European Online Journal of Natural and Social Sciences 2020; www.european-science.com
Vol.9, No 2 pp. 425-442
ISSN 1805-3602

# Evaluating Energy Security Performance in Pakistan and India through Aggregated Energy Security Performance Indicators (AESPI)

**Farhan Ali [1*], Khawar Ahmed Khan [2], Shafaq Jahan [1]**
[1] Shandong University, Jinan Shandong, P. R. China; [2] Chang'an University, Xian, China
[*]Email: farhanalivirk@yahoo.com

Received for publication: 31 January 2020.
Accepted for publication: 22 April 2020.

**Abstract**

This article computes the energy security performance between two crucial South Asian neighboring countries in the region through aggregated energy security performance indicators (AESPI) using time series data of time spanning 1990-2018. The findings of this manuscript suggest that total primary energy supply, final energy consumption, household electricity consumption, the Share of non- carbon energy per total immediate energy consumption, net energy import dependency $Co_2$ emissions per capita and GDP and residential energy consumption lead to making better energy security performance in Pakistan. However, total primary electricity consumption, total primary, and final energy intensity, reserve production ratio of oil & gas, and transformation losses adversely affect energy security performance in Pakistan. On another end, in India final energy consumption, total primary energy intensity, household electricity consumption, the Share of the capacity of renewable energy per whole electricity generation, the percentage of renewable energy per final energy consumption, net energy import dependency, and $Co_2$ emissions per capita lead to improve energy security performance. Conversely, total primary energy supply, total immediate electricity consumption, final energy intensity, transformation loss, reserve production ratio of oil & gas, the Share of non-carbon energy per total primary energy supply, and $Co_2$emissions per GDP may cause to reduce energy security performance in India. In conclusion, the overall energy security performance is improved in both the countries by time, India (more improved than Pakistan), and Pakistan, as the findings of this manuscript suggest.

**Keywords**: Energy Security Performance; AESPI; India; Pakistan; PCA

## Introduction

Energy security is one of the most critical global concerns of the 21st century. As quoted by Ludwig Boltzmann, The struggle for existence is the struggle for available energy (Boltzmann, 1886). Energy is a certainty for all dimensions of life. It is not just a necessity for high economic growth but also a prerequisite for human development. Increasingly changing climatic along with socioeconomic conditions, may also have poverty-related implications worldwide regardless of developing as well as developed nations (Ali et al., 2020; Farhan & Hassan, 2018). Although there is no universal definition of energy security, however generally, it emphasizes three critical aspects as affordability, reliability, and environmentally friendly. Where affordability refers to such energy prices that can promote sustainable economic growth, security means that secured energy form in more excellent supply and environment-friendly implies that clean energy (McEvoy, 2012).

According to (Brown et al., 2014), the proposed definition regarding energy security is: equitably providing available, affordable, reliable, efficient, environmentally benign, proactively governed, and socially acceptable energy services to end-users. Energy Security is continuous, as well as sustainable availability of energy at such affordable prices, which cannot adversely affect the economic performance of an economy (Jewell, 2014; Chester, 2010). Moving forward, International Energy Agency (IEA) defines energy security for two periods of time as the short-run energy security that changes at sudden and the long-run energy security that depends on economic development and environmental sustainability (International Energy Agency, 2016). Especially in developing countries, energy security can be defined as uninterrupted access to cheap and clean energy. That can cause to alleviate the poverty level of poor communities in society, raising their standard of living as it has been found that energy consumption and economic growth have causal as well as the long-term relationship in Pakistan (Ali et al., 2019).

The increasing demand for energy is due to a rise in population and economic activity. The total energy demand is expected to surge by 145% in 2030 worldwide and is predicted to be doubled by 2050 (Skowron, 2016). A country is needed to be less dependent on imported energy to improve self-dependency and for energy security. On the other hand, it is found that Europe imports half of the power consumes out of total and each day the cost of imports exceeding €1 billion, mostly they import mainly for crude oil and natural gas. As compared to Europe, South Asia region emerging as fastest developing regions in the world, but the economic development of South Asian countries may suffer due to potential constraint (Rasul, 2016) which includes Pakistan, India, Bangladesh, Afghanistan, Maldives, Nepal and Sri Lanka. Moreover, the South Asia region also believed as the world's worst air pollution, India ranked as highest in the area followed by Pakistan (Hasnat et al., 2019).

According to (Palit, 2013) 37% of people of South Asia do not have enough access to clean forms of energy. Shah et al., in their study (Shah et al., 2018), urged that people of rural areas have not sufficiently accessed to electricity. They mostly rely on traditional fuel like wood and biomass for cooking purposes burning. The conflicts between Pakistan and India also lead to energy security because of the higher risk of war in the region, so they are reluctant to invest a significant amount of funds. Thus, to create domestic energy sources and decreasing reliance on imported energy are severe concerns for the country. Nuclear power has been one of the energy sources that could reduce dependence on fossil fuels (Matsumoto & Shiraki, 2018).

Furthermore, energy security does not only mean that the availability of energy in excess, but efficient use is also essential. Power Shortage in both nations indicates reduced transmission, distribution infrastructure, and inefficient or insufficient energy generating capacity. For energy security, energy efficiency is much critical. Especially in Pakistan & India, like countries for which energy prices play a vital role. Mainly where the prices are rising in the sense that high rates of security to careful, efficient use of available energy avoidance from wastage and misuse of energy.

This study focuses on the comparison of energy security performance from the perspective of energy supply between Pakistan and India. Two South Asian countries, India, which is among the top ranks in the list of high energy-consuming and highly populated countries in the world, and Pakistan, which is also among top populated countries with a high population growth rate, particularly in the region. Uninterrupted access to clean and affordable energy is one of the fundamental rights of country residents.

***Literature Review***

South Asia region is also called the southern part of the Asian continent and is in the south of the Indian Ocean. South Asia consists of eight countries, i.e., Pakistan, India, Nepal, Bangladesh, Maldives, Bhutan, Afghanistan, and Sri Lanka. These countries are much dependent on imported oils (crude oil products). Irregularity in imports in terms of oil products and price changes may affect the performance of developing countries (Alam et al., 2015). It is expected that South Asian countries' energy demand will increase by around 33% by 2040 (International Energy Agency, 2015). This region is expected to be required three times additional energy during the year 2030–

2035 (Alam et al., 2015). Energy security scenario, particularly for South Asia, increasing demand and supply of domestic energy, leads to increase independence on imports (Singh et al., 2018).

