A Model for Strategizing Energy Security Dimensions and Indicators Selection for Pakistan

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Received: 20.03.2020 Accepted:09.04.2020

Abstract-Energy security is a complex field of research and has multitude of dimensions. There are five dimensions commonly utilized by researchers which are namely Availability, Affordability, Technology & Efficiency, Governance & Regulation and Environment & Sustainability. Upon synthesizing with energy sector policies, these five dimensions are also applicable in case of Pakistan. To quantify these dimensions there were 60 indicators are being selected from the last five-year studies and then through the Discrimination analysis, there 39 indicators are finalized for Pakistan. The availability dimension has 13, affordability has 10, technology & efficiency has 6, governance & regulation has all the 7 and environment and sustainability has 3 indicators to be utilized for further analysis. The selected indicators are robust as they are based on past data and has the major variations during the studied period. Hence, these indicators could be utilized for energy security recommendations in future policy scenarios for Pakistan.

Keywords: energy security, dimensions, indicators, coefficient of variance, discrimination analysis

1. Introduction

The energy is critical to all aspects of our lives from the food to clothing, to the cars, trains, airplanes, to the houses and building, lighting, cooling and heating. Energy security is a value that is highly prized by the states, societies and individuals. Introduction

Historically, energy security has evolved and still evolving and transforming due world's energy usage. This transformation presented the dominance. The dominance of non-renewable fossil fuels with their liberalization in various regions and markets, the development of nuclear, wind, solar and other form of energy, and the mounting energy demands in various nations across the world especially in developing nations coupled with political instability and large-scale natural events [1].

In literature, it is distinguished that any dimension which has an association with energy security, should be addressed. The explanation is that the energy security discourse must be extended to incorporate more dimensions or components as challenges are heterogeneous [2,3]. And because of this, the degree of significance differs regarding any dimension linking to energy security. Subsequently, there is a great deal of evidences in which researchers attempted to give a numerical value to energy security measurements so as to make a general assessment against risks or threats [2].

Sovacool (2011) saw Vivoda's idea of energy security as insufficient. He likewise found that, now and again, the

indicators conflate with dimensions. To fill this gap in energy security dimensions, another study by Sovacool and Mukherjee (2011) was brought in. In this, authors provided the depth in to the energy security concept via conducting an extensive review of the academic literature, semi- structured research interviews, a survey instrument, and a workshop with global energy security experts. The authors reviewed more than 90 peer-reviewed articles published on the topic of energy security. Afterwards, they conducted 68 semi-structured research interviews with senior energy security experts employed in International Energy Agency (IEA), U.S. Department of Energy, United Nations Environment Program, Energy Information Administration (IEA), World Bank Group, Nuclear Energy Agency, and International Atomic Energy Agency. Participants were selected based on civil society members, academicians, government officials, and private sector managers. Lastly, the authors organized a 3-day workshop which was attended by participants from 17 countries to discuss this multitude concept of energy security [4].

Based on this extensive research and effort, authors identified that energy security is composed of five dimensions. 1) Availability, 2) Affordability, 3) Environmental Sustainability, 4) Technology Development and Efficiency, and 5) Regulation and Governance. These dimensions have also been utilized by other studies such as Zhang et al. (2017), Erahman et al. (2016),Sharifuddin (2016), Brown et al. (2014), Ren & Sovacool (2014) and Sovacool (2013) [5-10].

It is recognized, based on literature review, that energy security dimensions need to be synthesized and then through the use of the indicators, the energy security performance of country is measured. In case of Pakistan, the gap analysis is conducted for last 10 years, as a result 60 studies were synthesized against energy security dimension, energy security indicators and energy security performance [11-69]. Up on synthesizing those studies, no such study covered all these aspects altogether for policy making and hence, the concept of energy security dimension and indicator selection is lacking in case of Pakistan. The aim of this study to strategize the energy security dimensions followed by selection of indicators via statistical method for energy sector of Pakistan based on data between the years 1991 -2018.

2. Energy Security Dimensions for Pakistan

Now, to assess and justify energy security dimensions, an *energy security dimension instrument with its methodology* is established as a means with which energy security dimensions to assess and justified. The detailed discussion is presented in next section.

