ENERGY SECURITY INDEX OF ALGERIA: AN INTEGRATED APPROACH

Hicham **BENAMIROUCHE**[*]
Amel **MEGHERBI**[**]
Nour El Islem **DJEDAA**[***]
Ratiba **BOUFERKAS**[****]

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Corresponding authors: hbenamirouche@yahoo.fr

SUMMARY

Energy security is considered as one of the most important challenge for world countries, given that it represents one of the main pillars of sovereignty. This study aims to evaluate and analyse the energy security performance of Algeria over the period 1980-2020 through the development of a composite index, named ESIA, on the basis of five dimensions; Availability, Affordability, Applicability, Acceptability and Governance. The results show that energy security presents a moderate performance, with score range of (5.29-7.51). The highest performance is showed during the sub-period 2005-2020. The availability, affordability and applicability indicators are the main drivers of this performance, respectively. While, the acceptability indicators play a little positive effect, and the proactive nature of energy sector governance is still considered as challenging for Algeria. Five important policy implications were identified in order to improve the energy security of the country.

KEY WORDS

Energy Security; Performance Indicators; Factoral Analysis, ESIA; Algeria.

JEL CLASSIFICATION: C38, C43, Q41, Q48

(*) (**) (***) (****) Centre de Recherche en Economie Appliquée pour le Développement, CREAD, Algiers.

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RÉSUMÉ

La sécurité énergétique est considérée comme un enjeu important pour les pays du monde étant donné qu'elle constitue un pilier de la souveraineté. Cette étude a pour but d'évaluer et d'analyser la performance de la sécurité énergétique de l'Algérie durant la période 1980-2020 à travers le développement d'un indicateur composé, nommé ESIA, et qui se base sur cinq dimensions ; la disponibilité, l'abordabilité, l'applicabilité, l'acceptabilité, et la gouvernance. Les résultats montrent que la sécurité énergétique de l'Algérie était modérée, avec un intervalle de score de (5.29-7.51). La performance la plus élevée a été enregistrée durant la sous-période 2005-2020. Les principaux drivers de cette performance sont respectivement les indicateurs de la disponibilité, l'abordabilité et l'applicabilité. Cependant, les indicateurs de l'acceptabilité jouent un faible rôle positif, et la gouvernance proactive du secteur de l'énergie reste encore un challenge pour l'Algérie. Cinq implications de politique ont été identifiées, dont le but est d'améliorer la sécurité énergétique du pays.

MOTS CLÉES

Sécurité Energétique ; Indicateurs de Performance ; Analyse Factorielle ; ESIA; Algérie.

JEL CLASSIFICATION : C38, C43, Q41, Q48.

مؤشر الأمن الطاقوي للجزائر: مقاربة تكاملية

ملخص

يعتبر الأمن الطاقوي أحد أهم الرهانات لكل دول العالم كونه يعد أحد أعمدة السيادة. تهدف هذه الدراسة إلى تقييم وتحليل كفاءة الأمن الطاقوي للجزائر خلال الفترة الممتدة من 1980 إلى 2020 عن طريق بناء وتطوير مؤشر مركب سمي بمؤشر كفاءة الأمن الطاقوي للجزائر، حيث يرتكز على خمسة معالم وهي الوفرة والقدرة على تحمل التكاليف والقابلية للتطبيق والقبول والحوكمة. تظهر النتائج أن كفاءة الأمن الطاقوي للجزائر كانت حسنة بحيث تراوحت قيمة المؤشر ما بين 5.29 و7.51، حيث حققت الجزائر أفضل كفاءة للأمن الطاقوي خلال الفترة 2005-2020. تعتبر المؤشرات الخاصة بالوفرة والقدرة والتطبيق أهم محددات تطور كفاءة الأمن الطاقوي على التوالي، وبالعكس من ذلك فإن مؤشرات القبول لعبت دورا إيجابيا ضعيفا، كما أن الحوكمة الاستباقية لقطاع الطاقة لا تزال تعتبر رهانا هاما في حالة الجزائر. من خلال النتائج تم تقديم خمس آثار للسياسة تهدف إلى تحسين مستوى الأمن الطاقوي للبلد.

كلمات مفتاحية: الأمن الطاقوي، مؤشرات الكفاءة، التحليل العاملي، ESIA، الجزائر.

تصنيف جال: C38, C43, Q41, Q48

INTRODUCTION

Energy is indispensable for continued human development and economic growth. With the depletion of fossil energy reserves, the increasing energy demand, the growing costs of energy and the negative environmental externalities, energy security becomes the most important challenge and the main pillar of each energy policy.

Even though the concept of energy security appeared in the academic literature as early as the 1960s, energy security as a subject of study emerged in the context of the oil crises of the 1970s (Jakstas, T.2020), and it is present in discussions on energy and climate change issues. Many countries consider energy security equivalent to national security because of its influence on national self-sufficiency and development objective (Aumnad Phdungsilp, 2015). Although, there is a vast literature and much discussion about the concept of "energy security", it is difficult to describe "energy security" because it is a dynamic field. At the simplest level, energy security means access to the required volumes of energy at affordable prices and sufficient with respect to both, available volume and time required for distribution (Jakstas, T.2020).