Pakistan, India & Bangladesh among the South Asia countries have substantial reserves of coal and natural gas in the region; these countries are significant in terms of area and population. Other South Asian countries, i.e., Nepal and Bhutan, have a potential of hydro-power, which can meet the country's energy demand and can also help in improving the energy security condition of the region of exporting hydroelectricity in the area (Singh et al., 2018). In addition to the above, utilization and bringing substitute of energy sources may not be utilized adequately due to insufficient finance and research capabilities to meet the increasing energy demand (Safeer & Fatima, 2019).

According to the theory of (Sovacool & Brown, 2010), a hike in oil prices and energy shortage leads to severe concerns amid investors and policymakers because energy security has a close relationship with continuous progress and economic development. Energy security has different definitions and dimensions; different kinds of methods are used to measure energy security performance. Energy security can be seen from two perspectives, i.e., short term and long term. In a short time, energy problems can be reduced by immediate remedial actions, i.e., political and weather. At the same time, the long-term mainly focuses on the stability of energy sources, i.e., oil resources. Although, both short-term and long-term are related but long-term technique is more highlighted because it requires finance for improvement (Kruyt *et al.* 2009). If the energy sources are substantially available on a long-term basis, however, exporting countries will remain key players in the global oil market. Aim of net importing states is to reliance on minimized energy import sources. Policymakers can work for energy supply risk levels for the country, and to achieving this, threshold levels can be set either for lower or upper (Soliman et al., 2019).

It has been pointed out that nearly 70 percent share of fossil fuel energy in total primary energy supply in India during 2015 and anticipated to rise to 80 percent till 2030 (International Energy Agency, 2015). Since the 1970's many studies have been suggested to supply sides of energy for energy security, but the demand side also remains essentially the same as the supply side (Costantini et al., 2007; Löschel et al., 2010).

(Sovacool et al., 2011) provided an index to measure energy security and economic performance for the US, EU, Japan, Australia, China, New Zeeland, India, South Korea, Laos, Malaysia, Indonesia, Thailand, Singapore, Brunei, Myanmar, Cambodia, Vietnam, and the Philippines. Energy security comprises five dimensions, availability, affordability, development of technology, sustainability as well as regulation. They introduced twenty indicators in their index and resulted from 1990-2010 that Japan, Brunei, and the USA showed high performance and energy security, Vietnam, India, and Myanmar showed the worst performance, Malaysia and Australia led the most improvements in energy security, Laos, Cambodia, and Myanmar showed the most decline

Different countries have different specific characteristics of their energy security (Martchamadol & Kumar, 2014). According to (Sovacool, 2013), some countries like South Africa relate energy security as well as poverty alleviation. Energy security has two dimensions qualitative as well as quantitative. This study used aggregated energy security performance Indicator (AESPI) to examine it quantitatively, which may be further very helpful for policymakers to identify better choices of energy indicators for energy security in the region.

***Energy Security Condition***

*Pakistan*

Energy concerns in Pakistan can be viewed from different perspectives, i.e., policy, technical, financial, and governance issues. According to (Khalid & Mukhtar, 2016), energy concerns are mainly due to poor planning, ineffective management, political influence, and lack of technical and financial problems. While another author (Kugelman, 2013) pointed out that crises of energy are not just seriously concerned with the energy sector. Still, other areas also get influenced as well, which will also affect the industries and economy of a country. Moreover, it can also be said that technical inadequacies and transmission losses also consumes a large amount of energy.

Around the world, dependency on oil is decreased by about 5%, but still, Pakistan using a significant portion of fuel for electricity generation. Pakistan imports 70% (5.9 million tons) of oil demand from Middle Eastern countries with an estimated cost of 1.84bn US$. According to data of 2014, consumption of oil is 450 thousand barrels/ day, which is indeed an enormous change as compared to 150 thousand barrels/ day in 1980. The production also increased from 65,866 barrels/ day to 97 thousand barrels/ day for the year 2016 (Safeer & Fatima, 2019).

The Pakistani government has many gas reserves took the initiative of CNG; a project was to use CNG as a fuel in vehicles in 1992. In the current scenario, all over the world, 05 million vehicles using compressed natural gas (CNG) as a fuel agent and in Pakistan ranked as 03rd place in the world with an estimation of 900,000 vehicles using CNG. Pakistan is favored by many coal reserves. Estimated coal reserves of Pakistan are 186bn tons, and out of total resources, 175bn tons of coal reserves only available in the Thar region (Safeer & Fatima, 2019). In 2005, an energy security plan estimated 25,000-Megawatt power generation by utilizing Thar coal, but unluckily reserves of coal were not adequately used to meet the country's requirement due to different aspects. For instance, Infrastructural development cost, technology, technical skills, and more dominantly political disputes. Pakistan is also rich in solar energy; all round the year, the sun is available, and it can also contribute to the economy of Pakistan as well as to overcome the energy crises by making appropriate policies and implementation of the project for renewable energy sources. Most of the population belongs to the rural part of Pakistan; solar energy can be used to facilitate the rural areas people and the upbringing of their life. In Sindh, there are few projects inline that will significantly contribute to achieving the future requirements of a country.

Pakistan has a capacity separately to generate electricity 50,000MW from hydel and Wind. According to the figures, Pakistan is currently producing 5,928 MW from hydel and 356 MW from wind energy. However, many projects are in line under the CPEC development project, and progress is comparatively slow. Internationally, already large-scale modification headed to renewable and domestic sources of energy (Safeer & Fatima, 2019). Energy security performance can also be enhanced by utilizing nuclear energy; currently, 450 nuclear reactors are operational, while Pakistan has 05 operable nuclear reactors generating 7% from nuclear power plants (Hayashi and Hughes, 2013).

*India*

According to the latest statistics, 244 million people of India do not have access to electricity out of 1.3 billion (18% of the world population). However, the demand for energy is increasing rapidly day by day in contrast with human society, modernization, and urbanization. This problem may become more severe because around 70% of the people of India belong to rural areas. The slow growth in the energy sector of India has left rural areas families to get leverage from energy supply (Rathore et al., 2019).