2.1. Methodology

In an instrument, the methodology chosen to evaluate energy policies of Pakistan is Qualitative Content Analysis (QCA). QCA can assess a variety of social phenomena, and in the past has been used to assess economic growth, education, nursing research and aesthetics, among others, suggesting its applicability to the investigation of energy policies [70]. Furthermore, QCA allows for an organized, systematic analysis of text in order to reveal common elements, themes and patterns [70,71]. A visual representation of the QCA process flow for this study is shown in Figure 1.

Earlier it was stated, *energy security dimension instrument* is being established as a means for energy security dimensions to assess and justify. In this instrument, the five dimensions along with their themes being synthesized with current energy sector policies of Pakistan as shown in Table 1 and Table 2. The definitions of dimensions along with underlying explanation of each theme in particular dimension is coded. The objectives and goals of each energy sector policy is also coded and then on the basis of those codes, matching and mapping being done in an instrument. The score is given to a corresponding theme of each dimensions based on coding and matching as shown in Table 1. The purpose of providing the score is to finalize the dimensions.

Figure 1. Framework for Energy Security Dimension for Pakistan

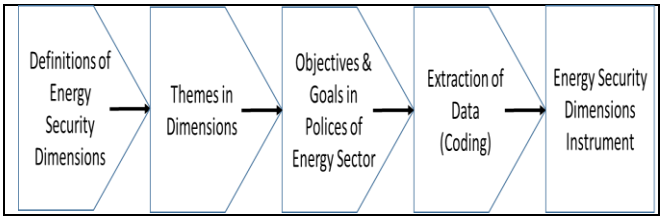

Table 1. Dimensions and Themes with their basic meanings.

Source: [4,6,8,72].

Themes	Dimension	**Explanation**
Security of Supply	Availability (AV)	Being energy independent, producing domestically available fuels and energy resources, self-sufficiency, resource availability,
Security of Supply & Production		
Production		
Dependency		

Diversification		security of supply, independence, imports, variety, balance, disparity.
Price Stability Access Equity Access & Equity Affordability	Affordability (AF)	Having predictable prices for energy fuels and services, producing energy services at the lowest cost, cost stability, predictability, equity, justice, reducing energy poverty.
Innovation and Research Safety and Reliability Resilience Efficiency and Energy Intensity	Technology & Efficiency (TE)	Researching and developing new and innovative energy technologies, capacity to adapt and respond to the challenges induced by climate change or disruptions in supply, producing energy in the most efficient manner possible, investment, employment, technology development and diffusion, energy efficiency, stockholding, safety and quality.
Land Use Water Climate Change Pollution Greenhouse Gas Emissions	Environment & Sustainability (ES)	Stewardship, aesthetics, natural habitat conservation, water quality and availability, human health, climate change mitigation, climate change adaptation, mitigating greenhouse gas emissions associated with climate change, minimizing destruction of forests and degradation of land, possessing sufficient quantities of water, minimizing ambient and indoor levels of air pollution.
Governance Trade and Regional Interconnectivity Competition and Markets Knowledge and Access to Information Decentralization Investment Literacy	Governance & Regulation (GR)	Having stable, transparent, and participatory modes of energy policymaking and permitting, Promoting the trade of energy technologies and fuels, Transparency, accountability, legitimacy, integrity, stability, resource curse, geopolitics, free trade, competition, profitability, interconnectedness, security of demand, exports, Making proper investments in infrastructure and maintenance, social and community knowledge and education about energy issues, promoting a diversified and decentralized collection of different energy technologies.

Table 2. Instrument to synthesize energy security dimensions for Pakistan.

Source: [4,6,8,72-80].

Dimension	E&P	NPP	NGP	NCCP	REP	ESP	UNSDG	Themes	Score
Availability	✓	✓	✓			✓		1	4
		✓					✓	2	2
	✓	✓			✓	✓		3	3
		✓						4	1
		✓		✓	✓	✓		5	2
Affordability	✓				✓			6	2
	✓				✓		✓	7	3
				✓	✓			8	2
		✓		✓	✓		✓	9	3
	✓	✓	✓				✓	10	4
Tech & Eff.							✓	11	1
		✓	✓		✓			12	3
					✓		✓	13	1
		✓	✓		✓		✓	14	4
Env & Sus	✓							15	1
	✓							16	1
		✓		✓	✓		✓	17	4
		✓		✓	✓		✓	18	4
	✓			✓				19	2
Govern. & Regul.	✓	✓				✓	✓	20	4
	✓					✓		21	2
	✓					✓		22	2
		✓						23	1
					✓			24	1
	✓	✓	✓				✓	25	4
		✓		✓			✓	26	3