The definition of energy security is kinetic in nature, due to the fact of being a concept framed on context (Ang, Choong, Ng, & reviews, 2015). The US energy security is based on independency and raising the share of renewable energy, but the Brazil's vision to promote energy security were exactly the opposite (Winzer, 2012). This means that energy security is going to be more different for the producers and net-exporters of fossil fuels. In this last case, Algeria constitutes a typical example because of the importance of hydrocarbon sector in its economy (90% of total export revenues and 20% to 40% of GDP (National Office of Statistics, 2019). The domestic energy demand is likely satisfied at 95% from domestic energy sources (National Energy Balance, Energy Ministry, 2018). The growing domestic demand is stimulated by large energy price subsidies and an important technologic investment is realised in power generation, grid, and refineries.

However, satisfying domestic energy demand from domestic source at subsidised prices could not be considered as a high-energy security performance but as the continuous availability of various energy sources at reliable prices (IEA, 2014). The insignificant development of renewable energies, the energy inefficiency and the instability of energy sector governance constitute some issues that could affect negatively the performance of energy security.

Therefore, this study aims to give an adequate definition of energy security in the Algerian context, and, then, to evaluate its performance over the period 1980-2020. For this purpose, we propose an integrate approach, starting from the identification of energy security dimensions, and using a set of quantitative and qualitative indicators that can reflect all the dimensions, in order to develop a composite index offering a pertinent information about the energy security performance in Algeria.

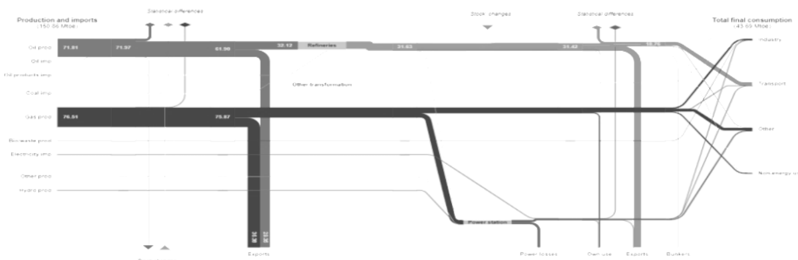
The rest of the paper is structured as follow; the first section focuses on the Algeria's energy system, the second one on the literature review. In the third section, we describe our methodology and data. The fourth section presents the results about the final composite index, group index and discussion. To conclude, we are going to summarise the results and analysis before providing some policy implications.

1- ALGERIA'S ENERGY SYSTEM

The Algerian energy context has been dominated for decades by hydrocarbon resources, either energy production and consumption or the economic dependency on energy exports. (Figure01) displays the Sankey diagram for the national energy balance of 2019, the share of oil and gas in the total primary energy supply represents 47.6% and 50.7%, respectively. The dominance of natural gas appears clearly either in the energy supply or in the energy demand side, mainly due to natural gas reserves availability. In the downstream side of the energy system (the demand side), the transport sector represents 35% of the final consumption, where the oil products share is 95%. Electricity and natural gas represent only 1% and 4%, respectively.

The energy flow to the household and industry sector represents 30% and 17% respectively. According to the Algerian energy ministry, the final energy consumption has doubled since 2006 (from 25.7 to 50.4 Mtoe in 2019). Household energy consumption had witnessed a total rapid increase of 949% between 1980 and 2019. By and large, more than 95% of domestic energy demand is satisfied through the domestic energy production.

Figure 1. Algeria's Energy System



Source: International Energy Agency, Sankey 2019.

The energy demand growth is a real dilemma for the Algerian's energy system equilibrium. Thus, energy efficiency program is of vital importance to reduce energy consumption, either by energy-recovery such as CCPP in the energy conversion side or energy-saving building thermal insulation, LED and CFL bulbs, on the energy demand technologies, to mitigate the energy supply chain's risks. However, the implementation of this program in Algeria is still in its early stage. Another challenge that stimulates the growing energy demand is the price subsidies policy. The low regulated energy prices had a significant positive effect on energy demand (Aissaoui, 2016).

Besides that, the reliance on fossil fuels in the long term will raise the energy supply risks due to the fossil fuel reserves depletion problematic, especially when the national energy consumption is oil and gas-based model, which is the case for Algeria, and the risk will be higher when the future economic model will be energy-intensive.

Moreover, energy security depends on a technological development overtime. Thus, decreasing the dependency on external energy technologies suppliers is challenging for Algeria, in both hydrocarbons and renewable energy sectors.

Renewable energies production represents less than 1% on the total energy balance of Algeria. Certainly, the development of these energies cannot overcome all kinds of energy security problems, but it can improve and resolve the long-term availability problem (Johansson, 2013). However, the development of renewables energies face significant barriers (Cost and pricing, legal and regulatory and market performance) (Beck & Martinot, 2016). These barriers have raised in different contexts due to the heterogeneity of the energy systems. Therefore in the Algerian case, new barriers most certainly will rise. Indeed, selecting an energy transition model should satisfy the future energy demand respecting the trilemma equilibrium, the energy security, environmental sustainability and economy competitiveness (Ang et al., 2015).

2- LITERATURE REVIEW

Despite the high importance of energy security, a large literature review is still focusing on the conceptualization and the measurement of energy security.

