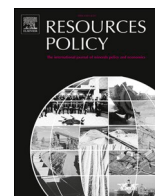


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# Establishing and comparing energy security trends in resource-rich exporting nations (Russia and the Caspian Sea region)

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## ABSTRACT

In the international arena, it is often the case that in countries which largely depend on foreign resources, energy security, and its key components i.e. security of energy supply, environment, technology, geopolitical, and economic factors, is a subject of concern. However, due to the abundance of fossil fuel resources in resource-rich exporting nations, there is a lack of understanding of the risks around energy security and accordingly often a policy vacuum. Conceptualising energy security from different geopolitical vantage points will allow future concerns around energy supply security, climate change, and regional economic crises to be evaluated. By using policy documents and developing a time series approach and normalized z-scores for a range of comparable metrics this article compares the energy security performance in six Caspian Sea countries individually and collectively. The article results show that Azerbaijan, Iran, Kazakhstan made significant progress in energy security since 1990, while energy security indicators in Russia, Uzbekistan, and Turkmenistan regressed. Iran has a leading position in energy security performance, while Uzbekistan and Turkmenistan have the lowest level of the energy security indicators compare to other region countries. This article both contributes a replicable definition of energy security that can be undertaken for other global regions, and begins to incorporate diversification and renewables development to enhance domestic energy security assessment.

## 1. Introduction

Over the last years, the concept of energy security (ES) attracts a strong attention academia, policymakers as well as business. The number of publications on ES research is growing year-on-year due to the importance of energy for economic development (Ang et al., 2015a, b; Azzuni & Breyer, 2018a, b). However, most of the published literature on ES deals with resource-poor, energy-importing countries and regions (EC, Baltic States, ASEAN, Visegrad Group, Eastern Block) and focuses on the resource availability (UN, 2000; IEA, 2001; Mišik, 2016), economic prices (Nurdianto and Resosudarmo, 2011), energy diversity (Goldthau and Sovacool, 2012), environmental impact, climate change, sustainability, nuclear waste management (Müller-Kraenner, 2008; Mouraviev and Koulouri, 2018). While the concept of energy security has received less attention in resource-rich countries with high exports, global geopolitical, environmental, and energy transition trends, mean energy security is gaining political importance for resource-rich

energy-exporting countries. Our contribution here is to establish a replicable energy security framework that responds less to a normative definition of what energy security should be as established by OECD scholars and respond more concretely to the ES priorities of constituent nations with a comparative analytical framework.

Energy Security in resource-rich, energy-exporting countries is vulnerable to external shocks which can have profound and multiplier impacts on non-resource sectors, capital formation, environmental programs, technology transfers, and overall economic growth (Griffiths, 2017; Nepal and Pajja, 2019). This paper was written during the 2020 Covid-19 pandemic which saw an unprecedented oil price shock with prices falling to zero in mid-April on some exchanges (Becker, 2020). In particular, there is strong interests in ES in the Caspian Sea resource-rich countries, where the abundance of energy resources are the reason of environmental degradation, economic instability and a geopolitical game between China's western expansion and stable export markets in Europe (Kumar and Chatnani, 2018; Wrobel, 2014). In recent years the

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reducing costs of renewable energy technologies mean Central Asian regions with high wind, solar or biomass potential must contend with a new factor in assessing domestic energy security. Under the Kyoto Protocol, Copenhagen and Paris agreements, resource-rich energy-producing countries are mandated to reduce carbon emissions and explore alternative methods of energy supplies. In exploring these renewable resources alongside traditional fossil reserves, resource-rich energy-exporting regions face a more complex set of energy security options and may benefit from improved modeling and energy scenario analysis (De Miglio et al., 2014).

In spite of this increased scholarly interest, there have been little comparative regional analyses on ES across national contexts, and no replicable statistical framework has yet been developed to assess Energy Security performance in the Caspian Sea region. By using published literature, policy documents, and indicator-based approach, this article aims to answer the following questions: How ES in this region is established in national policy frameworks? How ES can be measured and compared across this region? How has ES changed over recent decades, is the concept of ES making progress or regressing? This article is structured as follows: Section 2 analyses the current socio-economic and energy background of Caspian Sea countries; Section 3 presents the meaning of ES in context of Caspian Sea region, which is important for analysing past, current, and future ES trends in study-region; Section 4 discusses indicator-based approach with a focus on key aspects of ES covered in national ES doctrines in resource-rich countries; Section 5 presents the empirical finding of ES performance in Caspian Sea region and Section 6 provides concluding discussions.