1= security of supply, 2= security of supply & production, 3= Production, 4= Dependency, 5= Diversification, 6= Price stability, 7= Access, 8=Equity, 9= Access & Equity, 10= Affordability, 11= Innovation & research, 12= Safety & reliability, 13= Resilience, 14= Efficiency & energy intensity, 15= Land use, 16= Water, 17= Climate change, 18= Pollution, 19= Greenhouse gas emissions, 20= Governance, 21= Trade & regional connectivity, 22= Competition & Market, 23= Knowledge & access to information, 24= Decentralization, 25= Investment, 26= Literacy

From the Table 2, no policy has scored zero in any theme. There is maximum score of four in an instrument. The criteria to reject any dimension is to score zero which in case of Pakistan is not applicable since there is no score of zero. The acceptance of any dimension is to score of 50 percent in any of the theme in relevant dimension. Since, there are seven polices synthesized therefore score of 3.5 is needed for dimension to qualify. Other than this, dimension is also be qualified if any of the theme in that particular dimension scored four.

On the basis of an instrument and its analysis, all of the five dimensions are applicable in case of Pakistan's energy sector. The availability means sufficient supplies of energy which is appeared to be the important factor and highly emphasized in policies especially in power policy 2013 and E&P policy 2012. The affordability means producing energy at lowest cost which appeared to be the priority for energy sector polices. The power policy 2013 and generation policy 2015 highly stressed this dimension to ensure economic development. Efficiencies and distribution losses of power sector have always been an issue and Power policy 2013 and E&P policy 2012 have had goals for efficient technology input through private sector partnership. The technology dimension ensures reliable energy services to the citizen which these two policies are aiming in longer terms. Currently environmental dimension is missing in power policy 2013 but this dimension was taken care in the Renewable energy policy 2006 and SDG's by United Nations. These policies developed to ensure access to modern energy services in a manner that is not harmful to the environment. Even this side also being covered in E&P policy 2012 to ensure production and exploration to keep safeguard of eco system. Lastly, governance dimension is also come under high scrutiny as circular debt is another major problem which is caused due to miss- management and governance issues in ministries.

Now next is the quantification of those dimensions which is based on the indicators. The fundamental challenge here is that there is no standard list of indicators available for energy security assessment [4,6,7,81-83]. The discussion on indicators selection is covered in next section as followed.

3. Energy Security Indicators

This research is emphasizing that the energy security is a complex field of research and include many strands [84-86]. The first strand is definition of energy security and its dimension which is being discussed in previous sections Now the second strand is for energy security assessment. For assessing the energy security, different indicators are used to assess the energy security. These indicators are called ***energy security indicators***. Energy security indicators in a form of index to measure energy security or risk of a country has become popular in recent times. Energy security assessment using single indicator is difficult rather a basket of indicators are used in specific dimensions for the assessment [4,6,7,81-84].

It is established that indicators are prerequisite for an assessment of energy security. These indicators facilitate the assessment of national policies and performance regarding energy security [85-89]. Further, the literature has emphasized that an indicator-based approach is elegant, as it avoids the complexity. Not only this, they also help identify "trade-offs" in different dimensions and recognize areas of improvement clearly [84,85]. In following section, the selection of indicators is discussed in detail and it will facilitate our understanding regarding energy security assessment in case of Pakistan.

3.1. Energy Security Indicators Applicable for Pakistan

As discussed, many indicators are available for assessment and there is no standard list of indicators for energy security assessment has created creating a paradox [4,6,7,81-83]. Therefore, to simplify, this study has compiled the list of indicators in those five dimensions (above) utilized in various studies between the years 2012 to 2019 as shown in appendix A. This list will serve the starting point for energy security assessment in case of Pakistan.

For these indicators, the estimations are finalized between the years 1991 to 2018. On the basis of these estimation, the omission of indicators would be carried out as discussed in following section.

4. Indicator Selection for Pakistan

From these 60 indicators, omission of indicators is required due to the following reasons.