2.1- Energy Security: Concept and Definitions

Energy security concept does not have an acceptable and agreed definition within the existing literature in the field (Azzuni and Breyer, 2018). Filipovic et al., (2018) noted that energy security definitions can be divided into those focused on the security of supply (short-term energy security) and those focused on its a broader concept (long-term energy security). Many authors and institutions have offered numerous definitions, but in general, energy security is defined as the continuous availability of various energy sources at reliable prices (Malik et al., 2020; Abdo and Kouhy, 2016; Franki and Viskovic, 2015; Yao and Chang, 2014; Kovacovska, 2010, Chester, 2010; Jamasb and Pollit, 2008; Frondel and Schmidt, 2008; Spanjer, 2007; UNDP, 2009; IEA, 2014). In its meta-study of different definitions, Winzer (2012) concluded, "*the common concept behind all energy security definitions is the absence of protection from or adaptability to threats that are caused by or have an impact on the energy supply chain*". However, Cherp and Jewell (2014) noted, "*energy security means different things in different situations and to different people*". The authors argued that the presence of different meanings of energy security do not necessarily imply the existence of different concepts.

Moreover, the definition of energy security remains dynamic and changes over the time and over the place because it is associated to a number of challenges, which are not relevant to all countries equally, and their importance changes over time. Cherp and Jewell (2014) noted that there is an important difference between contemporary and classic energy studies. Indeed, the authors explained that if the availability and the affordability dimensions featured in the classic energy security studies, the contemporary studies included two other dimensions, which are the accessibility and the acceptability of sources. The authors pointed out that these two later dimensions were among the global energy goals proclaimed by the World Energy Council in its Millennium declaration (Khatib, 2000), but were not connected to energy security until the 2007 APERC report.

Furthermore, energy security is a highly context-dependant concept, such as the robustness of national energy system and the level of economic development (Ang et al, 2015). Therefore, Amin et al., (2022) noted that many studies believe that energy security is multidimensional concept that captures the economic, environmental, political, institutional, technological and geopolitical aspects. Indeed, past definition of energy security is less suitable, and recently these aspects have gained more momentum in the previous definition (Esfahani et al., (2021).

Based on 83 energy security definitions in the literature, Ang et al., (2015) identified seven major energy security dimensions: energy availability, infrastructure, energy prices, societal effects, environment, governance, and energy efficiency. From these 83 definitions, the authors showed that energy availability is included in

82, infrastructure in 60, and energy prices in 59. Besides these three dimensions, environmental sustainability has received increasing attention, and some studies focused only on the importance of this dimension in energy security (Shah et al, 2019; Pasqualetti and Sovacool, 2012, Chalvatzis and Hooper, 2011, Bang, 2010).

Moreover, the literature included an increasing number of studies criticizing the supply-centred conceptualization of energy security. Many authors noted that both supply and demand should be equally investigated in this field (Novikau, 2022; Von Hippel et al., 2011). Energy supply/demand side has been discussed through energy efficiency (Mouraviev and Koulouri, 2019; Hughes, 2009; Kemmeler and Spreng, 2007), prices (Romanova, 2013; Vivoda, 2012), societal effects (Ang et al., 2015; Von Hippel et al., 2011), infrastructure (Gary, 2015; Lacher, 2011; APERC, 2007), governance (Zman and Brudermann, 2018; Brown, 2014; Goldthan and Sovacool, 2012; Chevalier, 2011), and geopolitical perspective (Novikau, 2022; Bompard, 2017; Munoz et al., 2015).

2.2- Energy security indicators

Amin et al., (2022) noted, "*Given the wide range of definitions, understanding and evaluation energy security became a complex tasks and requires a holistic approach*". Therefore, there is no standard instrument or method to measure it, and many studies have proposed different energy security indices (Coutinho et al., 2020). Based on their 372 indicators, Sovacool and Mukharjee (2011) have highlighted that indicators' choices should depend on data availability and should not be more than 20. Ang et al., (2015) argued that choosing the indicators depends also of the contextual dynamic.

Given that the 4As (Availability, Affordability, Accessibility, Acceptability) are the frequent starting point of contemporary energy security studies, and based on the literature in the field, Yao and Chang (2014) had proposed an approach known as 4As framework; 1. Availability of indigenous and sustainable supply of natural, extractable, or renewable energy resources 2. Applicability of technologies and infrastructure to economically extract and harness the available energy resources 3. Acceptability of the energy sources' environmental and social impacts and 4. Affordability of the energy sources for the end-user (Malik et al., 2020). This framework has twenty indicators in total (five indicators under each A). The authors examined how China's energy security has changed over 30 years of reform and the opening period. They showed that China's energy security situation appears not to improve over its reform period. They suggested that China needed to develop renewable energy resources on a large scale. This approach is frequently applied in the literature because it is less complex and captures energy security issues for any country or region (Amin et al., 2022; Malik el al., 2020; Obadi and Korcek, 2020; Abdullah et al., 2020; Tongsopit et al., 2016).

Beyond the 4As approach, many studies proposed alternatives approaches based on more dimensions of energy security, and then, more simple and composite indicators are constructed. Gasser.(2020) reviewed 63 energy security indices with respect to their scope, geographical coverage, a number of countries analyzed, time frame covered, the number of indicators considered, data treatment approach, multivariate analysis, normalization, weighting and aggregation of the indicators, and the assessment of uncertainty, sensitivity and robustness. Most of the indicators, he identified, are quantified for countries in Europe, Asia, and North America. While, there is a need for more energy security assessments in South America and Africa.