At present, India imports oil around 82%, and it is a plan to reduce oil imports by 15% until 2022 by improving domestic energy exploration and other energy sources. The latest statistics shared by the author, India, is 3rd largest importer of crude oil followed by China and the United States of America (USA), and according to data as of 31st March 2017, total crude oil reserves estimated around 604 million tons. For the year 2017-18, India imported crude oil 220 million tons and exported to other countries 36 million tons. Currently, India has 23 crude oil refineries with a total refining capacity of 247.6 million tons per annum, out of which 18 are state-owned, 03 are private, and 02 are joint ventures. In the case of LPG, India imported LPG around 16 million tons in 2017-19, which is expected to be increased by 30 million tons per year by 2022.

India is ranked as the 2nd largest importer of LPG in the world (Alam et al., 2019). The author engraved that India ranked as 3rd largest coal producer in the world but still required to import coal from South Africa, Indonesia, and Australia, coking coal due to problems in transportation and low quality of domestic fuel (presence of a high amount of ash). While natural gas reserves, India has 39 trillion cubic meters and biomass reserves 223 million tons. Energy consumption of India got doubled between the year 2000 – 2015 and one-third energy per capita demand of the world average. India is a high reliance on import on different energy sources, i.e., crude oil, natural gas, and coal.

Moreover, high dependence on imported energy sources raises concern over energy security supply, and reliance on energy would be increased by 90% in 2040 with an estimation of 9.3 million barrels/ day (Mehra & Bhattacharya, 2019). India and Bangladesh have initiated power trading, and as a result, India exported 1160 MW electricity to Bangladesh through 400KVA high power lines. Energy security performance in terms of nuclear energy, currently 450 nuclear reactors are operational all over the world. In comparison, India has 22 operable nuclear reactors generating 3% electricity of the country's consumption from atomic power plants (Hayashi and Hughes, 2013).

## Materials and Methods

Based on energy security definitions, it is evident that energy security in a country includes in social, economic as well as environmental aspects of the country. There may be two types of energy security indicators to measure energy security; disaggregated indicators of energy security and aggregated indicators of energy security. A prior variety includes a collection of individual indicators like Reserve Production Ratio, Net Energy Import Dependency, Shannon-Wiener Index, Market Liquidity, etc. (Kruyt *et al.* 2009). The following type of energy security indicators includes a list of combinations of indicators like OVI, which is composed of seven oil market and oil supply related indicators (Gupta, 2008).

It is pertinent to consider all dimensions of energy concerns, i.e., production to consumption, transport or delivery, demand & supply efficiencies, and process of conversion to discuss the energy concerns at present and in the future. Notably, economic, social, and environmental aspects also need to be considered.

WEC made an energy security index using 46 indicators to measure named as Assessment Index (AI). Energy sustainability country index is made up of 22 energy security indicators, Energy Development Index (EDI) includes four energy security indicators, etc. International Atomic Energy Agency (IAEA), World Energy Council (WEC), International Energy Agency (IEA), Organization for Economic Cooperation and Development (OECD), Asia-Pacific Energy Research Centre (APERC), European Environment Agency (EEA) and European Commission (EC) have provided different lists of energy security indicators to measure energy security.

There are also some benefits of aggregated energy security performance indicators as aggregated indicators stand for holistic presentation at a regional or national level. They present the status to rank the provinces or countries. They also can give a baseline about energy security at the provincial or state level. It might be practical to examine the development and scrutiny of energy security fence (Doukas *et al.*, 2012).

The existing aggregated indicators don't provide performance in time series data, improvement in energy security, and energy performance in the future about the energy strategy of a country. AESPI shows the trend and does not only the past performance based on time-series data but also tells about energy performance in the future based on the energy policy of a country. It can also be used to rank the countries among countries according to the energy performance level. AESPI is based on Principal Component Analysis (PCA) and uses component weight.

AESPI includes 25 indicators in its construction, AESPI erection can also be seen through the table in the Appendix.

These three indicators total primary energy supply per capita (TPEnS), final energy consumption per capita (FEnC) and total electricity consumption per capita are used to include per capita consumption as well as the demand side efficient policies management, their outcome and to check the utilization of modern form of energy (Electricity). Total primary energy intensity and Final Energy Intensity are both used for efficient use of energy for economic productivity. Agriculture Energy Intensity, Industrial Energy Intensity, Transportation Energy Intensity, and commercial energy intensity used to check the efficient use of energy by economic sectors of the economy. Transmission and transformation losses are utilized for the efficiency of the supply side. Reserve production ratios of traditional energy sources, i.e., oil, coal, and gas, are used for the supply side of a country in the sense of availability of conventional energy sources.

Residential energy consumption per household, household electricity consumption per capita, the Share of income spent on electricity is used for living quality, demand, and affordability of the people. Household access to power is used as a proxy for the people to the modern form of energy. For environmental representation, carbon dioxide emissions per capita carbon dioxide emissions per GDP, the Share of non-carbon power per total primary energy supply, the percentage of renewable energy per final energy consumption, and the amount of the capacity of renewable energy per whole electricity generation are used. Net energy import dependency is used for the market of import of power.

We have collected time-series data from 1990-2018, keeping in view the indicators included in the Aggregated Energy Security Performance Index for both the countries (Refer to see Appendix for the further details).

***Steps involved in measuring energy security performance through AESPI***

- Time series data for indicators to be collected for AESPI.
- Collect information based on the energy policy of the country, data collected in the previous steps to forecast future energy demand, alternative energy strategies, etc.
- Formulate indicators using the previous two steps.
- Make the data/indicators standardized because different indicators have different units. Standardization means indicators have zero mean and one standard deviation.
- Principal Component Analysis testing, but before doing so, standardized variables have to pass the KMO test for sampling adequacy whose value ranges between 0.5 and 1. If the calculated value of the KMO test using data collected in the 1$^{st}$ step falls between the ranges, then PCA is suitable otherwise not. Bartlett's test for Sphericity also used for correlation among the variables. The significance of the chi-square value should be less than 0.05 for PCA suitability. In the case of PCs, then another way named 'expert judgment' (refer to see Appendix at the end of this study) is utilized for further PCA proceeding.
- KMO (Kaiser-Meyer-Olkin) test for Sampling Adequacy (SA): It is used to detect the multi co-linearity in the data for the appropriateness of PCA. Its value should lie between 0.5 & 1 (Krishnan, 2016; Ordoudi, 2014; Hakan, 2011; Abdul Rahman, 2013).
- Bartlett's (1954) Test of Sphericity: It is used to test the strength of relationships among variables. It examines the Ho = variables in the correlation matrix that are uncorrelated. The results should be that the probability less than 0.05 (Ho rejected) usually results show 0.00. So, this

result concludes that a healthy relationship is there among the variables (Nejati, 2013; Peres-Neto, 2005).