- **Must not be in large number:** Large numbers of indicators are difficult to use effectively [90]. Hence, to evaluate, a reasonable number of indicators for energy security are to be identified to ensure a holistic approach for energy security assessment in case of Pakistan. Moreover, if few indicators were selected than the index would become too sensitive to an indicator and even a slight change in any indicator would present a bigger drift in index. In case if too many indicators are selected, there could be a chance that a significant change might get neglected to become a priority concern for policy makers [4,8,72,91-95].
- **Must avoid Double Counting:** The indicators may contain similar information. Due to this, the indicators would be overlapped and double counted and may cause

huge drift in an index [96-99]. This reflects that the indicators with similar information need to be avoided.

- **Must provide Integration:** An indicator-based index should present a holistic and integrated view. It should also be capable of presenting the past energy performance but also represents the current and future energy security performances [100-110].

In view of the above, the number of indicators is to be decreased. The bring robustness in indicator omission process, this study has set the omission criterion based on statistical technique called "Discrimination Analysis" which is discussed in following section.

4.1. Discrimination Analysis

In this criterion, the omission of indicators is done with the coefficient of variance whose equation is

$$Cof\,Var = S_i / \overline{X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

S_i - Standard Deviation of each Indicator, $\overline{X}$ – Mean of indicator.

For estimation of standard deviation (S_i) and Mean ($\overline{X}$), the statistical tool SPSS version 21 is utilized. The calculations for coefficient of variance is presented in Table 4. This step is also called *discrimination analysis.* The dropping the indicators is done with the values less the 0.12 [111]. The coefficient of variance refers to an ability to distinguish the feature differences of the indicator evaluated. If an indicator has the similar values across the years, it means coefficient of variance is going to be too weak. Therefore, that particular indicator can be dropped for further analysis as shown in Table 3. In this step there are twenty-one (21) indicators have value less than 0.12 and hence they will be dropped. As a result of this process, there are thirty-nine (39) indicators available for index formulation as shown in Table 4.

Table 3. Indicators with the values of Coefficient of Variance (CofVar).

Ind	Mean	Std Dev	CofVar	Ind	Mean	Std Dev	CofVar	ind	Mean	Std Dev	CofVar
AV1	1.6	0.2	0.1	**AF1**	47.1	21.7	0.46	**TE6**	2.5	2.5	1.0
AV2	31.5	1.5	0.05	**AF2**	354.	20.7	0.06	**TE7**	14.5	8.6	0.5
AV3	70.9	0.7	0.01	**AF3**	1.06	0.6	0.6	**TE8**	61.3	2.6	0.04
AV4	13.6	6.07	0.4	**AF4**	1.05	0.7	0.7	**TE9**	35.1	3.7	0.1
AV5	13.2	2.7	0.2	**AF5**	24.0	3.8	0.1	**TE10**	7.04	0.7	0.1
AV6	13.3	8.03	0.6	**AF6**	20.6	1.96	0.1	**TE11**	40.7	13.8	0.3
AV7	397.4	68.7	0.1	**AF7**	38.9	6.2	0.1	**GR1**	4.9	1.6	0.3
AV8	243.8	49.7	0.2	**AF8**	68.6	3.8	0.06	**GR2**	147.	66.0	0.4
AV9	5.9	1.3	0.2	**AF9**	81.8	6.15	0.08	**GR3**	31.7	7.3	0.2
AV10	1.3	0.1	0.1	**AF10**	8.7	1.5	0.1	**GR4**	0.7	0.2	0.2
AV11	77.3	14.8	0.1	**AF11**	3.00	3.3	1.1	**GR5**	12.3	4.01	0.3
AV12	16.1	0.7	0.05	**AF12**	1079	208.	0.1	**GR6**	9.5	2.1	0.2

Table 4. List of Indicators selected in each dimension through Discrimination Analysis

AV1	AV4	AV5	AV6	AV7	AV8	AV9	AV11
AV13	AV14	AV15	AV16	AV18	AF1	AF3	AF4
AF5	AF7	AF10	AF11	AF12	AF14	AF5	TE1
TE2	TE5	TE6	TE7	TE11	GR1	GR2	GR3
GR4	GR5	GR6	GR7	ES2	ES5	ES6	

AV = Availability, AF = Affordability, TE= Technology & Efficiency, GR= Governance & Regulation, ES= Environment & Sustainability