In the case of the South and East Asian countries, there are a many studies that performed simple and composite indicators to quantify the energy security performance from different perspectives and dimensions (Malik et al., 2020; Li et al., 2020; Abdullah et al., 2020; Shah et al., 2019; Amin et al., 2019; Song et al., 2019; Matsumoto and Shiraki, 2018 Zhang et al., 2017; Chung et al., 2017 Tongsopit et al., 2016; Yao and Chang, 2015; Khatum and Ahamad, 2015; Ren et al., 2014). In general, the authors specified the 4As dimensions, where the results showed a moderate energy security performance for the countries of this region. In the European and North American case, many energy security indexes are developed for the European Union (EU) or a specific country and region (Cergibozan, 2022. Obadi and

Korcek, 2020; Golbal Energy Institute, 2020; Korasi and Unesaki, 2020; Filipovic et al., 2018; Bekhrad et al, 2019; Victor et al., 2014; Badea et al., 2011). The authors took mainly into account the economic, technical, environmental and geopolitical dimensions of energy security. By and large, the results show that countries with a higher index of macroeconomic stability and an improvement in the diverse energy supply also reported a higher value of the energy security index. In the two cases, the authors are based mainly on a same rang of normalisation and aggregation methods, such as z-score standardisation, min-max method, the Bayesian Method, Random Differential Equation, Principal Component Analysis (PCA).

Lobova et al. (2019) collected a dataset for constructing an energy security performance index of the eight countries of the Commonwealth of Independent States (CIS). The z-score normalization and the z-scored standardization methodology were applied for each indicator to evaluate energy security performance. The authors used them to operationalize four dimensions of energy security: energy availability, energy affordability, energy and economic efficiency, and environmental stewardship. We note that an energy security performance indexes are a composite indexes, which developed for both single and union of countries. Its development passed different steps such normalization and aggregation. The key advantages of this type of indicators is the presentation of multidimensional issues in one aggregate value. These indexes place priority issues of country's performance and progress at the fore of the policy area. They are developed for many countries, such as China, Japan, Pakistan, India, Singapore, Thailand, Bangladesh, OECD countries, EU, Baltic States, Turkey, etc. However, there are no studies, in our knowledge, focused on the energy security performance for Algeria through indicators or composite index.

Based on the development of the Algerian energy system and on the literature discussed above, we can suppose, in this stage, that energy security for Algeria is defined as "equitably providing available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to endusers", as stated in Wang and Zhou (2017). Therefore, in order to test this hypothesis, energy security for Algeria is assessed in this study through a composite index, named ESIA (Energy Security Performance Indicator for Algeria), which regrouping all these dimensions.

3- METHODOLOGY AND DATA

Composite indexes were largely developed in the literature to assess energy security performance. The index development requires three (03) main steps: 1. Selection of indicators and data collection, 2. Standardization of indicators, 3. Weighting and Aggregation of indicators.

3.1- Selection of indicators and data

Based on the definition above, the selection of energy security indicators for Algeria is based on two main criteria; Algeria's energy sector issues, and data availability. A part of these indicators is used in the studies cited above, and the other part is specific mainly to the Algerian case since the country is a producer and net-exporter of fossil fuels. All the selected indicators for this study were subject of discussion with a panel of expert from the energy sector (Ministry of Energy, National Energy Companies: Sonatrach and Sonelgaz, Regulatory Agencies: CREG, ARH). As a result, 51 indicators were selected and classified into five (05) dimensions, as shown in Table 01 in Appendix. This first list of indicators should be examined and tested via some statistical techniques in order to obtain a final list of reliable indicators.

3.1.1- Data

Time series data covered the period 1980-2020, and were collected from different sources: National Energy Balance (Ministry of Energy), Annual Reports of Sonatrach, Sonelgaz, CREG and ARH, and Economic reports of ONS (National Office of Statistics). The data have different measuring units (See table 01 in appendix) and need to pass a standardisation step.

3.1.2- Discrimination and reliability testing

Discrimination analysis is an important sub-step since an indicator could have a similar value across years. Three tests could be employed in this stage, coefficients of variance, the Kaiser-Meyer-Olkin (KMO) (respective to each indicator), and the final communality. Some indicators can be dropped from the analysis if their coefficients of variance are going to be weak (Nardo et al., 2008). The coefficients are calculated via the following equation

$$Coef\ Var = \frac{s_i}{\bar{X}} \dots \dots .. (1)$$

Where:

s_i: is the standard deviation of each indicator; and

$\bar{X}$: is the mean of indicator.

Any indicator, with the value of coefficient variance less than 0.12, is going to be eliminated (Bin Abdullah et al., 2021). The indicators with a value of KMO and final communality less than 0.5 and 0.7, respectively, must be dropped from the further analysis (Carricano and Poujol, 2008). In our case, seven (07) indicators from 51 were eliminated based on these three tests (See table 01 in annexe).

Thus, to test the indicators' reliability to measure the same construct; energy security, we are based on the Cronbach alpha value, where the acceptation value is above 0.7 (Cronbach, 1951). Therefore, the estimated indicators' reliability, in our case, was 0.929 greater than the critical value. Then, the indicators could be standardised and aggregated.

3.2- Standardisation of indicators

We are based, in this study, on the z-score method of standardisation, where the scaling is based on the deviation from the mean. The significance of this method compared to the other methods (min-max and distance to reference methods) is that all indicators are subjected to the same treatment and the extreme values of any indicator could not have an inherently higher effect on an index (Bin Abdullah et al., 2020). The z-score formula can be written as follow:

$$z_{ij} = \frac{x_{ij} - m_{ij}}{s_j} \dots\dots\dots (2)$$

Where:

z_{ij}: is the z-score (standardised value) of each indicator;

x_{ij}: is the indicators of the dimension i;

m_{ij}: is the mean of indicators in dimension i, which is calculated via the formula: $m_j = \frac{\sum_{j=1}^{N} x_{ij}}{N} \dots\dots (3)$

s_j: is the mean absolute deviation, which is calculated via the formula: $s_j = \frac{\sum_j^N (|x_{ij} - m_j|)}{N} \dots\dots (4)$

N: is the number of indicators for the respective dimension.

