossil fuels in the overall energy mix in the future and further made a case for undertaking initiatives for the adoption of renewables (Rehman et al. 2017a). Another paper has discussed the barriers to the use of renewable energy resources, such as aging infrastructure and policy gaps, and stressed the need to make hard policy-level decisions to assure energy security (Hassan, Afridi, and Khan 2018). Other studies have simulated the future production of primary energy resources using the STELLA (Systems Thinking, Experimental Learning Laboratory with Animation) model, illustrating Hubbert peaks for coal, natural gas, and crude oil to make the case for an energy security policy that ensures the sustained supply of these hydrocarbon resources in the future (Rehman et al. 2017b). Studies have presented scenarios of renewable portfolio supply (RPS) in the energy mix from 10% to 50% and carbon tax from 10% to 30% that show positive impacts, such as reduced dependence on imported fuel, decreased energy intensity, the use of energy-efficient technologies, and greenhouse gas (GHG) mitigation (Anwar 2014).

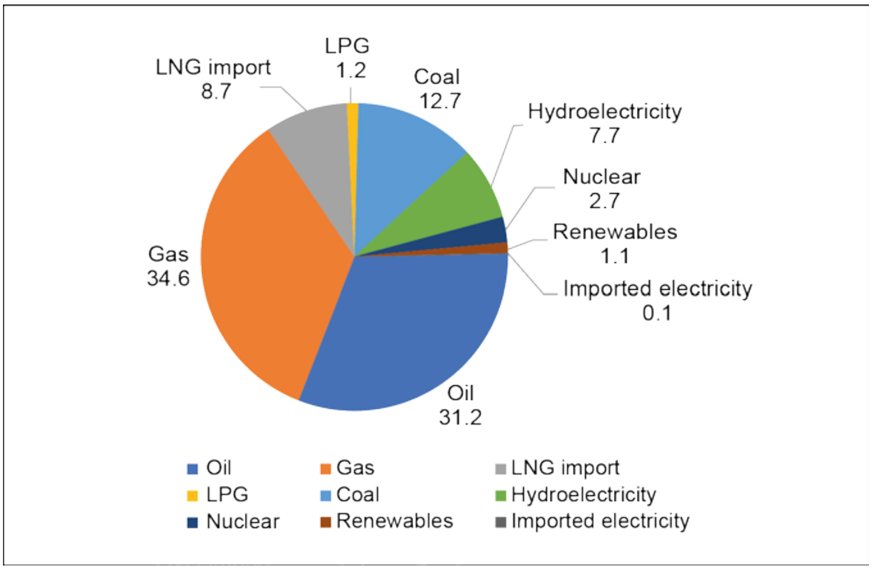
There seems to have been no comprehensive analysis to quantify the energy security in Pakistan. This paper undertakes a quantitative assessment of Pakistan's energy security for the period 2011–2017 using the 4As framework. Using a set of indicators, it quantifies Pakistan's energy security on each of the four dimensions and tracks the trends of each indicator in the study period. It groups the indicators together under their respective "A" categories and analyzes progress by using a rhombus plot to measure changes in the overall energy security and on each energy security dimension. This study aims to prioritize areas in the energy value chain to achieve greater energy security, which in turn will help policy makers. The method and results of this study could be useful for other countries with similar energy demand patterns.

3. ENERGY SECTOR IN PAKISTAN

3.1 Current Energy Mix

Successive discoveries of large natural gas reserves have shaped Pakistan's energy history since the 1950s. These sparked, in the 1960s, the growth of the domestic fertilizer industry and large public-sector gas distribution utilities. Between the mid-1970s and the 1990s, all the major power plants that the government set up were based on dual fuel, with natural gas as the primary fuel. The share of gas in Pakistan's primary energy mix stood at approximately 50% in 2005. Since then, in the absence of major gas field additions, gas production has plateaued and imported oil has begun to take on a greater burden of the energy demand. More recently, higher coal and LNG imports have offset the decreasing share of local gas supplies. In 2017–18, the indigenous gas supply made up ~35% of Pakistan's total primary energy supplies and oil accounted for 31% of the total supplies (Ministry of Energy 2018).

Figure 1: Pakistan's Total Energy Supplies 2017–18 (% Primary Energy Supplies by Source)



Source: MOE (2018).

At the beginning of this decade, Pakistan experienced widespread power and gas shortages. Many parts of the country, particularly the rural areas, suffered 8–12 hours of blackout every day during the peak summer months and low gas pressure or supplies during the peak winter months. Then, in 2013, a new government came into power, winning on a mandate to eliminate energy shortages. Over the next 5 years, Pakistan invested heavily in its energy infrastructure, adding at least 10 GW in new power generation capacities (including about 2 GW of coal) and commissioning 1.3 billion cubic feet per day of LNG-importing infrastructure. Resultantly, Pakistan has managed to reduce its energy shortages; however, it now faces structural challenges, like improving energy security by reducing the share of imported fuels and reducing the cost of energy.

In the year 2017–18, power generation consumed almost 37% of the primary energy supplies.[1] Over 55% of the primary energy used for electricity was lost during generation and another 7% in transmission and distribution (MOE 2018). Generation losses tend to be high in thermal power plants (oil, gas, and coal), ranging from 40% to 60%. While some of these losses are due to Pakistan's degraded power generation assets, these are typically the level of energy losses that thermal power plants experience worldwide due to technological and operational limitations (General Electric 2015).