5. Discussion & Recommendations

In availability dimension "transport consumption/FEC" (AV2) is omitted instead transport consumption/ capita (AV11) is selected as AV11 has more variations between the studied time period. The "access to energy" (AV3) and "access without electricity" (AV19) are not selected as no significant change reflected in accessibility to energy is reported between the studied period. The Reserve to production ratios in oil and gas (AV5 & AV6) are selected which are considered to be most critical in case of Pakistan as oil production is low and gas reserved have been depleted very fast between 1991 and 2018. Noticeably, the "R/P ratio oil & gas" (AV4) is the aggregated indicator of AV5 and AV6 also being selected, here, in this case researcher has an option either utilized AV4 only or instead utilized AV5 and AV6 separately. The discrimination analysis in this case revealing that AV6 has more significance for which policy makers need to look in to for future scenario in Pakistan. Renewable indicator (AV9) also reported to be significant for Pakistan

whereas diversity index is omitted as it does not have significant variations to be considered by policy makers.

In affordability dimension imports has more significant as "import dependency (NEID)" (AF1), "imported oil consumption" (AF14), "imported gas consumption" (AF15) and "energy imports/ TPES" (AF5) are selected. For Pakistan, import bill is huge burden for economy as almost all of the foreign reserves get exhausted which creates turmoil for economy. One such occasion was encountered in the year 2015, when Pakistan had settled $15 billion and nearly all of the foreign reserves were exhausted due to energy imports [112]. In intensity domain, the "transport and industrial intensity" (AF8 & AF9) have not registered variations instead "commercial and agriculture intensity" (AF10 &AF11) have more variations during the studied period. As Pakistan is an agricultural state, the discrimination analysis is revealing that AF11 had played a significant role in energy security in the past.

In technology and efficiency dimension, the "transmission and distribution losses" (TE1) played critical role during studied period. In Pakistan, once these losses were 25 % which through government strict policies levelized to 17% in the 2016 [113]. Still much more work need to be done in this regard acceptable range for this is about 5% to 6% [114]. Efficiency of power is another domain which Pakistan government had been criticized. In the year 1992, the efficiency was 68% which onwards improved to 79% in the 2002, however government failed to maintain this level as a result the efficiency reduced to the level of 52% in the year 2018 (See Appendix). Hence, "TPES-FEC/FEC"(TE2) needs to be included in policy making for future scenario in Pakistan. "Access to clean fuel" (TE11) is 63% (See Appendix) is another indicator which needs to be included for future policy making as signified by discrimination analysis.

The governance and regulation is the only dimension where no indicator is omitted by discrimination analysis. This is revealing that "corruption ranking "(GR2), "governance index" (GR3), "oil stock" (GR4, GR5 & GR6) and "resilience" of the energy system (GR7) across Pakistan, all has a critical role in improving the energy security of a country in future policy scenarios.

In environment and sustainable dimension, the analysis is pointing out that "CO_2 and SO_2 emissions" (ES2 & ES5) are important and "intensity of CO_2" (ES7) must be included in energy policies. Currently, the integrated view of policy making is realized to ensure improvements in energy security in Pakistan [115].

In summary, the discrimination analysis is pointing out that the all of the five dimensions are required with different sets of indicators to ensure energy security for Pakistan. Additionally, an integrated view is required in policy framing as it is observed that in the past the energy security is hampered. In Pakistan, policy making is fragmented as there are number of institutions and ministries are involved, however, this research is emphasizing that the concept of energy security can improvised energy security of Pakistan through an indicator-based approach as they reveal priority areas to be worked on for policy framing.

Along with energy security, the reliability of the infrastructure related to energy supply chain, especially in electricity transmission network, also needed to be considered on longer basis. As per ministry of finance congestion, inefficiency and lack of infrastructure on the transmission and distribution side of the supply chain had hampered sustained delivery of electricity and energy services. However, Pakistan has successfully removed bottlenecks on the generation side of electricity during previous government [113]. Further, all Distribution Companies (DISCO's) will continue executing Power Distribution Enhancement projects in different phases for increase in power distribution capacity for up to 27913 MVA (Mega Volt Ampere) [115].

In addition to this, Pakistan opted an aggressive capacity addition which are now a fundamental part of energy forecast mechanisms of near- and medium-term future. Contextualizing the aggressive capacity additions of previous governments will help us guide our way forward in addressing the capacity payment issues of near to medium term future. Moreover, an integrated energy plan, which details the demand projections from power as well as petroleum divisions also being employed that will help in foreseeing the evolving energy mix as well as keeping the focus on indigenous resources. Also, Pakistan is aiming to provide sustainable energy for all and off grid solutions to masses under the new renewable energy policy [113, 115].