- After Kaiser-Meyer-Olkin and Bartlett's Tests, the PCA output as, suitable weighting factor for each variable, correlation matrix, Eigenvalues, and factor loadings.

The variables having the highest Eigenvalues representing high variation capturing are considered for further, and the smallest values showing profound difference capturing are abandoned for further. Some indicators show positive and negative values (see discussion portion and Appendix). High positive values show improvement in energy performance, whereas low negative values also show improvement in energy performance.

Finally, the AESPI equation is as under,

$$AESPI_{j} = \Sigma (W_{k} * GI_{kJ}) / \Sigma W_{k} \qquad \text{. . . . . . . . . . . . (1)}$$

Where, '**GI** $_{\mathbf{kJ}}$' represents a group indicator of 'k' for year 'j.' $\mathbf{W_k}$ is a component weight obtained after running PCA. AESPI represents the energy security level of a country by showing a range between 0 and 10. Where 0 indicates energy insecurity and ten means energy security AESPI is the combination of many indicators; it shows the overall performance of the energy security of the country. It can also be used for comparison among countries. For this purpose, the benchmark country must be selected. ESCI & AI represent the indicator just for a specific year and used for comparison among countries, whereas AESPI represents past, present scenario as well as a future scenario based on the energy policy plan of the government (Martchamadol & Kumar, 2014; Martchamadol & Kumar, 2013).

**Results**

For the computation of energy security performance to reduce the dimensionality of the dataset for appropriate energy security indicators, we firstly used Principal Component Analysis (PCA) and further AESPI. The following estimation through Kaiser-Meyer-Olkin and Bartlett's test verifies the prerequisite for PCA.

KMO = 0.76 (Middling) lies between (0.50 - 1) which shows the suitability of the variables (data) for PCA. Bartlett's test (sig. 0.00) also favored the suitability condition for PCA (Table 1).

**Table 1. Kaiser-Meyer-Olkin and Bartlett's Test (Pakistan's Case)**

| | | |
|---|---|---|
| KMO Test for Sampling Adequacy | | 0.76 |
| Bartlett's Test of Sphericity | Chi-Square | 1137.50 |
| | d.f. | 136 |
| | Sig. | 0.00 |

Source: Estimation by the Author

Initial Eigen-values and percentage of explained Variance are presented in Table 2. As it is clear that the first five components till initial Eigen-value (total) = 1.004 showed about 92.64% variation as cumulative, from which maximum individual difference (53.140%)is explained by the first component (Refer to see Table 2 for exact values).

In table 3, all principal components (PC1-PC5) showed positive as well as negative values. PC1 showed a maximum variation of about 53% in the case of Pakistan. This column (PC1) represented the weighting factor of the indicators. Total primary energy supply (TPEnS), final energy consumption (FEnC), Household Electricity Consumption (HHEC), Share of non-carbon energy per total primary energy consumption, net energy import dependency (NEnID), $Co_2$ emissions per capita and GDP and residential energy consumption (REnC) have strong positive loads on component 1 having coefficients 0.92, 0.832, 0.887, 0.589, 0.611, 0.907, 0.795 and 0.992, respectively. In contrast, Total Primary Electricity Consumption (TPEC), Total Primary Energy Intensity (TPEnI), Final Energy Intensity (FEnI), and Reserve Production Ratio of Gas (RPRG) has strong negative correlation on component 1 with corresponding coefficients -0.831, -0.908, -0.814, and -0.897.

**Table 2**. **Estimation of Total Variance Explained through PCA**

| Component | Initial Eigenvalues | | | Extraction Sum of Squared values | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 9.034 | 53.140 | 53.140 | 9.034 | 53.140 | 53.140 |
| 2 | 2.580 | 15.174 | 68.314 | 2.580 | 15.174 | 68.314 |
| 3 | 2.037 | 11.985 | 80.299 | 2.037 | 11.985 | 80.299 |
| 4 | 1.093 | 6.431 | 86.730 | 1.093 | 6.431 | 86.730 |
| 5 | 1.004 | 5.904 | 92.635 | 1.004 | 5.904 | 92.635 |
| 6 | 0.768 | 4.517 | 97.152 | | | |
| 7 | 0.213 | 1.251 | 98.402 | | | |
| 8 | 0.098 | 0.576 | 98.979 | | | |
| 9 | 0.073 | 0.431 | 99.410 | | | |
| 10 | 0.045 | 0.262 | 99.673 | | | |
| 11 | 0.027 | 0.160 | 99.833 | | | |
| 12 | 0.014 | 0.081 | 99.913 | | | |
| 13 | 0.008 | 0.046 | 99.959 | | | |
| 14 | 0.005 | 0.028 | 99.987 | | | |
| 15 | 0.001 | 0.008 | 99.995 | | | |
| 16 | 0.001 | 0.004 | 99.999 | | | |
| 17 | 0.000 | 0.001 | 100.000 | | | |

Source: Estimation by the Author

Loss in transmission (LT) and net energy import dependency (NEnID) have a substantial positive impact on component 2. In contrast, the Share of renewable energy per final energy consumption (SREn/FEnC) has an active negative load on element 2, describing 15.174% total variation with corresponding individual coefficients 0.63, 0.637, and -0.857, respectively.

Component 3 explains 11.985% variation against strong positive correlation 0.533 with final energy consumption (FEnC), 0.532 with final energy intensity and strong negative correlation (-0.80) with transformation loss. Similarly, reserve production ration of oil (RPRO) has a strong negative load (-0.884) on component 4, which illustrates 6.431% individual variation and Share of the capacity of Renewable Energy per total Electricity Generation has strong positive correlation (0.85) with component 5.