After losing over 60% of the energy during generation, transmission, and distribution, households and the residential sector buy around 50% of the final electricity sold on the grid. Thus, overall, Pakistan uses around 18% of its primary energy supplies in providing electricity to households (including the associated losses incurred in generating and supplying this electricity). While it is important to fulfill the basic needs of a population, it is essential to realize that power consumption in homes is not an income generation activity. It is not sustainable for Pakistan to feed the energy requirements of its homes through imported thermal fuels, more than half of which tend to be lost during generation

[1] This does not include energy consumed by captive power units, only energy consumed by grid connected power units, so the actual consumption for power generation is much higher.

and transmission. Introducing and promoting the adoption of green energy solutions, like rooftop solar solutions for homes and commercial buildings, and better building insulation can make a significant contribution to reducing energy imports.

Households consume another 7%–8% of the primary energy supplies in the form of gas for cooking and heating purposes. Shifting this demand to renewables would require the adoption of home appliances like solar-powered water heaters and electric stoves to replace gas-based heaters and stoves.

3.2 Natural Gas

The share of natural gas in Pakistan's primary energy mix stood at approximately 50% in 2005. Since then, in the absence of major gas field additions, gas production has plateaued. Today, natural gas makes up around 35% of the country's primary energy mix. Overall, Pakistan imports nearly a third of its energy supplies in the form of oil, coal, and recently LNG. The expectation is that this share of imports will grow drastically as the local gas reserves deplete. Oil & Gas Regulatory Authority projects that local gas production will fall from ~4 billion cubic feet per day currently to about 2 billion cubic feet per day by 2025. Over the same period, it expects the demand for gas to increase by 1.5 billion cubic feet per day. If energy imports were to replace this additional 3.5 billion cubic feet per day of gas shortfall, Pakistan's energy imports would have to increase by more than double (in tonnes of oil equivalent).

3.3 Oil

Over 85% of the oil and petroleum products supplied are imports. Since 2014, there has been a considerable change in the share of the components of oil consumption. The share of the power sector in oil consumption has declined significantly, while the share of the transport sector has increased as the newer installed power plants have moved toward cheaper fuels, whereas the increase in the share of transport is mainly due to the decline in the domestic prices of petrol and higher imports of used cars. During July–February in the FY 2017–18, the share of transport in oil consumption increased further to 64.4% compared with 57.2% during the same period in the previous year. However, the share of power decreased to 26.4% from 33.2% during the period under discussion with the availability of cheaper alternative power (from LNG, hydro, and coal).

3.4 Coal

Pakistan has fairly large indigenous coal resources (over 186 billion tons), which are sufficient to meet the energy requirements of the country on a long-term sustainable basis. The domestic production of coal is likely to increase in the coming years with the start of mining activity at Thar coalfield. Presently, brick kilns mostly consume indigenous coal production, and cement factories utilize a small quantity. Power plants, cement manufacturing units, Pakistan Steel, and other industries use imported coal. The imports of coal have increased substantially comparative to the preceding year (FY 2016–17) due to the commissioning of new coal-based power plants at Sahiwal and Port Qasim.

3.5 Hydro Power

Estimations indicate that Pakistan has a hydropower potential of 40 GW, whereas its installed hydro-based power capacity is around 8 GW (this does not include the installed base of micro-hydel power projects, ranging from 5 kW to 100 kW in size). The government owns almost all the operating hydro-power projects. Long project gestation periods, tariff-related challenges, and competition from solar and wind projects have limited private investors' interest in hydro projects (Malik, Qasim, and Saeed 2018). Pakistan has also successfully adopted micro-hydro power projects to provide off-grid communities with electricity. These have mostly been community projects in collaboration with local governments or local not-for-profit companies, sometimes with funding from international donor agencies.

3.6 Renewables—Solar, Wind, and Bagasse-Based Power

Over the last 5 years, eighteen wind power projects of 937.27 MW cumulative capacity have achieved commercial operation and are supplying electricity to the national grid, while six solar power projects of 418 MW capacity have also become operational. Wind power projects in Pakistan have received the highest level of private sector interest due to their bite-size investment and short gestation period (Malik, Qasim, and Saeed 2018). Utility-scale solar power projects, although easy to execute, have large land requirements and therefore have not attracted as much private sector interest as wind power. The private sector almost entirely drives the distributed solar power solutions (rooftop solar solutions) industry. Due to low financial and regulatory barriers to entry, many small players, each with a limited market share, characterize the industry (Malik, Qasim, and Saeed 2018).

Sugar mills in Pakistan (with cumulative capacity of 201.1 MW) have set up power generation from bagasse cogeneration. Sugar mills produce bagasse as a by-product, and generating power is a natural extension of their existing business.

4. QUANTITATIVE ASSESSMENT OF PAKISTAN'S ENERGY SECURITY

4.1 Methodology

The Asia Pacific Energy Research Centre introduced the 4As of energy security (availability, accessibility, affordability, and acceptability) as key dimensions of its contemporary definition of energy security that address the "energy security paradigm shift" (APERC 2007) of the 2000s. This paper utilizes the suggested framework of energy security that Yao and Chang (2014) developed. The framework encompasses the essential 4A dimensions—the availability of resources (AV), the applicability of technologies (AP), the acceptability by society (AC), and the affordability of energy resources (AF)—with four indicators in each to measure the energy security of Pakistan. The 4As framework, with its 16 energy security indicators, provides us with a rhombus plot. The plots help to visualize the trends and compare the dimensions, providing a more holistic perspective on the direction of energy security.

4.2 The 4As Framework and Indicators

The 4As methodology attempts to measure and present graphically the change in the energy security of a region by mapping it onto four dimensions—namely availability, applicability, acceptability, and affordability.