## 2. Socio-economic and energy background of region

The Caspian Sea Basin is composed of Russia (RUS), Iran (IRN), and former four Soviet countries - Azerbaijan (AZE), Kazakhstan (KAZ), Uzbekistan (UZB) and Turkmenistan (TKM). All these countries except Uzbekistan share the common sea coast and the region covers a land area of 22.58 million km<sup>2</sup>, 4.3% of the total land area of Earth (Table 1). The combined population of the region is approximately 293 million people, 3.4% of the world's population (WB, 2019). Russia had the highest GDP (1.7 trillion USD), while Turkmenistan remains the country with the lowest GDP output (40 billion USD). Regarding the welfare of the population, Russia and Kazakhstan demonstrate the highest GDP per capita. The difference between Russia and Kazakhstan reached a minimum: 1.957 USD (11.3 thousand USD in Russia and 9.3 thousand in Kazakhstan). According to the forecast provided by World Bank, GDP per capita in Kazakhstan will increase to 13.0 thousand dollars in short-term perspectives. In Russia, GDP per capita will drop to 11.0 thousand dollars (WB, 2019).

Based on the IMF definition, Caspian Sea countries can be classified as resource-rich countries. IMF defines a country to be resource-rich when exports of non-renewable natural resources such as oil, gas, coal, minerals, and metals account for more than 25% of the value of the country's total exports (Lashitew et al., 2020). In 2018 Azerbaijan exported 14.3 USD billion, the export of non-renewable natural

resources was 13.5 billion USD or 94.4% of total exports (OEC, 2019). The top exports of Azerbaijan were crude petroleum (11.7 USD billion) and petroleum gas (1.29 USD billion). According to OEC (2019), the share of non-renewable natural resources in total exports accounts for 76.4% (in Kazakhstan), 77.8% (in Iran), 62.7% (in Russia), 90.3% (in Turkmenistan) and 54.7% (in Uzbekistan). While the region is 'resource-rich' there are differences across constituent nations in resource endowments and stages of economic development which make a comparative ES analysis instructive. Historically, the first international offshore oil production began in the Caspian Sea, in Azerbaijan's offshore in 1925. Between 1930 and 1950, about 2.2 million tons of oil and 3.1 billion cubic meters of gas were produced in Azerbaijan's offshore (Serikova and Zulfugarova, 2013). Recently, according to BP Statistical Review, proven oil reserves of the Caspian countries are: Russia – 103.2 billion barrels, Iran – 157.8 billion barrels, Kazakhstan – 30.0 billion barrels, Azerbaijan – 7.0 billion barrels (Table 2) (BP, 2018; Tofigh and Abedian, 2016). The region has the second-largest natural gas reserve with 3275.1 trillion cubic feet, following Middle East reserves of 2549.4 trillion cubic feet. The highest proved natural gas reserves are in Russia (24% of global reserves) and Iran (16.8% of global reserves) (IEA, 2019). Kazakhstan and Russia have also significant coal reserves. Its total recoverable coal reserves were estimated at around 176.7 and 62.2 million short tons respectively in 2015 (Karatayev et al., 2016).

After the collapse of the Soviet Union, one of the ways to overcome the economic difficulties faced by new independent states was the development of the oil and gas industry (Kandiyoti, 2008). Attracting foreign investment mainly in the oil and gas industry made economies of Caspian Sea countries vulnerable to external shocks. Economic growth trends over 1990–2018 demonstrate how Caspian Sea countries vulnerable to commodity price fluctuations in global markets (Fig. 1). In fact, a decrease of oil prices on the global market shows Dutch disease syndrome, where fossil resource discovery unbalances the economy towards its exploitation, then in shock conditions, the economy can be left in a worse condition that previously, in all Caspian Sea resource exporting countries, especially it has been well observed in Azerbaijan and Kazakhstan (Hasanov, 2013; Kutan and Wyzan, 2005). In Azerbaijan, for example, crude oil, and oil products make up over 80% of national total energy exports, and gas makes up over 20% (Ciarreta and Nasirov, 2012). During the middle of 2000s in the period of high oil prices, the economy demonstrated 24.05–33.00% of GDP growth which was the highest in the world (Vidadili et al., 2017). After decreasing oil prices, Azerbaijan's GDP dropped by –15.76%. The same pattern exists for Kazakhstan, Russia, and Iran.

Total primary energy consumption is an important indicator of energy security, energy consumption in the Caspian Sea countries in 2018 was 1.005 Mtoe, 24% higher than in 1990–1995 (Fig. 2). Final energy consumption has increased slowly since 1997, while the significant energy consumption growth was especially higher in years of the economic boom between 2000–2008 and 2010–2013. The biggest increases in gross inland consumption of energy between 1995 and 2015 were recorded in Turkmenistan (49.5% higher than in 1995), followed by Kazakhstan (44.8%), Iran (42.7%), Russia (11.0%) and Azerbaijan (4%). The average primary energy consumption growth in Iran was recorded at about 8.5% per year over the last two decades. According to estimates, the final energy consumption in the region is estimated to increase at an average annual rate of 4.5% in 2030 (Hasanov et al., 2013). This growth is very much higher than the world's average growth rate of 1.5% per year in energy demand over 2015–2040 (IEA, 2019).