**Table 3. Evaluation of a Component Matrix through PCA**

| Indicators | Component | | | | |
|---|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 | PC5 |
| Total Primary Energy Supply | 0.932 | 0.067 | 0.259 | -0.063 | -0.190 |
| Final Energy Consumption | 0.832 | 0.028 | 0.533 | -0.098 | -0.069 |
| Total Primary Electricity Consumption | -0.831 | 0.423 | 0.266 | 0.186 | 0.062 |

| Indicators | Component | | | | |
|---|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 | PC5 |
| Total Primary Energy Intensity | -0.908 | 0.176 | 0.298 | 0.159 | -0.032 |
| Final Energy Intensity | -0.814 | 0.151 | 0.532 | 0.133 | 0.017 |
| Loss in Transmission | -0.424 | 0.630 | -0.477 | 0.013 | -0.137 |
| Transformation Loss | -0.139 | 0.084 | -0.798 | 0.069 | -0.267 |
| Reserve Production Ratio of Oil | -0.158 | 0.302 | 0.092 | -0.884 | 0.074 |
| Reserve Production Ratio of Gas | -0.897 | -0.210 | 0.052 | -0.252 | 0.069 |
| Household Electricity Consumption | 0.887 | 0.318 | 0.053 | 0.059 | -0.198 |
| Share of capacity of Renewable Energy per total Electricity Generation | 0.409 | -0.059 | -0.243 | 0.023 | 0.853 |
| Share of non-carbon energy per TPEC. | 0.589 | -0.469 | 0.160 | 0.199 | -0.070 |
| Share of renewable energy per FEC. | -0.390 | -0.857 | 0.062 | 0.098 | -0.010 |
| Net Energy Import Dependency | 0.611 | 0.637 | -0.020 | 0.279 | 0.284 |
| Co2 Emissions per Capita | 0.907 | 0.345 | 0.202 | -0.019 | -0.064 |
| Co2 Emissions per GDP | 0.795 | 0.465 | 0.261 | 0.145 | 0.011 |
| Residential Energy Consumption | 0.992 | 0.038 | -0.008 | 0.019 | 0.006 |

Source: Estimation by the Author

KMO = 0.83 (Meritorious) lies between (0.5 - 1), and the significance of Bartlett's test (sig. 0.00) confirms the appropriateness of the variables (data) for PCA (see Table 4).

**Table 4. Kaiser-Meyer-Olkin and Bartlett's Test (India's Case)**

| KMO Test for Sampling Adequacy | | 0.83 |
|---|---|---|
| Bartlett's Test of Sphericity | Chi-Square | 1801.32 |
| | d.f. | 136 |
| | Sig. | 0.00 |

Source: Estimation by the Author

For each component provided Eigen-values, as it is clear from Table 5 first three components till initial Eigen-value (total) = 1.006 illustrate 92.808% cumulative variation, and element 1 explains maximum (67.696%)variation.

In table 6, three principal components (PC1 – PC3) showed positive as well as negative values. PC1 showed a maximum variation of about 67.696%, whereas element 2 represents 19.196%and component 3 contributes 5.916% variation. Therefore, part 1 (PC1) provides the main weighting factor of the indicators.

Final energy consumption (FEnC), total primary energy intensity (TPEnI), household electricity consumption (HHEC), the Share of capacity of renewable energy per entire electricity generation, the percentage of renewable energy per final energy consumption (SREn/FEnC), net energy import dependency (NEnID) and $Co_2$ emissions per capita strongly correlate with component 1 having individual coefficients 0.961, 0.981, 0.584, 0.992, 0.769, 0.602, 0.979 and 0.981, correspondingly. Conversely, total primary energy supply with factor -0.958, total immediate electricity consumption with factor -0.714, final energy intensity having -0.835, loss in transmission against -0.564, transformation loss with -0.884, reserve production ratio of oil (-0.819), reserve production ratio of gas with -0.763 and Co2 Emissions per GDP (-0.714) have substantial negative weights on component 1 in the case of India.

Component 2 and component 3 elucidates 19.196%and 5.916% variation. Also, total primary electricity consumption with coefficient 0.683, final energy intensity with 0.529, $Co_2$ emissions per GDP by 0.683, and residential energy consumption by 0.972 positively and strongly correlate with component 2, but reserve production ratio of gas negatively & strongly correlate. In the case of component 3, loss in transmission strongly but negatively (-0.656) relate to component 3.

**Table 5. Estimation of Total Variance Explained through PCA**

| Component | Initial Eigenvalues | | | Extraction Sum of Squared values | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 11.508 | 67.696 | 67.696 | 11.508 | 67.696 | 67.696 |
| 2 | 3.263 | 19.196 | 86.892 | 3.263 | 19.196 | 86.892 |
| 3 | 1.006 | 5.916 | 92.808 | 1.006 | 5.916 | 92.808 |
| 4 | 0.759 | 4.464 | 97.272 | | | |
| 5 | 0.228 | 1.342 | 98.614 | | | |
| 6 | 0.104 | 0.615 | 99.228 | | | |
| 7 | 0.057 | 0.334 | 99.562 | | | |
| 8 | 0.028 | 0.167 | 99.730 | | | |
| 9 | 0.022 | 0.127 | 99.857 | | | |
| 10 | 0.009 | 0.055 | 99.911 | | | |
| 11 | 0.008 | 0.045 | 99.957 | | | |
| 12 | 0.004 | 0.022 | 99.978 | | | |
| 13 | 0.001 | 0.009 | 99.987 | | | |
| 14 | 0.001 | 0.007 | 99.994 | | | |
| 15 | 0.001 | 0.005 | 99.999 | | | |
| 16 | 0.000 | 0.001 | 100.00 | | | |
| 17 | 0.000 | 0.000 | 100.00 | | | |

Source: Estimation by the Author

**Table 6. Evaluation of Component Matrix through PCA**

| Indicators | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| Total Primary Energy Supply | -0.96 | 0.27 | 0.04 |
| Final Energy Consumption | 0.96 | 0.10 | -0.23 |
| Total Primary Electricity consumption | -0.71 | 0.68 | -0.07 |
| Total Primary Energy Intensity | 0.98 | 0.01 | -0.16 |
| Final Energy Intensity | -0.84 | 0.53 | -0.11 |
| Loss in Transmission | -0.56 | -0.46 | -0.66 |
| Transformation Loss | -0.88 | 0.20 | 0.38 |
| Reserve Production Ratio of Oil | -0.82 | 0.16 | -0.41 |

| Indicators | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| Reserve Production Ratio of Gas | -0.76 | -0.56 | 0.17 |
| Household Electricity Consumption | 0.99 | 0.02 | -0.07 |
| Share of capacity of Renewable Energy per total Electricity Generation | 0.77 | 0.45 | 0.11 |
| Share of non-carbon energy per TPES | -0.86 | -0.46 | 0.10 |
| Share of renewable energy per FEC | 0.60 | -0.06 | 0.29 |
| Net Energy Import Dependency | 0.98 | 0.08 | 0.03 |
| Co2 Emissions per Capita | 0.98 | 0.03 | -0.15 |
| Co2 Emissions per GDP | -0.71 | 0.68 | -0.07 |
| Residential Energy Consumption | -0.17 | 0.97 | -0.01 |

Source: Estimation by the Author

After multiplying the weighting factors with initial variables values, yearly summation was taken where also some positive and negative values. To make all the values definite and easily comparable and comprehensive for the readers, and to keep the results between the ranges '0 to 10', some of the basic mathematical operations have to be done as both countries summated values were dividing by 25, then multiplied by five and then added 5. So, in response, the results obtained shown in Table 7.