Availability

In the framework, *availability* is a dimension that indicates the existence and sufficiency of fossil fuels and other indigenous sources of energy to meet a region's needs. The higher the reserves, potential, and sufficiency of indigenous sources of energy, the higher the region ranks on this dimension. This paper measures Pakistan's performance on the availability dimension through the following four indicators:

- Share of Imports in the Oil Supply
- Share of Imports in the Gas Supply
- Share of Imports in the Coal Supply
- Hydropower Generation

The larger the share of energy imports, the lower the rank on the *availability* dimension. Conversely, the higher the generation of power from local resources like hydropower, the higher the rank on the *availability* dimension.

Applicability

The *applicability* dimension reflects the ability of a region to access and increase its reserves of indigenous energy. For example, the ability to use new technologies to reduce energy wastage and increase energy conservation and hence extend the use of the same energy reserves improves the performance on the *applicability* scale. Similarly, adopting new technologies that increase the country's indigenous energy reserves' size (extracting previously inaccessible resources) improves the country's rating on the *applicability* scale.

This paper measures Pakistan's performance on the *applicability* dimension through the following four indicators:

- Power Generation Efficiency from Gas
- Number of New Exploratory Wells Drilled for Oil and Gas
- Energy Intensity of Agriculture and Transport
- Energy Intensity of Industry

Nearly a third of electric power generated in Pakistan is from natural gas. Improving the generation efficiencies of gas-based power plants or conversely reducing the energy lost during electric power generation could reduce the rate of depletion of Pakistan's gas reserves and hence increase its energy security.

Oil and gas drilling activity in Pakistan slowed down in the last decade (2000–10) with a lack of policy support and government will and due to security unrest in high-potential areas (fallout from the start of the War on Terrorism in neighboring Afghanistan). After a change in government in 2013 and several military operations to improve security in these and neighboring high-potential areas, oil and gas drilling activity has now increased. Higher oil and gas drilling leads to an increased likelihood of finding significant reserves, which in turn would improve the energy security of the country.

It is possible to calculate the energy intensity of a sector by dividing the total energy used in each year by the GDP generated by the sector (tonnes of oil per million Pakistani rupees). It represents the amount of energy consumed for every rupee that the sector earns. A reduction in energy intensity could represent increased efficiency and energy conservation and hence an increase in energy security. A reduction in energy intensity could also be due to a structural change in the sector. For example, certain industries could be stagnating due to demand saturation and new investments could be moving into those industries with better returns or unmet demand. If the stagnating industries are energy intensive and the new emerging industries were less so, a decrease in the energy intensity of the industrial sector would reflect this. However, even in this case, it is possible to consider the country to be improving its energy security, as it can now maintain or grow its industrial GDP with less energy.

Acceptability

The *acceptability* dimension covers the social and environmental aspects of the new sources of energy. For the adoption of a new source of energy, the social and environmental barriers must be clear (Tongsopit et al. 2016). Changing the energy mix of a region to increase the share of renewable fuels would improve its energy security. Renewables like nuclear, hydropower, solar, and wind each face a unique set of challenges on the social and environmental fronts. For example, the 2011 earthquake and tsunami that led to the Fukushima nuclear plant disaster in Japan put the future of nuclear power generation into question. Additionally, the declining costs of wind and solar energy have made nuclear non-competitive. The result is that globally, while wind and solar power output grew, nuclear power generation (other than in the People's Republic of China) declined for 3 years in a row from 2015 to 2017 (Schneider et al. 2018). New nuclear power projects are facing increasing opposition due to safety concerns and the presence of safer and more affordable alternatives.

This paper measures Pakistan's performance on the *acceptability* dimension through the following four indicators:

- Share of Nuclear and Renewable Energy in Power Generation
- CO^2 Emissions per Capita
- Pakistan's Share of Global CO_2 Emissions
- Number of Energy Sources/Adoption of New Sources

Affordability

The *affordability* dimension represents the ability of an economy or society to access energy resources at a reasonable price (Tongsopit et al. 2016). Moreover, it covers equitable access to energy; that is, energy should be accessible to all income groups. A decreasing affordability level for a country indicates its decreasing accessibility for people and therefore its inability to meet the energy needs of its people.

This paper measures Pakistan's performance on the *affordability* dimension through the following four indicators:

- Energy Supply per Capita
- Gas Price
- Electricity Price
- Gasoline Price

4.3 Data and Sources

For each indicator listed in the previous section, the authors collected data for the financial years (July–June) 2011 to 2017. Table 1 provides the raw data and the formula that they used to derive the indicators.