6. Conclusion

The study presented that energy security has a key role to play in improving the energy situation of Pakistan. As, Pakistan energy requirements are increasing rapidly, so the focus should be to ensure availability and security of sustainable supply and delivering the energy services along with the development of natural resources. For future, on following, the energy strategy should be focused for energy sector of Pakistan.

- Expansion in the capacity to deliver energy and required supporting expansion in the transmission infrastructure for evacuation of the power.

- In future, ensuring energy security with affordability and universal access, based on indigenous resources should be aimed as Pakistan is blessed with enormous hydro and coal potential.
- The government must encourage local and foreign investment in the generation, transmission and distribution supply chains of the delivery of service to fuel the economy [100].
- The single national power tariff should be disallowed and de-centralized to the multiple power distribution & marketing companies (DISCOs) to reflect the true power costs in different parts of the country [90].
- Hydel and nuclear power generation to remain a state responsibility, and their tariffs to be adjusted to provide funds for building new capacity [85].
- Capability of local refineries be enhanced through time-bound fiscal support to enable them to produce better-quality fuels.
- All energy sector functions of the government must be consolidated under a single Ministry of Energy to facilitate long-term energy sector investments and also a single energy regulatory Authority must be created to manage the proposed de-regulation of the energy market in Pakistan [33].
- The Government of Pakistan (GoP) must focus on exploiting the abundant potential of wind and solar resources for power generation whilst keeping in view the best possible mode for benefiting with declining prices of renewable energy.

Summarizing, the Availability, Affordability, Technology, Governance and Environment dimensions are applicable and must be strategized for energy sector of Pakistan. In view of that, a method for selecting the indicators in those dimensions are also presented for further assessment to develop enhanced energy security policy in future. Nevertheless, this study has involved selection methodology based on the statistical technique to provide the robustness in the results and hope that future research would help in policy recommendations through further analysis of those presented dimensions and indicators.

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Appendix

Availability	Electricity/Capita (KWh/Capita)	AV1	Technology & Efficiency	T&D Losses (%)	TE1
	Transport consumption /FEC	AV2		TPES-FEC/FEC	TE2
	Access to Energy (%)	AV3		Electricity	TE3
	R/P Ratio (Years)	AV4		Demand Met	TE4
	R/P Oil	AV5		Oil & Well	TE5
	R/P Gas	AV6		Renewable	TE6
	TPES/Capita (Kgoe/Capita)	AV7		Nuclear	TE7
	FEC/Capita (Kgoe/Capita)	AV8		Self Sufficiency	TE8
	Renewable Share/FEC (%)	AV9		RE Share	TE9
	SWI	AV10		Non-Carbon Fuel	TE10
	Transport Consumption/Capita	AV11		Access to Clean	TE11
	Electricity Consumed/FEC (%)	AV12	Governance & Regulation	Losses/TPES (%)	GR1
	Household Energy/Capita	AV13		Corruption	GR2
	Residential Energy/Household	AV14		Governance	GR3
	Electricity/Household	AV15		Oil Rent (% of	GR4
	Renewable Potential	AV16		Oil Stock/ Oil	GR5
	Indigenous/TPES (%)	AV17		Oil Stock (% of	GR6
	Oil Use In Transport % of Oil	AV18		Resilience (Net	GR7
	Access w/o EElectricity (%)	AV19	Environement & Sustainability	CO2/TPES	ES1
	Share of Non- Carbon	AV20		CO2/Capita	ES2
Affordability	NEID	AF1		CO2/Electricity	ES3
	TPES/GDP (1000Kgoe/$)	AF2		CO2/Houshold	ES4
	Gasoline Price/Litre	AF3		SO2/Capita	ES5
	Diesel Price (2010$/Litre)	AF4		Forest Area/Land	ES6
	Energy Imports/TPES (%)	AF5		CO2/GDP (Kg/$)	ES7
	NEIR (%)	AF6			
	Energy Imports/FEC (%)	AF7			
	Transport Intensity	AF8			
	Industrial Intensity	AF9			
	Commercial Intensity	AF10			
	Agricultural Intensity	AF11			
	$GDP/Capita (2010)	AF12			
	% of Income towards energy	AF13			
	Imported Oil Consumption (%)	AF14			
	Imported Gas Consumption (%)	AF15			