The stable growth can be observed also in electricity consumption especially in Iran and Turkmenistan. The electricity consumption growth was recorded at about 7.9% per year in Iran and 8.7% in Turkmenistan (Fig. 3). As for the structure of gross electricity consumption, fossil fuels remain the main resources in almost all Caspian Sea countries. While Russia, Iran, and Turkmenistan are highly natural gas consumers, Kazakhstan is mainly a consumer of coal. Oil and gas

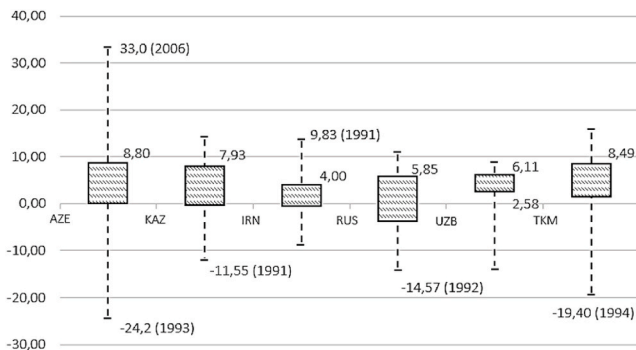
**Table 1**  
Key indicators of Caspian region, 2018

	Surface area (million km <sup>2</sup> )	Population (million)	GDP (billion USD)	GDP per capita (2018 USD)
AZE	0.09	9.942	46.95	4.721
IRN	1.75	81.800	454.013	5.627
KAZ	2.72	18.276	170.539	9.331
RUS	17.10	144.478	1658.831	11.288
TKM	0.49	5.850	40.761	6.966
UZB	0.44	32.955	50.50	1.532
Region Total	22.58	293.301	2421,594	6.5775*

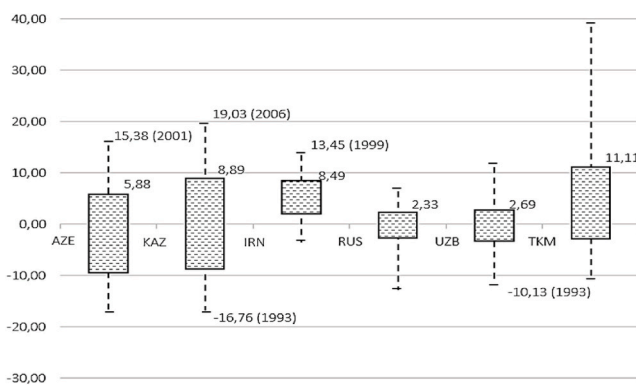
\*Average

**Table 2**  
Availability of non-renewable resource, 2018

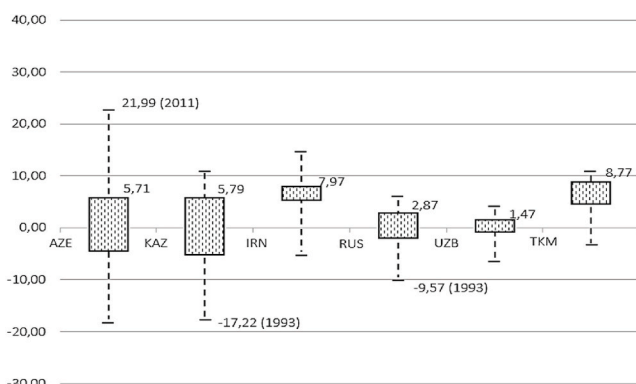
	Availability of oil		Availability of natural gas		Availability of coal	
	Billion Barrels	Reserves to production ratio	Trillion cubic feet	Reserves to production ratio	Billion Tonnes	Reserves to production ratio
AZE	7.0	15.40	1.2	35.00	0.00	0.00
IRN	157.8	158	34.0	1200.70	0.00	1.350
KAZ	30.0	48.0	1.5	85.00	33600	176.70
RUS	103.2	80.0	32.6	1670.10	157010	62.27
TKM	0.6	0.60	17.5	265.00	0.00	0.00
UZB	0.3	0.30	1.1	160.00	0.00	0.10
Region total (% of world)	298.6 (17.6%)	–	86.8 (46.4%)	–	190.6 (21.4%)	–
World	1700.1	52.5	187.1	54.1	891.5	110



**Fig. 1.** GDP growth (%), 1991–2018.



**Fig. 2.** TPEC trend (%), 1991–2018.



**Fig. 3.** Electricity output (%), 1991–2018.

account for over 99% of the overall energy utilized in Azerbaijan. Despite significant renewable energy potential including wave and tidal energy potential of the Caspian Sea, the share of renewable energy

sources in the energy mix has been negligible small in all Caspian Sea countries; it means that dependence on fossil fuels in energy production has remained very high in all Caspian countries.