Table 1: Specification of Variables

Indicators	Raw Data (Unit of Measurement)	Formula	Data Source
Availability			
Share of Imports in Oil Supply	Oil Imports (TOE), Total Oil Supply (TOE)	Oil Imports ÷ Total Oil Supply	Pakistan Energy Yearbook 2018
Share of Imports in Gas Supply	LNG Imports (TOE), LPG Imports (TOE), Total LPG Supplies (TOE), Indigenous Gas Supplies (TOE)	(LNG Imports + LPG Imports) ÷ (Total LPG Supplies + Indigenous Gas Supplies)	Pakistan Energy Yearbook 2018
Share of Imports in Coal Supply	Coal Imports (TOE), Total Coal Supplies (TOE)	Oil Imports ÷ Total Oil Supply	Pakistan Energy Yearbook 2018
Hydro Power Generation	Hydro Electricity Supply (TOE)	Hydro Electricity Supply	Pakistan Energy Yearbook 2018
Applicability			
Gas Power Generation Efficiency	Gas Consumed in Power (MMCft), Gas-Based Power (Gwh)	(Gas-Based Power × 3412 btu/Kwh) ÷ (Gas Consumed in Power × 980 btu/Cft)	Pakistan Energy Yearbook 2018
No. of Exploratory Wells Drilled for Oil and Gas	No. of Exploratory Wells Drilled for Oil and Gas		Pakistan Energy Yearbook 2018
Energy Intensity—Agriculture and Transport	Energy Consumption in Transport (MTOE), Energy Consumption in Agriculture (MTOE), GNP at Constant Prices—Agriculture (PRs trillion), GNP at Constant Prices—Transport and Communication (PRs trillion)	Sum of Energy Consumed in Transport and Agriculture ÷ Sum of GNP at Constant Prices from Agriculture, Transport and Communication	Pakistan Energy Yearbook 2018, Pakistan Economic Survey 2016-17
Energy Intensity—Industry	Energy Consumed in Industry (MTOE), GNP at Constant Prices—Industry (PRs trillion)	Energy Consumed ÷ GNP from Industry	Pakistan Energy Yearbook 2017, Pakistan Economic Survey 2016–17
Acceptability			
Share of Nuclear and RE in Power Generation	Nuclear Power Generation (Gwh), RE Power Generation (Gwh), Total Power Generation (Gwh)	Nuclear and RE Power Generation ÷ Total Power Generation	Pakistan Energy Yearbook 2017
CO_2 Emissions per Capita	CO_2 Emissions of Pakistan (million Tonnes), Population (Million)	CO_2 Emissions of Pakistan ÷ Population	BP Statistical Review of World Energy 2017, Pakistan Economic Survey 2016–17
Share of Global CO_2 Emissions	CO_2 Emissions of Pakistan (million Tonnes), CO_2 Emissions of World (million Tonnes)	CO_2 Emissions of Pakistan ÷ CO_2 Emissions of World	BP Statistical Review of World Energy 2017
No. of Energy Sources/Adoption of New Sources	# of Energy Sources	Simple Count	Author's own list
Affordability			
Energy Supply per Capita	Total Primary Energy Supply (MTOE), Population (Million)	Total Primary Energy Supply ÷ Population	Pakistan Energy Yearbook 2017, Pakistan Economic Survey 2016–17
Gas Price	Average Retail Prices of Gas Charges (100cf)—Average of 17 Centers		Pakistan Economic Survey 2016–17
Electricity Price	Average Retail Prices of Electricity Charges (up to 50 Units)—Average of 17 Centers		Pakistan Economic Survey 2016–17
Gasoline Price	Average Retail Prices of Petrol Super (per Ltr)—Average of 17 Centers		Pakistan Economic Survey 2016–17

Source: Authors’ compilation.

4.4 Data Transformation

The study then transformed the indicator values to derive normalized values with a range from 1 to 10 using the following formula:

$$\frac{X' - 1}{10 - 1} = \left(\frac{X - Min\ A}{Max\ A - Min\ A}\right)$$

$$X' = 1 + \left(\frac{X - Min\ A}{Max\ A - Min\ A}\right) \times (10 - 1)$$

where:

X': Transformed indicator

X: Untransformed indicator

A: Data range of X

Min A: Minimum value in A

Max A: Maximum value in A

However, some indicators are inversely related to the scale. In this inverse relationship, a higher value corresponds to less energy security. For example, a larger share of energy imports indicates lower energy security. In this case, we can consider the maximum value of the raw score as the minimum scale value of the indicator and equal to 1 and convert the minimum raw score into the maximum value or 10 on the scale. The equation in this case becomes:

$$X' = 1 + \left(\frac{X - Max\ A}{Min\ A - Max\ A}\right) \times (10 - 1)$$

Transforming the data in this way enables us to identify the progress made for each indicator. However, the scale only measures performance relative to the data range that we used to derive the indicators. If the data points in the data range that we used to develop the indicators are not significantly varied, then the indicators will reflect even a small change as a significant change. Therefore, care is necessary in interpreting these indicators in conjunction with an assessment of the untransformed values.

4.5 Results

Table 2 provides the untransformed values of the 16 indicators.

Table 3 presents the transformed values of the 16 indicators as well as the averages across each of the four dimensions.

Table 2: Untransformed Values of 16 Indicators

	Unit	Raw Values					
		2011–12	2012–13	2013–14	2014–15	2015–16	2016–17
Availability							
Share of Imports in Oil Supply	%	58.2	50.7	50.6	54.3	54.8	56.6
Share of Imports in Gas Supply	%	0.2	0.2	0.2	1.9	8.0	13.5
Share of Imports in Coal Supply	%	26.9	26.1	26.6	26.6	27.7	32.3
Hydro Power Generation	MTOE	6.8	7.1	7.6	7.8	8.3	7.7
Applicability							
Gas Power Generation Efficiency	%	26.9	26.1	26.6	26.6	27.7	32.3
No. of Exploratory Wells Drilled for Oil and Gas	#	21	35	50	47	46	48
Energy Intensity—Agriculture and Transport	TOE per PRe million	4.0	3.9	3.9	3.9	4.3	4.6
Energy Intensity—Industry	TOE per PRe million	7.6	7.1	6.6	6.8	6.9	7.3
Acceptability							
Share of Nuclear and RE in Power Generation	%	5.5	4.7	4.9	6.2	5.5	7.8
CO_2 Emissions per Capita	Tonnes per capita	0.80	0.79	0.81	0.84	0.90	0.95
Share of Global CO_2 Emissions	%	0.45	0.44	0.46	0.49	0.54	0.57
No. of Energy Sources	#	10	11	12	14	14	14
Affordability							
Energy Supply per Capita	TOE per capita	0.36	0.35	0.36	0.37	0.38	0.40
Gas Price	PRe. per 100cf	132.7	119.6	124.2	124.2	127.7	128.7
Electricity Price	PRe. per unit	1.9	2.0	2.0	2.0	2.0	2.0
Gasoline Price	PRe. per liter	92.9	101.3	111.0	88.6	73.7	68.1

Source: Authors' compilation.