In both the countries with some little bit ups and downs, the improvements are observable in energy security performance from 1990 to 2018. Energy security performance value close to '10 or 10' means an increase in energy security and close to '0 or 0' energy insecurity. From 1990 to 2003 (1993, 1994 and 1996 exclusive) relatively better energy security situation has observed in Pakistan than India; however, from 2004 to 2018, the situation reversed. Figure1 also represents an energy security performance trend in both countries.

**Table 7. Computation of Energy Security Performance Trends between Pakistan and India**

| Years | Pakistan's Energy Security Performance (PESP) | India's Energy Security Performance (IESP) | Conclusion |
|---|---|---|---|
| 1990 | 3.174 | 2.004 | PESP > IESP |
| 1991 | 3.520 | 2.363 | PESP > IESP |
| 1992 | 3.190 | 2.650 | PESP > IESP |
| 1993 | 2.997 | 3.158 | PESP < IESP |
| 1994 | 3.346 | 3.380 | PESP < IESP |
| 1995 | 3.657 | 3.244 | PESP > IESP |
| 1996 | 3.492 | 3.533 | PESP < IESP |
| 1997 | 3.958 | 2.981 | PESP > IESP |
| 1998 | 4.062 | 3.530 | PESP > IESP |
| 1999 | 3.785 | 3.370 | PESP > IESP |
| 2000 | 4.408 | 3.966 | PESP > IESP |
| 2001 | 4.881 | 4.074 | PESP > IESP |
| 2002 | 4.994 | 4.662 | PESP > IESP |
| 2003 | 5.053 | 4.995 | PESP > IESP |

| Years | Pakistan’s Energy Security Performance (PESP) | India’s Energy Security Performance (IESP) | Conclusion |
|---|---|---|---|
| 2004 | 4.906 | 5.216 | PESP < IESP |
| 2005 | 4.961 | 5.661 | PESP < IESP |
| 2006 | 5.667 | 5.842 | PESP < IESP |
| 2007 | 5.399 | 5.985 | PESP < IESP |
| 2008 | 5.232 | 6.253 | PESP < IESP |
| 2009 | 5.714 | 6.385 | PESP < IESP |
| 2010 | 6.012 | 6.673 | PESP < IESP |
| 2011 | 6.523 | 7.174 | PESP < IESP |
| 2012 | 7.275 | 7.490 | PESP < IESP |
| 2013 | 7.649 | 8.030 | PESP < IESP |
| 2014 | 7.668 | 7.884 | PESP < IESP |
| 2015 | 7.784 | 8.380 | PESP < IESP |
| 2016 | 8.326 | 9 | PESP < IESP |
| 2017 | 8.714 | 9.426 | PESP < IESP |
| 2018 | 8.755 | 9.426 | PESP < IESP |

Source: Estimation by the Author

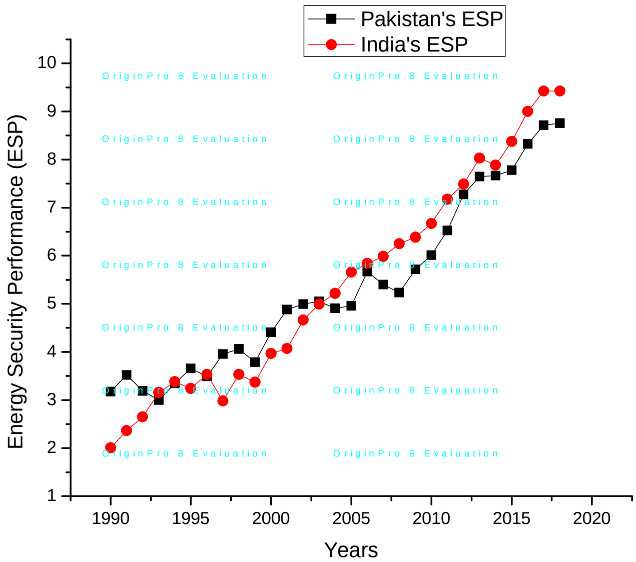


**Figure 1. Graphical representation of energy security performance in both countries**
Source: Author has drawn after AESPI estimation

**Conclusion**

Energy security is the main objective of any country’s energy policy to have economic efficiency as well as environmental safeguards. An important matter of concern regarding energy does not only need of high production of power but also an efficient use of the available energy is one of the most critical issues of interest now, especially in developing countries. Everything from enlightenment, to access to resources to strategy and cultural standards of particular places influences perception and understanding of energy security. Consumer advocates and users are likely to view energy security as rationally priced energy services with no distraction. Essential oil and gas producer countries focus on the steadiness of their access to new reserves, while electric utility companies emphasize the integrity of the electricity grid. Politicians dwell on protecting energy resources and infrastructure from terrorism and war. From a distinct vantage point, scientists, engineers, and entrepreneurs characterize energy security as a function of strong energy R&D, innovation, and technology-transfer systems.

This study is aimed at measuring the energy security performance of Pakistan and India, utilizing aggregated energy security performance indicators. In Pakistan, total primary energy supply, final energy consumption, household electricity consumption, and net energy import dependency, $Co_2$ emissions per capita and GDP, residential energy consumption, and Share of non-carbon energy per total primary energy consumption are strongly and positively correlated with energy security performance. However, overall direct energy intensity, total immediate electricity consumption, final energy intensity, and reserve production ratio of gas negatively and significantly affect energy security performance.

In India, final energy consumption, total primary energy intensity, household electricity consumption, the Share of capacity of renewable energy per entire electricity generation, the percentage of renewable energy per final energy consumption, net energy import dependency, and $Co_2$emissions per capita positively impact energy security performance. Still, total primary energy supply, total immediate electricity consumption, final energy intensity, transformation loss, reserve production ratio of oil, reserve production ratio of gas, $Co_2$emissions per GDP, and Share of non-carbon energy per total primary energy supply has considerable adverse effects on energy security performance. This study might be beneficial for policymakers in both countries to frame their better energy security performance policies.