### 3. Energy security conceptualisation

Energy Security is a difficult concept to define and conceptualise due to multidimensional character. However, as stated by [Cherp and Jewell \(2016\)](#) and [Valdés \(2018\)](#), a well-defined meaning of ES is an important prerequisite for analysing past, current, and future ES trends. [Valdés \(2018\)](#) claims that most of the studies lack a formal or more concise definition of ES, while [Azzuni & Breyer \(2018a, b\)](#) show that most of ES definitions are narrow and incomplete, many aspects of ES (e.g., location, culture, literacy, cyber security, military, research and development expenditure) are not included. According to [Azzuni & Breyer \(2018a, b\)](#), there are up to 15–20 dimensions of ES. Some proposed concepts have practical challenges and limitations. [Valdes \(2018, p. 265\)](#) notes that “in any methodology special attention should be devoted to present and discuss the definition ... The importance of giving clear and contextualized definition of the concept lies in the identification of threats and risks that will define the indicators choice”. Furthermore, when considering the concept of ES, [Valdés \(2018\)](#) points out that “the definition may also affect the election of the weighting method” (p. 266) as well as the method to normalize and aggregate data. We first proceed with the definition utilized by [Sovacool et al. \(2011\)](#) and [Sovacool \(2013\)](#) and (2013b) which has seven ‘dimensions’ “how to equitably provide available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users”; these seven dimensions have 18 components by which to measure them. In what follows we develop a hybrid set of components which are more concise, and respond to the various definitions given by the constituent nations of the region. We retain the spirit of the definition of Energy Security that focuses on availability, affordability, reliability, efficiency, environmental impact, proactive governance and a degree of social acceptance, but within the stated priorities of host countries to work with the following definition suited to resource-rich nations: sufficient level of presence of non-renewable resources of oil, gas, coal, nuclear and electricity first of all for domestic use and then for international export with expected maximum economic and social development benefits, progress towards exploiting low carbon source, pro-active scenario planning, and minimum environmental impact during production, transportation, transformation, and end-use application. It is to the definitions of ES offered by each nation in the region that we now turn.

In terms of importance ES concept for resource-rich countries, only Kazakhstan has a published suite of energy and climate change studies linked to nationally modeled scenarios. [Sarbasov et al. \(2013\)](#) used MARKAL-TIMES model to show energy-saving potential. [Karatayev and Clarke \(2016\)](#) used the GIS tool to estimate wind, solar and biomass energy potential in Kazakhstan. [Karatayev et al. \(2016\)](#) also used a hierarchy model to analyse existing barriers to renewable energy development. [Ahmad et al. \(2017\)](#) discussed the potential of the nuclear industry for electricity generation in long-term perspectives.

Assembayeva et al. (2018) indicated the economic model of the power generation sector in Kazakhstan. According to Karatayev et al. (2016), in case of Kazakhstan, there are three ES definitions provided in a number of documents including National Development Strategy “Kazakhstan 2030” (Directive № 377 of November 05, 1997), Nuclear Development Programme (Directive № 728 of June 29, 2011) and Concept of Developing the Fossil Fuel and Power Generation complex up to 2030 (Directive № 724 of June 28, 2014). Fossil fuel and power generation concept (Directive № 724 of June 28, 2014) sees ES as means of “the internal and external position of a nation in which there are not threats to end-use consumers arising in the process of extracting, processing, transporting, trading and using energy resources”. The definition shows the importance of availability and affordability of energy resources to satisfy national energy needs, while generating national income through the export of energy resources.