Table 3: Transformed Values of 16 Indicators

	Unit	Transformed Values					
		2011–12	2012–13	2013–14	2014–15	2015–16	2016–17
Availability							
Share of Imports in Oil Supply	%	1.0	9.9	10.0	5.6	5.1	2.9
Share of Imports in Gas Supply	%	10.0	10.0	10.	8.8	4.7	1.0
Share of Imports in Coal Supply	%	6.7	6.2	10.	4.1	6.0	1.0
Hydro Power Generation	MTOE	1.0	3.0	5.9	6.8	10.0	6.4
Average Availability		**4.7**	**7.3**	**9.0**	**6.3**	**6.5**	**2.8**
Applicability							
Gas Power Generation Efficiency	%	2.2	1.0	1.7	1.7	3.3	10.0
No. of Exploratory Wells Drilled for Oil and Gas	#	1.0	5.3	10.0	9.1	8.8	9.4
Energy Intensity—Agriculture and Transport	TOE per PRe million	8.4	9.6	10.0	9.4	4.8	1.0
Energy Intensity—Industry	TOE per PRe million	1.0	5.1	10.0	8.5	7.6	3.2
Average Applicability		**3.1**	**5.2**	**7.9**	**7.2**	**6.1**	**5.9**
Acceptability							
Share of Nuclear and RE in Power Generation	%	3.3	1.0	1.5	5.2	3.3	10.0
CO_2 Emissions per Capita	Tonnes per capita	9.1	10.0	8.8	7.3	3.6	1.0
Share of Global CO_2 Emissions	%	9.5	10.0	8.6	6.7	3.2	1.0
No. of Energy Sources	#	1.0	3.3	5.5	10.0	10.0	10.0
Average Acceptability		**5.7**	**6.1**	**6.1**	**7.3**	**5.0**	**5.5**
Affordability							
Energy Supply per Capita	TOE per capita	2.4	1.0	1.9	3.9	6.1	10.0
Gas Price	PRe. per 100cf	1.0	10.0	6.9	6.9	4.5	3.8
Electricity Price	PRe. per unit	10.0	1.0	1.0	1.0	1.0	1.0
Gasoline Price	PRe. per liter	4.8	3.0	1.0	5.7	8.8	10.0
Average Acceptability		**4.6**	**3.8**	**2.7**	**4.4**	**5.1**	**6.2**

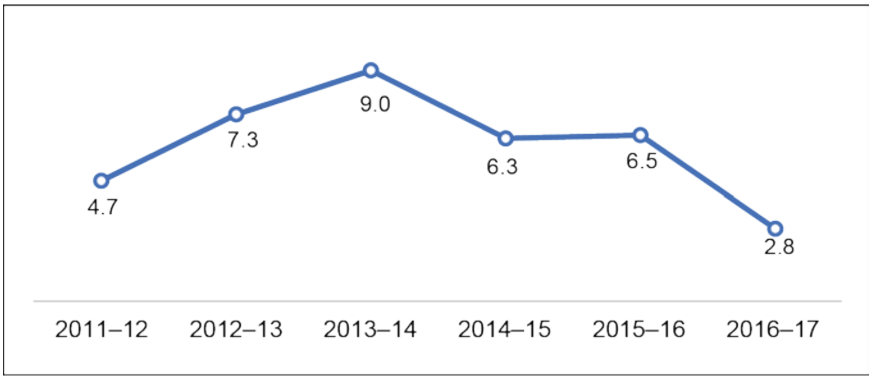
Source: Authors' compilation.

4.6 Analysis of the Results

Availability

Figure 2 depicts the time series of the averages of the indicators on the *availability* dimension. Between 2011 and 2017, the availability of Pakistan's energy sources improved and then declined. The apparent improvement in the first 3 years is misleading, as, during these years, consumers in Pakistan were facing electricity and gas shortages. Increased energy imports could have overcome these shortages if no infrastructural bottlenecks had occurred. By 2014–15, the first liquid natural gas (LNG)-importing terminal started operations in Pakistan, which enabled the country to import gas. Moreover, construction commenced on new imported coal- and LNG-based power projects, and the expectation is that these will increase the demand for imported fuels from 2018 onward.

Figure 2: Availability Dimension



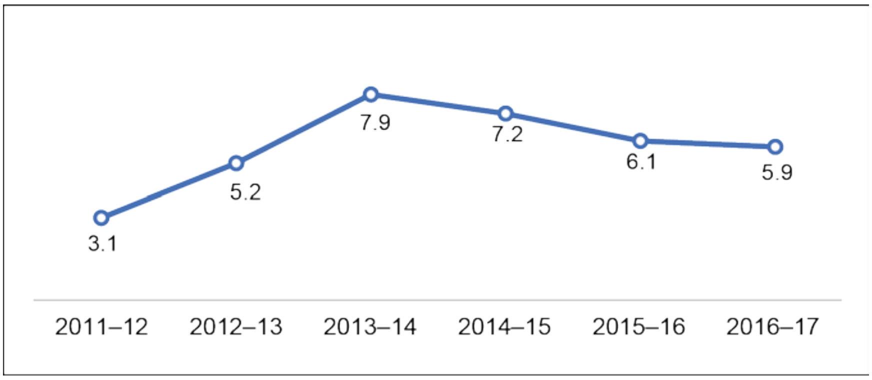
Source: Authors' compilation.