**References**

Alam, A., Malik, I. A., Abdullah, A. Bin, Hassan, A., Faridullah, Awan, U., Ali, G., Zaman, K., & Naseem, I. (2015). Does financial development contribute to SAARC'S energy demand? From energy crisis to energy reforms. In *Renewable and Sustainable Energy Reviews* (Vol. 41, pp. 818–829). doi.org/10.1016/j.rser.2014.08.071

Alam, F., Saleque, K., Alam, Q., Mustary, I., Chowdhury, H., & Jazar, R. (2019). Dependence on energy in South Asia and the need for a regional solution. *Energy Procedia*, *160*, 26–33. doi.org/10.1016/j.egypro.2019.02.114

Ali, F., Huang, S., & Cheo, R. (2020). Climatic Impacts on Basic Human Needs in the United States of America: A Panel Data Analysis. *Sustainability,* 12(4), 1508. doi:10.3390/su12041508

Ali, F., Khan, K. A., & Raza, A. (2019). Determining the relationship between energy consumption and economic growth in Pakistan. *Ukrainian Journal of Ecology*, *9*(3), 322–328. doi.org/10.15421/2019_98

Boltzmann, L. (1886). The Second Law of Thermodynamics (excerpt) *. *Theoretical Physics and Philosophical Problems*, 13–32.

BP Statistical. (2017). Review of World Energy. *Review of World Energy*. doi.org/10.1021/acs.joc.5b02605

Brown, M. A., Wang, Y., Sovacool, B. K., & D'Agostino, A. L. (2014). Forty years of energy security trends: A comparative assessment of 22 industrialized countries. *Energy Research and Social Science*, *4*(C), 64–77. doi.org/10.1016/j.erss.2014.08.008

Costantini, V., Gracceva, F., Markandya, A., & Vicini, G. (2007). Security of energy supply:

Comparing scenarios from a European perspective. *Energy Policy*, *35*(1), 210–226. doi.org/10.1016/j.enpol.2005.11.002

Doukas, H., Papadopoulou, A., Savvakis, N., Tsoutsos, T., & Psarras, J. (2012). Assessing the energy sustainability of rural communities using Principal Component Analysis. In *Renewable and Sustainable Energy Reviews* (Vol. 16, Issue 4, pp. 1949–1957). doi.org/10.1016/j.rser.2012.01.018

Farhan, A., & Hassan, M. (2018). Socioeconomic Impacts of Climate Extremes on American's Poverty-Related Human Needs (A New Approach by Nonprofits). *Journal of international business research and marketing*, *4*(1), 41–54. doi.org/10.18775/jibrm.1849-8558.2015.41.3005

Gupta, E. (2008). Oil vulnerability index of oil-importing countries. *Energy Policy*, *36*(3), 1195–1211. doi.org/10.1016/j.enpol.2007.11.011

Hasnat, G. N. T., Kabir, M. A., & Hossain, M. A. (2019). Major Environmental Issues and Problems of South Asia, Particularly Bangladesh. In *Handbook of Environmental Materials Management* (pp. 109–148). doi.org/10.1007/978-3-319-73645-7_7

International Energy Agency. (2015). World Energy Outlook 2015 Factsheet. *Global Energy Trends to 2040:The Energy Sector and Climate Change in the Run-up to COP21*, 1–4. doi.org/10.1787/20725302

Khalid, I., & Mukhtar, A. (2016). Energy Crisis: An Issue of Good Governance, A Way Forward. *Journal of Political Studies*, *23*(1), 101.

Krishnan, V. (2016). Constructing a multidimensional socioeconomic index and the validation of it with early child developmental outcomes. In *Emerging Trends in the Development and Application of Composite Indicators* (pp. 163–199). doi.org/10.4018/978-1-5225-0714-7.ch008

Löschel, A., Moslener, U., & Rübbelke, D. T. G. (2010). Indicators of energy security in industrialised countries. *Energy Policy*, *38*(4), 1665–1671. doi.org/10.1016/j.enpol.2009.03.061

Martchamadol, J., & Kumar, S. (2013). An aggregated energy security performance indicator. *Applied Energy*, *103*, 653–670. doi.org/10.1016/j.apenergy.2012.10.027

Martchamadol, J., & Kumar, S. (2014). The Aggregated Energy Security Performance Indicator (AESPI) at the national and provincial levels. *Applied Energy*, *127*, 219–238. doi.org/10.1016/j.apenergy.2014.04.045

Matsumoto, K., & Shiraki, H. (2018). Energy security performance in Japan under different socioeconomic and energy conditionsfile:///C:/Users/Mohram/Downloads/1-s2.0-0301421586900893-main.pdf. *Renewable and Sustainable Energy Reviews*, *90*(April), 391–401. doi.org/10.1016/j.rser.2018.03.070

Palit, D. (2013). Solar energy programs for rural electrification: Experiences and lessons from South Asia. *Energy for Sustainable Development*, *17*(3), 270–279. doi.org/10.1016/j.esd.2013.01.002

Rasul, G. (2016). Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. *Environmental Development*, *18*, 14–25. doi.org/10.1016/j.envdev.2015.12.001

Rathore, P. K. S., Chauhan, D. S., & Singh, R. P. (2019). Decentralized solar rooftop photovoltaic in India: On the path of sustainable energy security. *Renewable Energy*, *131*, 297–307. doi.org/10.1016/j.renene.2018.07.049

Safeer, R., & Fatima, N. (2019). Energy Scenario and Diversity in Pakistan: An Energy Security Perspective. *Advances in Energy and Power*, *6*(1), 1–11. doi.org/10.13189/aep.2019.060101

Shaffer, B. (2010). Energy politics. In *Energy Politics*. doi.org/10.1088/2058-7058/25/07/29

Shah, S. A. A., Valasai, G. Das, Memon, A. A., Laghari, A. N., Jalbani, N. B., & Strait, J. L. (2018). Techno-economic analysis of solar PV electricity supply to rural areas of Balochistan, Pakistan. *Energies*, *11*(7). doi.org/10.3390/en11071777

Singh, A., Jamasb, T., Nepal, R., & Toman, M. (2018). Electricity cooperation in South Asia: Barriers to cross-border trade. *Energy Policy*, *120*, 741–748. doi.org/10.1016/j.enpol.2017.12.048