There have been myriad studies focused on Russia’s energy sector and carbon emissions. Mitrova (2014), Pristupa and Mol (2015), Proskuryakova and Filippov (2015), evaluated the country’s energy system sustainability, with a focus on renewable energy, natural gas, and nuclear power. Both Tursoy and Resatoglu (2016) and Sharmina (2017) made carbon emissions reduction and energy efficiency improvement scenarios for Russia. Bruusgaard (2006), Bogoviz et al. (2017), Ragulina et al. (2018), Bogoviz et al. (2019) used some ES indicators to demonstrate historical trends on ES performance in Russia. Bruusgaard (2006) tends to pay attention to external threat and conclusively suggests an interpretation of ES from Russian perspective where the ES is best understood as “a situation in which the country, its citizens, society, state and economy are protected from threats posed to reliable fuel and energy delivery” (p. 13). Here, the focus is not on resource availability and economic prices but on the threats and risks. Furthermore, according to Bogoviz et al. (2019), in 2016 Russian Parliament adopted National Energy Security Doctrine up to 2030 (Directive № 683 of December 31, 2015), where ES is defined as “governmental policy mechanisms and actions to assurance regular energy supply for domestic and international energy markets and protect this energy supply from external and internal threats that can potentially bring serious damages to national economy and energy sector”. Furthermore, Russia’s ES 2030 doctrine seeks mechanisms to guarantee of security energy demand from importing countries. These guarantees should include competitive economic prices for energy resource supply. The ES has special importance for Russia due to facts that domestic energy consumption is growing, while the export of energy resources is an important part of national income and most of the country’s social, economic, and military-technological programs depend on revenues from oil and gas sectors. Therefore, the weakening of the competitiveness of Russia’s energy sector is seen in doctrines as a threat to the economic and political security of the country. In this respect, Russia’s ES 2030 doctrine sets long-term targets to increase the availability of resources and get access to modern technologies for resource extraction especially in deep-sea and Arctic Sea zones.

A number of studies have evaluated energy and climate policy under different trajectories in Iran. Bahrami and Abbaszadeh (2013), Najafi et al. (2015), Afsharzade et al. (2016), Khojasteh et al. (2017) analysed renewable energy potential including wave and tidal energy, policy and barriers in Iran. Other academics (Tofigh and Abedian, 2016; Barkhordari and Fattahi, 2017; Katal & Fazelpour, 2018) made a comprehensive analysis of energy prices and energy efficiency potential in Iran. According to Fazelpour et al. (2017), ES in Iran can be regarded as “national economic model, which is able to satisfy the needs of the economy with available, affordable and acceptable energy resources at any time to counteract the negative impact of internal and external threats, and in the case of the impact of these threats to minimise the damage from this impact”. This definition of ES shows that process of management of the national economic module involves going through evaluation of the current situation in the energy sector, identification external and internal threats affecting the ES, analysis the possible

consequences of these threats and development measures for prevention and overcoming these threats. The most important areas highlighted in national doctrine are market regulation, a transformation of the electric power industry, and sustainable use of energy resources. As cases of Russia and Kazakhstan, the security of external energy demand is also a core of Iran’s energy policy as the economy is largely depends in export of energy resources. The National Economic Vision “Iran 2030” stated that “Using country’s energy rich potential, first of all, for country economic needs, at the same time, for export needs to other countries for the purpose to guarantee additional national income”.

Some recent works (Ciarreta and Nasirov, 2012; Vidadili et al., 2017) have focused on fossil fuels and renewable energy sector in Azerbaijan but did not evaluate past and current energy security trends. Recently, Azerbaijan’s Parliament approved the State Programme for Poverty Reduction and Sustainable Development (Directive № 3043 of September 15, 2008), State Programme on Industrial Development for 2015–2020 (Directive № 964 of December 26, 2014) and State Programme for the Sustainable Use of Energy Resources and Energy Efficiency of End-Users for 2015–2020 (Directive № 173 of March 11, 2015). These programs reflect four aspects of ES. First, ES is understood as a complex issue, where the main indicator of ES is the sufficiency and availability of primary energy resources for the needs of the country’s economy. Secondly, ES requires the availability of technical equipment for the utilization of primary energy into final energy. Third, availability and sufficiency of transportation infrastructure for each type of energy including primary and final energy. Lastly, ES requires the environmental acceptability of various types and forms of energy during the extraction, conversion, transportation, utilization, and consumption. These programs aim to develop efficient and environmentally friendly energy technologies and increase the use of renewable energy sources as stated in concept “to satisfy current and future national energy demand”.

Energy Security in Uzbekistan and Turkmenistan like in the case of Russia and Kazakhstan needs to be understood in the context of concerns of availability of resource and external energy demand. An additional important feature of Uzbekistan and Turkmenistan’s ES concept is water-energy nexus approach due to the high water problem in both countries. According to Energy Security Programme for 2016–2020 (Directive № 2309 of May 13, 2015) national ES is defined as “National control of energy production, diversification of fuel and energy resources, the involvement of renewable energy sources in the national energy mix, and broad cooperation with neighboring countries in the field of sustainable water use”. Here is the place to characterize these definitions in Table 3, simple tick boxes for ‘protection from external threats’ ‘ensuring export capacity’ ‘ensuring domestic sufficiency’ ‘ensuring domestic affordability’ ‘diversifying domestic sources’ ‘planning for an energy transition’.