3.3- Weighting and Aggregation

For a single country, there are five (05) approaches to weight and aggregate the indicators. First, equal weight may be assigned to the indicators, in which there is no differentiation in terms of the indicator's importance (Hughes and Shup, 2010). Second, the weight is based on the relative importance of each type of fuel in the energy mix (Nardo et al., 2008). Third, the weights may be assigned based on experts' opinion. Fourth, the analytic hierarchy process (AHP) based on experts opinion could assign the indicator's weight (Zhang et al., 2017). Fifth, the Principal Component Analysis (PCA) or the Factor Analysis (FA) may be used and allows for robustness results based on statistical dimensions of data (Martchamadol and Kumar, 2014).

In this study, the weight estimation is based on the FA method. The main advantage of using FA is that it does not apply *ad hoc* and random weights to various indicators (Bin Abdullah et al., 2021). Its applicability requires that indicators pass the test of sampling adequacy via the KMO (Nardo et al., 2008). The results showed that KMO value was 0.778, which implies that FA could be employed.

The next sub-step focuses on the group indexGI_{kj}. Based on the results of FA, the ''number of groups'', ''suitable weighting factor of each group'' and ''the list of indicators in each group'' could be obtained. The number of appropriate groups (components or factors) would be selected only if the groups have eigenvalue higher than one

('M' groups that have eigenvalue > 1). The identification of the list of indicators in each group may be difficult, as some of indicators may have medium values of factor loading for more than one group. Therefore, to solve this problem, the factor rotation method; Varimax, was used (Martchamadol and Kumar, 2014, 2013). The weighting factors are estimated through "Root Mean Square" via the following equation:

$$w_k = \frac{Var_k}{\sum Var_k} \ldots\ldots (5)$$

Where:

w_k: is the weighting factor of group index k;

Var_k: is the percentage of variance of group index k.

It is important to note that there are two types of indicators, positive and negative. Positive indicators will improve energy security if their values increase, while negative indicators will reduce it. Only negative indicator is needed to calculate the inverse of indicator (Y_{ij}) through the following equation:

$$Y_{ij} = \frac{1}{X_{ij}} \ldots\ldots\ldots\ldots (6)$$

Where:

$X_{ij}$is the value of negative indicator *i* of year *j*. In this step, the original values of indicators are used, and not the standardized indicators (Martchamadol and Kumar, 2014, 2013).

The next sub-step focuses on the scaling of indicators. This step gives the normalization of each relative indicator in a range of 0 to 10. The scaling is done through the equation (7) and (8), in which we use the inverse of indicator (Y_{ij}) and not (X_{ij}) only for the negative indicator.

$$Max_{ij} = Max\{X_{ij}, \ldots\ldots, X_{ij}\} \ldots\ldots\ldots (7)$$

$$\varphi_{ij} = \frac{10 * X_{ij}}{Max_{ij}} \ldots\ldots\ldots\ldots (8)$$

The group index GI_{kj} is estimated, through "Root mean square (φi)" for both positive and negative indicators using the equation (9)

$$GI_{kj} = \sqrt{\sum \frac{\varphi_{ij}^2}{N}} \ldots\ldots..(9)$$

Where N is the number of indicators.

Finally, the composite index, named ESPIA (Energy Security Performance Index of Algeria), is calculated through the equation (10). This index depicts the Algeria's energy security performance.

$$ESIA = \frac{\sum(w_k * GI_{kj})}{\sum w_k} \ldots\ldots\ldots(10)$$

This performance could be categorised into four (04) classes, given the scores ranges.

Table 1. Performance Categories

Score	Performance
1 - 2.5	Very Poor
2.5 – 5	Poor
5 – 7.5	Moderate
7.5 - 10	High

Source: Authors' own based on (Martchamadol and Kumar, 2014, 2013).

4- RESULTS AND DISCUSSION

The application of FA with Varimax rotation, using XLSTAT.2016 Software, allowed for four (04) groups of indicators, named G1, G2, G3, G4, with different indicators. The group one G1 has 23 indicators from the initial dimensions ((07) Availability, (09) Affordability, (03) Applicability, (01) Acceptability, (03) Governance). This group reflects more the early definition of energy security (IEA, 2007). The second group G2 has 18 indicators shared into (04) from Availability, (03) from Applicability, (05) from Acceptability, and (06) from Governance. This group reflects the development of supply through infrastructure, mix diversification and legislation framework. Group G3 has two indicators reflecting electricity access and energy efficiency standards. The last group G4 has only one indicator reflecting the energy intensity of industrial sector from the Applicability dimension (See table 02 in Annexe).

The results of FA provide the rotation of percentage of variance, and rotation of cumulative of variance, as shown in table (02).