Another potential reason for the apparent growth on the *availability* dimension in the first 3 years, despite widespread energy shortages in Pakistan, is the high prices of oil (over $100 per barrel), which suppressed the demand for oil and petroleum products, leading to lower imports. Over the same period, a consistently falling trend in coal prices discouraged local traders from taking positions and importing large coal volumes. Overall, the factors leading to an improvement in the availability of energy sources over the period 2011–15 appear to be temporary and start undergoing correction in 2016.

Applicability

This paper measures Pakistan's performance on the *applicability* dimension through four indicators, namely Power Generation Efficiency from Gas, Number of New Exploratory Wells Drilled for Oil and Gas, Energy Intensity of Agriculture and Transport, and Energy Intensity of Industry. Figure 3 depicts the time series of the averages of the indicators on the *applicability* dimension. The averages of these indicators improved over the 2011–14 period and then dipped over the 2015–17 period.

Figure 3: Applicability Dimension



Source: Authors' compilation.

The average gas power generation efficiency in Pakistan remained low throughout the period 2011–17. Although it recovered by over 4 percentage points to 32.3% in 2016–17, it is still very low compared with the world average of 39% (GE 2015) and much lower than the generation efficiency possible with the latest gas power turbines. In 2018, Pakistan commissioned three large gas-based power plants with a cumulative installed capacity of 3.6 GW (~20% of Pakistan's combined gas, furnace oil, and coal-based power capacities) with a reported efficiency of over 60%. The addition of these power plants is likely to improve Pakistan's overall gas-based power generation efficiency.

The number of oil and gas exploratory wells drilled increased to around 50 from 2014 onwards. Over the period under study, security in the high-potential areas improved, leading to an improved level of drilling activity. Recently, the government has announced enhanced security measures to support oil and gas exploration companies (Kiani 2019); these should further boost drilling activity, increasing the likelihood of finding a significant reserve.

Energy intensity in agriculture and transport and industry improved initially and then worsened in the last year of the period under study. It is difficult to draw any conclusions on the efficiency of energy use for every rupee of the GNP that these sectors generate. The apparent improvement in energy conservation in the initial years could be due to the energy shortages before 2017, which forced these sectors to adopt informal sources of energy that the government energy numbers do not take into account (like biofuels). The apparent improvement may also be due to energy shortages in the initial years of the period under study, which forced high energy-consuming sectors simply to reduce their operating rates, and, as energy supplies improved, these sectors reactivated.

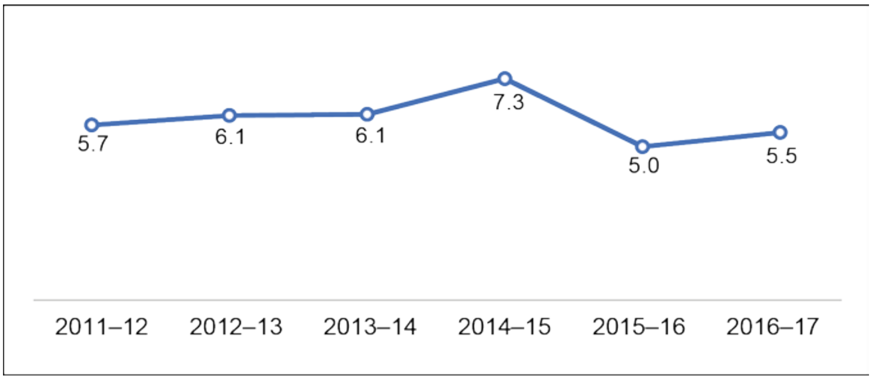
Overall, Pakistan seems to be displaying improved performance on the *applicability* dimension as it adopts newer power generation technologies and expands its oil and gas exploration activities, increasing the likelihood of finding indigenous reserves of oil and gas in the future.

Acceptability

Pakistan adopted new sources of energy over the period of study, namely wind power, solar power, bagasse-based power, and LNG-based power. However, except for LNG-based power, all these new sources of energy together contributed less than 1% to Pakistan's energy supplies. Despite the addition of new sources of energy, the scale of additions, particularly from indigenous or renewable energy, is not significant.

Thus, overall, Pakistan's performance on the acceptability scale, as Figure 5 reflects, remained more or less stable over this period.

Figure 4: Acceptability Dimension



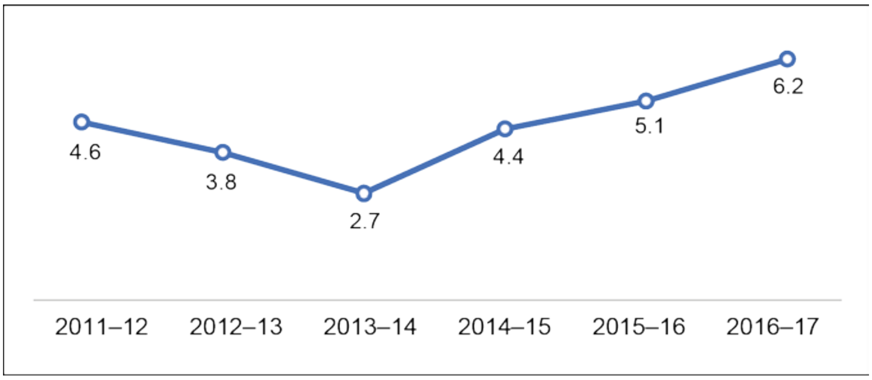
Source: Authors' compilation.

Since growth in Pakistan's primary energy supplies comes predominantly from an increase in the fossil fuel supply, Pakistan's CO_2 emissions per capita steadily increased over the period 2011–17. While Pakistan's share of the global emissions also increased over this period, it remains nominal at less than 0.6%.