#### 4. Energy security metrics

Inconsistent conceptual definitions on energy security go hand in hand with a lack of an accepted set of indicators and unifying methodology for energy security assessment. The above review has proposed a definition by Sovacool et al. (2011) and has reflected this against the inconsistent definitions used by nations constituting the region. Below we explore how others in the field draw metrics from various ES definitions and then use in country definitions cited above and the wide debate to create a framework we argue is more suited to the priorities of the regional actors, and one that is easily replicable.

There has been considerable debate as to how ES index should be constructed and how indicators should be selected and calculated with using different normalization, weighting and aggregation procedures, as “the way in which indicators are selected and constructed affects the evaluation in a significant way” (Valdes, p. 264, 2018). Meanwhile, indicator-based research is often a preferred quantitative method used for investigation energy security in different geographical regions and



**Table 3**  
Availability of non-renewable resource, 2018

Country	Strategic document	Definition
AZE	State Programme for the Sustainable Use of Energy Resources and Energy Efficiency of End-Users for 2015–2020 (Directive N <sup>o</sup> 173 of March 11, 2015)	ES is understood as complex issue, where the main indicator of ES is the sufficiency and availability of primary energy resources for the needs of country's economy.
IRN	State Programme on Energy Sector Development for 2020–2030 (Directive N <sup>o</sup> 964 of December 26, 2017)	ES in Iran can be regarded as "national economic model, which is able to satisfy the needs of the economy with available, affordable and acceptable energy resources at any time to counteract the negative impact of internal and external threats, and in the case of the impact of these threats to minimise the damage from this impact".
	National Economic Vision "Iran 2030" (Directive N <sup>o</sup> 47 of May 10, 2015)	ES understood as "using country's energy rich potential, first of all, for country economic needs, at the same time, for export needs to other countries for purpose to guarantee additional national income".
KAZ	Fossil fuel and power generation concept (Directive N <sup>o</sup> 724 of June 28, 2014)	ES as means of "the internal and external position of nation in which there are not threats to end-use consumers arising in the process of extracting, processing, transporting, trading and using energy resources".
RUS	National Energy Security Doctrine up to 2030 (Directive N <sup>o</sup> 683 of December 31, 2015)	ES is defined as "governmental policy mechanisms and actions to assurance regular energy supply for domestic and international energy markets and protect this energy supply from external and internal threats that can potentially bring serious damages to national economy and energy sector".
TKM	National Sustainable Development Strategy (Directive N <sup>o</sup> 64 of June 15, 2012)	ES presented as "development of renewable and non-renewable resources for domestic economic use".
UZB	Energy Security Programme for 2016–2020 (Directive N <sup>o</sup> 2309 of May 13, 2015)	National ES is defined as "National control of energy production, diversification of fuel and energy resources, involvement of renewable energy sources in national energy mix, and broad cooperation with neighbouring countries in the field of sustainable water use".

different periods. However, there is no universal agreement on the number of indicators to measure energy security. Instead, it is often investigated using a set of indicators that characterize the various dimensions mainly 4A's dimensions - availability, applicability, affordability, and acceptability (Kruyt et al., 2009; Ren and Sovacool, 2014; Yao and Chang, 2014; Tongsovit et al., 2016; Zaman and Brudermann, 2018). Some academics proposed more than 4A's dimensions. Both Von Hippel et al. (2011) and Sovacool (2013) works have made a huge contribution to energy security concepts and its measurement methodologies proposing 5's dimensional framework i.e. availability, affordability, efficiency, sustainability, and governance. Similarly, Bellos (2018) proposed the fifth A's to 4A's energy security concept, namely adaptability. Here adaptability explained by Bellos (2018) as the existence of adaptive programs and measures within national energy systems. In addition to concepts by Von Hippel et al. (2011) and Sovacool (2013), Chuang and Ma (2013) shared their views on vulnerability and dependence dimensions of energy security. In general, Azzuni and Breyer (2018b) applied a 15-dimensional framework for assessing

energy security in the context of new technology implication. In terms of indicators for assessing energy security, its numbers are also different. Vivoda (2010) proposed 7 dimensions and 44 indicators. According to Sharifuddin (2014), energy security can be measured by 35 indicators. In contrast to Sharifuddin (2014), who focused on five aspects of energy security i.e. availability, stability, affordability, efficiency, and environmental impact, WEC (2010) proposed 46 indicators. Augutis's ideas on a number of indicators based on technical, economic, and socio-political systems and includes 38 indicators (Augutis et al., 2012; Narula et al. (2017) measured energy security through 22 indicators related to availability, acceptability, affordability, and efficiency dimensions. Martchamadol & Kumar (2012) works greatly focuses upon the economic aspect of energy security which had proposed 19 indicators. Zhang et al. (2017) applied a five-dimensional framework with 20 energy security indicators, while Ang et al. (2015b) proposed three dimensions and used 22 indicators. It has shown in (Sovacool, 2011; Sheinbaum-Pardo et al., 2012; Anwar, 2016; Chung et al., 2017) that a number of indicators might vary from 6 to 370.