Table 2. FA Results

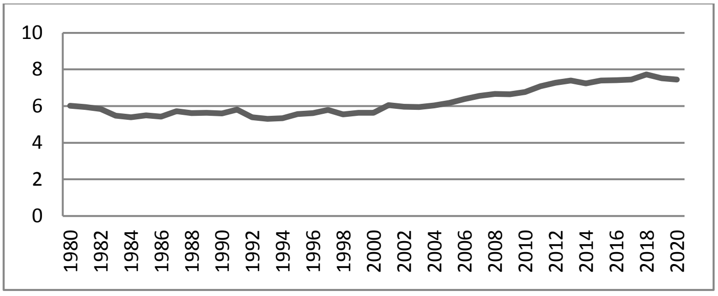
	Extraction of sum square loadings		Rotation sum square loading	
	% of Variance	Cumulative %	% of variance Var_k	Cumulative % ΣVar_k
1	65.740	65.740	45.064	45.064
2	15.140	80.880	33.936	78.999
3	6.680	87.560	7.212	86.211
4	3.023	90.583	4.372	90.583

Source: Authors' own estimations

Based on these results, we can calculate the weighting factor for each group through the equation (05). The values of weighting factor of G1, G2, G3, and G4 are 0.497, 0.375, 0.079, and 0.048 respectively. This means that the group G1 (23 indicators) and group G2 (18 indicators) could have the greater effect on the final composite index (ESIA).

From 44 selected indicators, 15 are considered as negative indicators (See table 01 in Annexe). Therefore, the inverse indicators are calculated via the equation (6) before scaling the original indicators. Based on the scaling values for each indicator, and the weighting factor results, the group indices and the final composite index (ESIA) are calculated for the period 1980-2020, as shown in figures (02) and (03).

Figure 2: ESIA evolution during the period 1980-2020

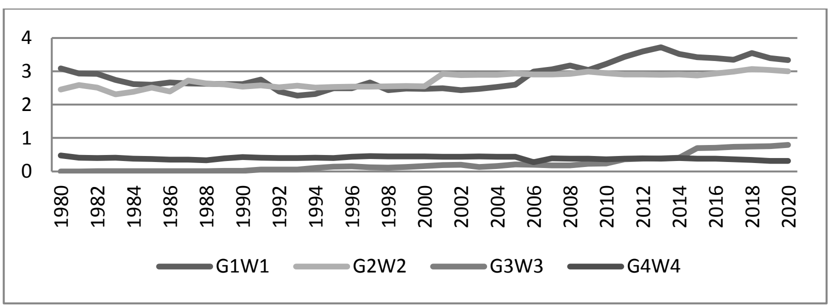


Source: Authors own estimation

By and large, the ESIA shows a moderate energy security performance in Algeria during the period 1980-2020, given that the ESIA value situates between (5.29 and 7.51). The energy security performance decreased during the period 1980-1986, where the ESIA score fell by about 10%. After that, the performance was stabilised with low fluctuation during the period 1987-2004, with score range of (5.29-6.06). However, the period 2005-2020 showed an increasing energy security performance by 28%, but remains moderate given the performance categories in table (01).

The group G1 and group G2 have the greatest effect on ESIA, followed by G4 and G3. Compared to G2, group G1 had the greatest effect during two periods: 1980-1986 and 2005-2020. The group G1 reflects more the availability, diversification, technological and economic access to the energy, and the economic aspects of energy policy. This group has 08 negative indicators focused on derived energy imports, agriculture energy intensity, and CO_2 emissions per capita. A second important group G2 reflects the importance of domestic energy production in supply (primary and derived), the performance of electricity generation and transportation technologies, CO_2 emissions by GDP, and the quality of energy sector governance. This group has five (05) negative indicators focused on services energy intensity, grid loss and CO_2 emissions by GDP and its share in the world.

Figure3: Performance of the Group Indices



Source: Authors' own estimation

Given that energy security performance of Algeria fluctuated during the whole period, it is more adequate to analyse and discuss the ESIA and group index over three sub periods: 1980-1986, 1987-2004 and 2005-2020. The choice of these sub-periods is based on two main change in the ESIA's evolution; 1986 (reflecting the implementation of the first hydrocarbon law), 2005 (reflecting oil boom and starting the change of hydrocarbons law's nature).

Period 1980-1986

The decrease of energy security performance during this period was derived mainly by the G1 index. This group has 08 negative indicators that present an increasing trend (energy primary imports and domestic energy prices). While, some positive indicators showed stability during this period, expect the three governance indicators (GV1, GV9, GV10), which had a low value because of the lack of operational energy law. It is important to note that, during this period, hydrocarbons proven reserves were decreased because of the low renewal level since that Sonatrach developed only the fields discovered during 1950s and 1960s. Therefore, G1 index fell by 15% and reduced the level of ESIA, given that the other group index had a little fluctuated impact.

Period 1987-2004

The ESIA decreased, between 1987 and 1993, by 8% before inversing the trend by 13% of increase since 1994. During the first sub-period (1987-1994), G1 and G2 had practically the same effect regarding their respective weighting factors. G2 index increased significantly in the first year because of the improvements in installed power generation capacities. While, the significant increase of G1 index in 1991 could be explained by the improvement of guarantee minimum wage. G1 index fell during the period 1992-1994 because of the economic crisis, which negatively affects the investment in energy sector and the evolution of the affordability indicators.

Moreover, the second sub-period (1995-2004) showed an increasing trend of ESIA because of the improvement of energy production and the economic stabilisation measures. A suitable trend is shown for all positive and negative indicators of G1 index, expect the electricity prices. A similar trend is shown for the G2, G3 and G4 index; expect the energy intensity and the share of the Renewable Energies (RE), which constitute negative and positive indicators of G2 index, respectively.

Period 2005-2020

The highest improvement in energy security performance was registered during this period (28%). G1 index was the main driver of this improvement, followed by G2 and G3 index. However, in terms of index growth rate, G3 showed the highest rate with 138%, followed by G1 (36%), and G2 (5.8%), while G4 index decreased by about 28%.