Affordability

The *affordability* dimension represents the ability of an economy or society to access energy resources at a reasonable price or equitable access to energy. This paper evaluates Pakistan's performance on this dimension by examining the trend in the energy supply per capita, gas price, electricity price, and gasoline price. Figure 4 depicts the averages across these indicators over the years 2011–17.

Figure 5: Affordability Dimension



Source: Authors' compilation.

The primary energy supplies over 2011–17 increased by 4% per annum on average. The Pakistan Bureau of Statistics has estimated that, over the same period, the population grew by 2% per annum on average. There was thus an increase in the energy supply per capita in the 6-year period under study.

Pakistan heavily subsidizes gas and electricity prices for the smallest consumers of utilities, and they remained more or less stable for most of the period under study. While this has ensured energy affordability for the consumers belonging to the lowest income group, the subsidy burden is becoming increasingly challenging to manage for a government running consistent and gradually increasing fiscal deficits. Moreover, low utility prices do not encourage conservation amongst consumers.

The gasoline prices in Pakistan are to a large extent reflective of international market prices (a regulator notifies the prices, which adds a time lag). In line with international oil prices, gasoline became more affordable over the period 2011–17.

Overall, Pakistan's performance on the *affordability* dimension has improved due to the combination of an increase in energy supplies (with the addition of infrastructure-supporting growth in energy imports) and the maintenance of energy prices for the lowest-income households through a system of subsidies. This improvement is not likely to be sustainable due to the lingering balance of payments and fiscal deficits. In the long term, a systematic shift toward cheap indigenous energy sources, like solar and wind power, is necessary to maintain performance on the *affordability* dimension.

Assessment of Balance

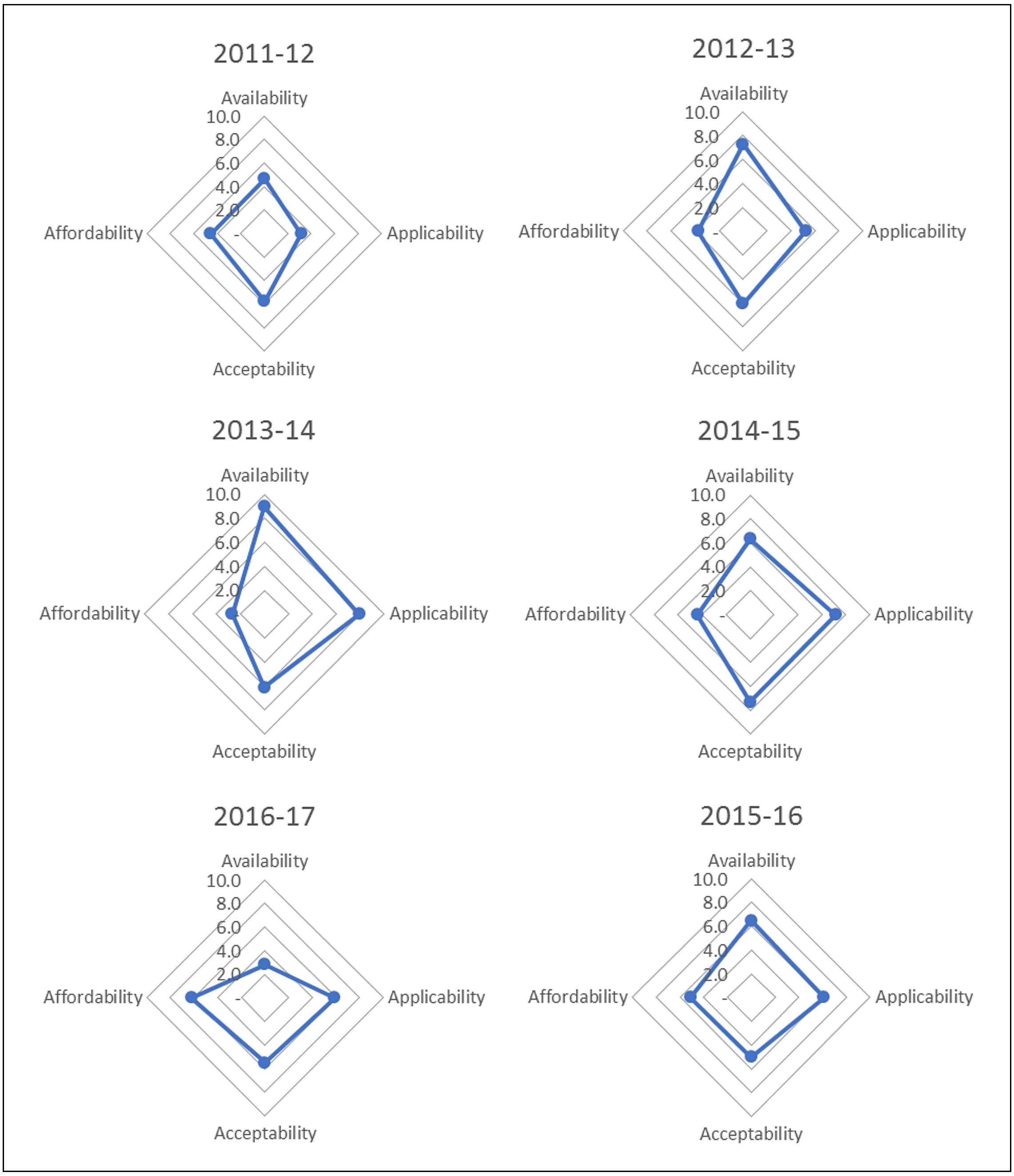
Figure 6 below presents the status and trend of Pakistan's energy security under the 4As framework by plotting the indicators on a four-point radar chart, thereby creating a rhombus for each year. Table 4 below quantifies the energy security in Pakistan by calculating the areas of the rhombuses. The area of a rhombus presents the status of energy security on the four dimensions, the availability of energy resources, the applicability of energy technologies, the acceptability of energy resources by society, and the affordability of energy resources.