According to Böhringer and Bortolamedi (2015) and Valdés (2018), indicator-based research method has both advantages and disadvantages. The advantages of the indicator-based methods are that it can be easily used in country self-assessment, scenario analysis, cross-country comparisons, ranking, and tracking progress. Regarding the disadvantages of using indicators as a research method, firstly as stated by Valdés (2018, p. 264) "that individual indicators as the level of energy independence do not tell us very much about energy security levels of national economies". Valdés (2018, p. 265) concluded that "a more consistent approach is needed to make available indicators useful to design, implement and assess energy policies". Böhringer and Bortolamedi (2015) highlighted that most of the energy security indicators are supply-oriented, thus, ignoring the demand-side aspect of energy security, economic cost, and external shocks. Furthermore, according to Matsumoto and Shiraki (2018), it seems challenging to develop a basket of indicators that will be applicable to all countries, primarily because there is not a definition of energy security which is clearly accepted by all and secondly because each country has a different endowment of energy resources, different economic growth, climate conditions, demographic indicators, priorities, and geopolitical position (Radovanović et al., 2017).

This article proposes that some of energy security indicators used by many academics and shown in detailed review (Ang et al., 2015a; Azzuni and Breyer, 2018a) are also suitable for assessing energy security in resource-rich countries. For example, the indicators related to the physical existence of conventional hydrocarbon resources and renewable resources can be applied in resource-rich countries alongside environmental indicators such as energy-related carbon emissions. This type of indicators is reflected in national ES doctrines of the Caspian Sea region. Thus, this article develops an indicator-based approach with a focus on key aspects of ES covered in national ES doctrines in resource-rich countries.

In this framework 'Resource & Dependency' reflects the quantitative level of domestic resource existence for national needs and international exports. It is also represented by the quantitative level of consumption of oil, gas, coal, nuclear and renewable energy resources. The proposed indicators are shown in Table 4. 'Intensity & Sustainability' covers the capacity to improve existing energy system or create new system considering technological trends. It also captures energy-related carbon emissions, water consumption during energy production, transportation and use, flaring gas. 'Cost & Poverty' measures a final cost for all energy users in the residential and industrial sectors, prices for gasoline, diesel fuel, liquefied petroleum gas as well as energy poverty measured in percentage of the population have little or no access to electricity. As stated before, the measurement, analysis, and monitoring of ES in resource-rich energy-exporting is critical for economic development and mapping sustainable energy transitions.

For data collection, the study used data provided by different

**Table 4**  
Selected energy security indicators.

Resources & Dependency	Intensity & Sustainability	Cost & Poverty
Availability of oil, thousand million barrels	Grid efficiency, percentage of energy loss	Industry electricity prices, USD per kWh
Availability of gas, trillion cubic feet	Energy use per capita, USD per kg oil equivalent	Household electricity prices, USD per kWh
Availability of coal, million tonnes	CO <sub>2</sub> emissions, kilotonnes	Price for gasoline, USD per litre
Primary energy production, quadrillion BTU	NO <sub>x</sub> emissions, kilotonnes	Price for diesel fuel, USD per litre
RES supply, percent of total final energy consumption	Water usage, million m <sup>3</sup>	Price for liquefied petroleum gas, USD per litre
Energy import dependency, thousand tones	Flaring gas, billion m <sup>3</sup>	Energy poverty, percent of population have little or no access to electricity

institutions including International Energy Agency (IEA), World Bank's World Development Indicators (WB), World Bank's Global Gas Flaring Reduction Partnership (GGFR), Renewable Energy Policy Network (REN21), World Energy Statistics provided by energy intelligence and consulting company 2019 "Enerdata", World Data Atlas provided by database 2019 Knoema, U.S. Department of Energy 2019 (EIA), World Resources Institute's Water Statistics (WRI). For data calculation, the study applied Z-score approach which has been used in a number of previous energy security studies with different sets of indicators at different countries, economic blocs and regions (e.g., Brown and Sovacool, 2007; Sovacool and Brown, 2010; Brown et al., 2014; Bogoviz et al., 2017; Ragulina et al., 2018; Bogoviz et al., 2019).