The improvement of G1 index is based on the increasing trend of its positive indicators and the decreasing trend of its negative indictors, expect the energy prices. These suitable trends could be showed in the high fossil fuels renewal rate, oil, LPG and electricity production, guarantee minimum wage that compensate the rise of energy prices, and the existence of operational energy laws that allowed for the participation of FDI and private sector in energy services activities. The main reason of all these improvement is the oil prices boom, which allowed for an important oil rent used in energy projects financing.

In the second side, the increase of G2 index could be explained by a positive trend in derived energy production and the high investments in power generation capacities (mainly the combined cycle) with a little increase of RE production.

The highest growing rate recorded in the G3 index is the result of implementation of energy efficiency policy in 2011 and the growing electricity subsidies. This later indicator reflects the public objective, which consists in improving standard living of population through different measures including large energy prices subsidies, compared to the other world's countries.

However, the G4 index showed a negative growth rate. This group contains one indicator, which is the industry energy intensity. This sector is the third final consumer of energy with (17%, Energy Balance, 2019). However, the industrial GDP rate situated between 2% to 3% annually (Economic Reports of ONS) during this period. Therefore, this sector showed continuous high-energy intensity.

Based on the previous analysis, it appears that energy security performance of Algeria was moderate over the whole period, during which three main sub-periods can be differentiated. The indicators relating to the availability and affordability were the main drivers of this performance. In this case, the definition of energy security for Algeria is close to the definition given by IEA (2014), in which "energy security is the continuous availability of various energy sources at reliable prices". This definition featured mainly in the classic energy security studies (Cherp and Jewell, 2014).

However, we noticed that from 1994 to 2004, the indicators reflecting the development of energy infrastructure and supply technologies (power generation capacities, refineries, and grid) played an important role in energy security performance. In the other side, the indicators related to the acceptability dimension, such as the share of RE in power generation and the level of CO_2 emissions, play a little positive role because of the marginal development of these energies in Algeria. The governance indicators have played a significant positive role on energy security performance since the adoption of the first hydrocarbons law in 1986, the electricity and gas distribution legislation in 2002, and finally the policy framework of the development of RE and energy efficiency in 2011. While the proactive nature of energy sector governance is considered as challenging for Algeria. Three hydrocarbons laws were implemented during the last 15 years, but the results in terms of FDI investment remains not significant. In the same way, the ecosystem of RE development presents many overlaps in the absence of operational law governing this sector.

Given that energy security is context-dependent, where Algeria is a producer and net exporter of fossil fuels, the energy security performance could well evaluated trough three dimension over the period 1980-2020; availability, affordability, and applicability. This situation could reflect until now the energy sovereignty, which is an autonomous option that refers to the empowerment of communities to decide about energy system (Schelly et al., 2020). This energy sovereignty is already associated to a number of economic and environmental externalities, which may be well examined (Schelly et al., 2020). In the Algerian case, the CO_2 emissions and the energy subsidies impacts are two important externalities that require more attention, in order to strengthen the energy sovereignty or the energy security because it is not possible to maximised them simultaneously (Thaler and Hofmann, 2022).

CONCLUSION

In this study, we are based on a growing literature review and recent Algeria's energy system trends to conceptualise energy security through five dimensions, which are used to evaluate and analyse the energy security performance of Algeria during the period 1980-2020. The study proposed a quantitative index (ESIA) based on availability, affordability, applicability, acceptability, and governance indicators. ESIA suggests that energy security of Algeria presented a moderate performance. Three main periods were differentiated in our analysis. The first one, from 1980-1986, was marked by 10% of decrease in total performance. The second period, 1987-2004, consisted on some fluctuations but the performance remains moderate. The third period, 2005-2020, registered net improvement of energy security by 28%, compared to the previous periods.

The main drivers of this performance are the availability, affordability, and applicability indicators, respectively. This means that energy security performance of Algeria can be evaluated mainly through these three dimensions, for which the definition of energy security in the Algerian case is close to the definition given by IEA (2014) and reported in the classic energy security studies.

Given that Algeria is a producer and net-exporter of fossil fuels, the energy sovereignty characterises more the Algerian energy context. However, some economic and environmental externalities such as the CO_2 emissions and the impacts of energy subsidies did not be considered and examined during this period. In the same way, we found that acceptability indicators have a little effect on energy security.

Moreover, the governance indicators have a positive effect since the implementation of the first hydrocarbons law in 1986. However, the proactive nature of the energy sector governance is considered as challenging for Algeria.

Based on the results, some policy implications could be identified, in order to strengthen the energy security performance. First, the investment in power generation technologies and refineries characterised by a high efficiency, constitute the good way to better preserve the available resources and optimise the supply chain. Second, oil rent has had the main effect on the energy investment, in order to perform the energy security. However, oil and gas prices are subject to significant fluctuations. Therefore, strengthening the role of private sector and FDI become more important, mainly in the energy downstream and the small power generation installations. Third, energy subsidies constitute a positive affordability indicator, but if we place it in the acceptability dimension, it will be a negative indicator because it plays a negative role in the development of RE. Then, the subsidies targeting requires more attention. Fourth, the development of RE plays a positive role as an acceptability indicator. It requires a suitable ecosystem and an operational law. It can play also a complementary role to the availability of resources and the diversification of energy mix. Fifth, more attention could be given to the application of the energy efficiency standards as governance indicator, which can improve other applicability indicators such as energy intensity. This later had a significant negative impact on energy security during the whole period 1980-2020.