Table 4: Pakistan's Energy Security during 2011–17 as Measured by Rhombus Area

Summary – Average Indicator Values and Area of Rhombus					
	Availability	**Applicability**	**Acceptability**	**Affordability**	**Area of Rhombus**
2011–12	4.7	3.1	5.7	4.6	40.1
2012–13	7.3	5.2	6.1	3.8	60.0
2013–14	9.0	7.9	6.1	2.7	80.2
2014–15	6.3	7.2	7.3	4.4	78.7
2015–16	6.5	6.1	5.0	5.1	64.4
2016–17	2.8	5.9	5.5	6.2	50.3

Pakistan's energy security, with the area of the rhombuses as a measure, improved in the first 3 years of the period under study, primarily as a result of the improved performance on the *availability* index and the *applicability* index, peaking in 2013–14 with a rhombus area of 80.2. It then decreased consistently over the next 3 years as the performance on the *availability*, *applicability*, and *acceptability* indexes deteriorated. Energy shortages in the earlier years may have skewed or artificially improved Pakistan's performance on the *availability* and *applicability* indexes, as infrastructural bottlenecks prevented energy imports from growing and meeting the energy shortages. However, as the import infrastructures became operational, the energy imports increased and the industrial and agricultural sectors, which had curtailed their demand or diverted it to informal energy sources (like wood, biofuels, etc.), reactivated their energy demand and redirected it to formal energy sources. Toward the end of the period of study, significant correction of performance is apparent, especially on the availability dimension.

Figure 6: Status and Trend of Pakistan's Energy Security



Source: Authors' compilation.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

The analysis of Pakistan's energy security under the 4A framework indicates that Pakistan's energy security improved initially but then deteriorated. However, since the analysis used relative comparison of data and was relative to the data range that the authors used to derive the indicators, it did not indicate whether the change in performance is material or significant. It is necessary to consider it in combination with the energy infrastructural and energy source developments in Pakistan.

Over the period of study, 2011–17, the energy sector in Pakistan experienced a much-needed phase of investment. It commissioned around 10 GW of new power generation, capacities, and 1.2 billion cubic feet per day of new LNG-importing infrastructure. The renewable energy sector also attracted investors' and lenders' interest, enabling Pakistan to commission over 1 GW of wind and solar power-based projects, with levelized tariffs falling sharply in the last 3 years from over 10 cents/kwh to less than 7 cents/kwh. Resultantly, Pakistan is well positioned to fulfill its immediate energy priority of eliminating power and gas shortages, which had slowed down industrial and economic growth in the country.

While investments are increasing the energy supplies and diversifying the energy mix, the new sources of energy, which are significant, have primarily consisted of imported fuel. Pakistan currently imports nearly a third of its energy. This share of imports will double by 2025 (in tonnes of oil equivalent) with the impending depletion of local gas reserves (Malik, Qasim, and Saeed 2018). Imported energy is expensive and requires increasing subsidization to continue to make energy accessible and affordable to Pakistan's large population, which in turn leads to government fiscal deficit challenges. As a result of this energy infrastructural investment, the level of unmet energy demand in Pakistan has decreased, as reflected in fewer electric power and gas shortages. However, this has also led to increased dependence on imported fuels and hence greater energy insecurity. Thus, despite significant investments in energy infrastructure over the past 5 years, Pakistan continues to be energy insecure.

Looking forward, the country needs to increase the share of alternative energy sources that it has already introduced into its energy mix, like solar, wind, distributed solar (residential rooftop solar solutions), and indigenous coal mining. Other green energy initiatives, like (a) rethinking electric power grid management to accommodate renewable power generation and distributed generation, (b) investing in infrastructure to reduce energy losses and theft, and (c) demand side initiatives like improving system efficiencies, incorporating better building and insulation standards, and shifting the demand to alternative local fuels, offer good solutions to improve Pakistan's energy security. These can improve the access to and demand for indigenous sources of affordable energy, reduce the country's import bill, and help Pakistan to develop a robust economy that is well insulated from international energy price shocks.

To facilitate these initiatives, the government needs to take certain policy measures, like setting a more ambitious target for solar (including distributed solar), wind, bioenergy, and small-hydro, increasing the 2030 target from just 5% of the total generation to at least 15%. In 2017, Pakistan used almost 25% of its thermal fuels (oil, gas, LNG, and coal) in power generation (MOE 2018), and, in the same year, the domestic sector consumed 48% of the final electric power sold on the grid (National Electric Power Regulatory Authority 2017). Households directly consumed another 10% of the thermal fuels (oil, gas, and LPG). Overall, the domestic sector consumes more than a third of thermal fuels (~35%). If there are no significant oil or gas discoveries in the near future, Pakistan will be feeding its domestic demand primarily through imported fuels, which is not economically sustainable. Moving the household energy consumption to distributed solar energy or increasing the energy efficiency by developing and implementing building insulation standards can have a significant impact on Pakistan's energy security. Therefore, Pakistan urgently needs to finalize regulations for distributed solar power and ensure widespread acceptance of net metering and distributed solar power solutions by the government-owned electric power distribution companies. Moreover, it needs to improve access to subsidized financing, encouraging homeowners to refurbish their homes with better insulation.

The method and the results of the analysis are useful for other countries with a similar energy demand pattern.

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