Soliman, J. L., Lopez, N. S. A., & Biona, J. B. M. M. (2019). Assessing the sustainability of long-term energy supply using desirability functions. *Energy Procedia*, *158*, 3723–3728. doi.org/10.1016/j.egypro.2019.01.885

Sovacool, B. K. (2013). Assessing energy security performance in the Asia Pacific, 1990-2010. In *Renewable and Sustainable Energy Reviews* (Vol. 17, pp. 228–247). doi.org/10.1016/j.rser.2012.09.031

Sovacool, B. K., & Brown, M. A. (2010). Competing Dimensions of Energy Security: An International Perspective. *Annual Review of Environment and Resources*, *35*(1), 77–108. doi.org/10.1146/annurev-environ-042509-143035

Sovacool, B. K., Mukherjee, I., Drupady, I. M., & D’Agostino, A. L. (2011). Evaluating energy security performance from 1990 to 2010 for eighteen countries. *Energy*, *36*(10), 5846–5853. doi.org/10.1016/j.energy.2011.08.040

**Appendix**

**Table A1. Ellipsis & Variables used in AESPI Construction**

| **No.** | **Indicators** | **Description of Indicators and (Source of Data)** | **Mathematical Description** | **Unit** | **Indicator Type** | **Impact** |
|---|---|---|---|---|---|---|
| 1. | TPES | Total Primary Energy Supply. (International Energy Agency, IEA) | TPES/Capita | Kgoe/capita | Economic | ↓ |
| 2. | FEC | Final Energy Consumption. (International Energy Agency, IEA) | FEC/Capita | Kgoe/capita | Economic | ↓ |
| 3. | TEC | Total Electricity Consumption. (International Energy Agency, IEA) | TEC/Capita | Kgoe/capita | Economic | ↓ |
| 4. | TPEI | Total Primary Energy Intensity. (International Energy Agency, IEA) | TPES/GDP | Kgoe/at current constant US$ | Economic | ↓ |
| 5. | FEI | Final Energy Intensity. (International Energy Agency, IEA) | TFEC/GDP | Kgoe/at constant US$ | Economic | ↓ |
| 6. | Transmission Loss | Loss in Transmission. (International Energy Agency, IEA) | | % | Economic | ↓ |
| 7. | Transformation Loss | Loss in Transformation. (International Energy Agency, IEA) | 1-((FEC/TPES))*100 | % | Economic | ↓ |
| 8. | RPR Crude Oil | Reserve Production Ratio of Crude Oil. (International Energy Agency, IEA) | Crude Oil Proven Reserves/Domestic Crude oil Extraction | Years | Economic | ↑ |
| 9. | RPR Natural Gas | Reserve Production Ratio of Natural Gas. (International Energy Agency, IEA) | Natural Gas Proven Reserves/Domestic Natural Gas Production | Years | Economic | ↑ |
| 10. | RPR Coal | Reserve Production Ratio of Coal. (International Energy Agency, IEA) | Coal Proven Reserves/Domestic Coal Production | Years | Economic | ↑ |
| 11. | IEI | Industrial Energy Intensity. (Economic Surveys) | Industrial Energy Consumption / Industrial GDP. | Kgoe/at constant US$ | Economic | ↓ |

| No. | Indicators | Description of Indicators and (Source of Data) | Mathematical Description | Unit | Indicator Type | Impact |
|---|---|---|---|---|---|---|
| 12. | AEI | Agriculture Energy Intensity. (Economic Surveys) | Agriculture Energy Consumption/ Agriculture GDP. | Kgoe/at constant US$ | Economic | ↓ |
| 13. | CEI | Commercial Energy Intensity. (Economic Surveys) | Commercial Energy Consumption/ Commercial GDP. | Kgoe/at constant US$ | Economic | ↓ |
| 14. | HHEC | Household Energy Consumption. (Economic Surveys) | Household Energy Consumption Per Capita. | Kgoe/capita | Economic | ↓ |
| 15. | HHEC | Household Electricity Consumption. (Economic Surveys) | Household Electricity Consumption Per Capita. | KWh/Capita | Economic | ↓ |
| 16. | TEI | Transport Energy Intensity. (Economic Survey of Pakistan) | Transport Energy Consumption/ Transport GDP | Kgoe/at constant US$ | Economic | ↓ |
| 17. | Share | Share of Capacity of Renewable Energy per Total Electricity Generation. (International Energy Agency, IEA & Economic Survey) | | | Economic | ↑ |
| 18. | Share | Share of non-carbon Energy per TPES. (International Energy Agency, IEA) | | | Economic | ↑ |
| 19. | Share | Share of Renewable Energy per FEC. (International Energy Agency, IEA) | | | Economic | ↑ |
| 20. | NEID | Net Energy Import Dependency. (World Development Indicators, WDI) | | | Economic | ↓ |
| 21. | $Co_2$ Emissions | $Co_2$ Emissions (International Energy Agency, IEA) | $Co_2$ Emissions per capita. | | Environmental | ↓ |
| 22. | $Co_2$ Emissions | $Co_2$ Emissions (International Energy Agency, IEA) | $Co_2$ Emissions per GDP. | | Environmental | ↓ |
| 23. | HHAE | Household Access to Electricity. (N/A) | | | Social | ↑ |

| No. | Indicators | Description of Indicators and (Source of Data) | Mathematical Description | Unit | Indicator Type | Impact |
|---|---|---|---|---|---|---|
| 24. | Share | Share of Income Spent on Electricity. (IEA & HDIP) | Electricity Expenses * Prices | | Social | ↓ |
| 25. | RE | Residential Energy Consumption (World Development Indicators, WDI) | Residential Energy Consumption per Household. | | Social | ↓ |

Source: (Jutamanee and Kumar, 2013)

Referring to the above Table A1, In the present study for both countries, due to the unavailability of eight variables data for India, we just use 17 out of 25 indicators. Unavailable data indicators are (Variable # 10, 11, 12, 13, 14, 16, 23 & 24).

Downward arrow symbol (↓**)** indicates a negative impact, i.e., low value means energy security improvement & vice versa. In contrast, an upward arrow symbol (↑**)** Indicates a positive effect, i.e., high value means energy security improvement & vice versa.

AESPI recommends using Kilograms oil equivalent at the base year 2000 US$, but in this study, the current year chosen as the base year.

'N/A' (Data Not Available)

'HDIP' (Hydrocarbon Development Institute of Pakistan)