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Appendix

Table 01. Selected Indicators of Energy Security for Algeria

Indicators	Abreviation	Unit	Positive or Negative Impact
Oil R/P	AV1	No	P
Natural Gas R/P	AV2	No	P
Total Primary Energy Production to Total Primary Energy Supply	AV3	%	P
Total Primary Energy Imports to Total Primary Energy Supply	AV4	%	N
Total Drived Energy Production to Total Drived Energy Supply	AV5	%	P
Total Drived Energy Imports to Total Drived Energy Supply	AV6	%	N
Oil Share in Total Primary Energy Production	AV7	%	N
Natural Gas Share in Total Primary Energy Production	AV8	%	N
Petroleum Products Share in	AV9	%	N

Total Drived Energy Production			
LPG Share in Total Drived Energy Production	AV10	%	N
Electricity Share in Total Drived Energy Production	AV11	%	N
Petroleum Products Share in Total Energy Imports	AV12	%	N
Electricity Share in Total Energy Imports	AV13	%	N
Natural Gas Prices	AF1	cDZD/Th	N
Gasoil Prices	AF2	DZD/L	N
Gasoline Prices	AF3	DZD/L	N
Electricity Prices	AF4	cDZD/Kwh	N
Garantuee Minimum Wage to Natural Gas Prices	AF5	Th	P
Garantuee Minimum Wage to Gasoil Prices	AF6	L	P
Garantuee Minimum Wage to Gasoline Prices	AF7	L	P
Garantuee Minimum Wage to Electricity Prices	AF8	KWh	P
Natural gas subsidies (Natural Gas Gap Price)	AF9	cDZD/Th	P
Gasoil subsidies (Gasoil Gap Price)	AF10	DZD/L	P
Gasoline Subsidies (Gasoline Gap Price)	AF11	DZD/L	P
Electricty Subsidies (Electricity Gap Price)	AF12	cDZD/KWh	P
Industry Energy Intensity	AP1	KTEP/GDZD	N
Household Energy Intensity	AP2	KTEP/GDZD	N
Agriculture Energy Intensity	AP3	KTEP/GDZD	N
Services Energy Intensity	AP4	KTEP/GDZD	N
Power Genration Efficiency	AP5	%	P
Grid Loss	AP6	%	N
Ratio of Total Installed Capacity to Maximum Demand	AP7	No	P
Natural Gas Access Rate	AP8	%	P
Electricity Access Rate	AP9	%	P
Share of Renewable Energy in Total Energy Production	AC1	%	P

Share of Renewable Energy in Power Genration	AC2	%	P
Share of Natural Gas in Power generation	AC3	%	N
Share of Gasoil in Power Generation	AC4	%	N
CO2 Emissions to Population	AC5	KG/Pop	N
CO2 Emissions to GDP	AC6	Kg/1000DZD	N
Algeria's Share of Global CO2 Emissions	AC7	%	N
Availability of National Energy Policies	GV1	0: None, 1: Policies are being worked out, 2: Policies framework ready, 3: Comprehensive Policies in place	P
Extent of Implementation of National Energy Policies	GV2	0: No plan, 1: Plan in place, 2: Process going on, 3: Implemented fully	P
Adequacy Energy Institutions	GV3	0:None, 1: Energy office, 2: Energy Department, 3:Energy Ministry	P
Public-Private Partnerships in Energy Sector	GV4	0: None, 1: Low, 2: Medium, 3: High	P
Efficacy of Institutions for Delivery of Energy Services	GV5	0: None, 1: Low, 2: Medium, 3: High	P
Availability Various Acts Related to Energy	GV6	0: No act, 1: In preparation, 2: Finalised, 3: In place	P
Energy Efficiency Standards	GV7	0: No standards, 1: In preparation, 2: Implemented partially, 3: Implemented fully	P
Availability of Enabling Framework for Private Sector Participation	GV8	0: None, 1: Being worked out, 2: Framework ready, 3: Comprehensive framework in place	P
Ease of Access to Finance for Energy Project Financing	GV9	0: None, 1: Low, 2: Medium, 3: High	P
Ease of Access to Finance for Energy Efficiency/Renewable Energy for HouseHolds	GV10	0: None, 1: Low, 2: Medium, 3: High	P

Source: Authors' own selection

Table 02. Rotated Component Matrix

	G1	G2	G3	G4
AV1	0,750			
AV4	0,951			
AV7	0,897			
AV10	0,952			
AV11	-0,869			
AV12	-0,960			
AV13	0,766			
AF1	0,849			
AF2	0,847			
AF3	0,850			
AF4	0,861			
AF6	0,682			
AF7	0,753			
AF9	-0,841			
AF10	0,833			
AF11	0,830			
AP3	-0,706			
AP8	-0,952			
AP9	0,952			
AC5	-0,719			
GV1	-0,729			
GV9	0,687			
GV10	0,687			
AV2		-0,876		
AV3		0,948		
AV5		0,918		
AV8		0,915		
AP4		0,710		
AP6		0,621		
AP7		-0,701		
AC1		0,848		
AC2		0,692		
AC4		-0,810		
AC6		0,859		
AC7		0,820		
GV2		0,834		
GV3		-0,951		
GV4		0,523		
GV5		0,523		
GV6		0,725		
GV8		0,523		
AF12			0,867	
GV7			0,835	
AP1				-0,502

Source: Authors' own estimation