## 5. Energy security performance

### 5.1. Resource & Dependency

Between 1991 and 2018, Resource & Dependency indicators have improved in all Caspian Sea countries. The greatest improvement in Resource & Dependency indicators occurred in Azerbaijan. Azerbaijan has improved indicators on the availability of oil and gas resources, primary energy production and energy import dependency. According to Ciarreta and Nasirov (2012), Azerbaijan's proven gas reserves are estimated at about 35.000 trillion cubic feet, and the potential for changes is expected to be between 100.000 and 200.000 trillion cubic feet. Furthermore, Azerbaijan has turned from an energy-importing into an energy-exporting country. In 1991, Azerbaijan's energy import dependency was 8.3270 thousand tonnes, while in 2018 it was -340.3850 (IEA, 2019). Apart from Azerbaijan, the greatest improvements in Resource & Dependency indicators occurred in Kazakhstan. The energy security performance in Kazakhstan in relation to proven fossil fuel reserves (oil and gas) and energy import dependency was higher in 2018 than in 1991. Kazakhstan has almost doubled primary energy production and energy import dependency enhanced from -23.8610 in 1991 to -116.8900 in 2018 (IEA, 2019). Russia also demonstrated an improvement in proven oil reserves, although indicators for gas and coal have deteriorated, but not significantly. After the collapsing Soviet Union, Russia discovered 40 new oil-and-gas fields. The average amount of deposits is 80,000 thousand million barrels as regards recoverable oil reserves, and 1670.100 trillion cubic feet (IEA, 2019). The largest new oil deposit is Nertsetinskoye field, located in the East European Plain, which is estimated at 17.4 million tons of recoverable oil reserves and Verkhneicherskoye field, located in the Eastern Siberia, with recoverable oil reserves of 11.4 million tons and 52.6 billion cubic meters of gas. The presence and development of new fossil fuel reserves allowed Russia to improve energy import dependency status from -47.0790 in 1991 to

-86.8440 in 2018 (IEA, 2019). Iran showed progress on the availability of fossil fuel reserves especially for gas and oil but the country worsened its position on energy import dependency from -170.9270 in 1991 to -53.3950 thousand tones in 2018 due to an increase in domestic energy consumption (IEA, 2019). The resource reserves include about 100 billion barrels of crude oil, 94 billion barrels of condensate and 207 billion barrels equivalent of natural gas (IEA, 2019). Uzbekistan and Turkmenistan were also able to improve its Resource & Dependency indicators, Uzbekistan has turned from an energy-importing into an energy-exporting country, 16.550 in 1991 and -29.9130 in 2018. Turkmenistan discovered new natural gas reserves at the Galkynysh and Halkabat sites in eastern Turkmenistan. These two sites have an estimated total natural gas reserve of 265.000 trillion cubic meters.

In 1991, Russia with coefficient 3.870920 was the most resource-rich energy independent state among Caspian Sea countries (Table 5), followed by Iran (0.779086) and Kazakhstan (0.293037). Uzbekistan and Azerbaijan had the worst resource indicators in 1991, -2.992214 and -1.260583, respectively (Fig. 4). In 2018, Russia and Iran remain the most resource wealthy and energy independent states with a coefficient of 3.942365 and 2.306490, respectively (Table 6). Kazakhstan and Azerbaijan improved their Resource & Dependency indicators with score 0.919813 and 0.245847, while Turkmenistan and Uzbekistan had the lowest indicators on Resource & Dependency compare to other Caspian Sea countries (Fig. 5).

### 5.2. Intensity & sustainability

Intensity & Sustainability represents environmental and safety dimension of energy security. This article chooses CO<sub>2</sub> emissions, NO<sub>x</sub> emissions, grid efficiency, energy use per capita, freshwater usage, and flaring gas as main indicators. Between 1991 and 2018, in Azerbaijan, Kazakhstan, Russia, and Uzbekistan the average score of CO<sub>2</sub> emissions was lower than at the beginning of 1990s, mostly due to a sluggish economy as a result of collapsing the Soviet Union. CO<sub>2</sub> emissions in Azerbaijan, Kazakhstan, Russia, and Uzbekistan accounted for 2571,75 in 1991 and 1830,18 kilotonnes in 2018. However, indicators demonstrate that the environmental situation has worsened in Turkmenistan and Iran since 1991. In fact, the CO<sub>2</sub> emissions in Iran increased from 171.18 in 1991 to 552.40 kilotonnes in 2018 (IEA, 2019).

As with efficiency, between 1991 and 2018, Azerbaijan, Uzbekistan, Kazakhstan, and Turkmenistan have the highest energy losses, with the average ratios at 10–15% due to geographical conditions and poor efficiency of existing power generation and transmission technologies. Furthermore, Kazakhstan's energy consumption per capita is about 4538.60, which is higher than that of OECD countries (2410.08 USD per kg oil equivalent). Due to coal energy dominated the primary energy field, the effectiveness of plans and strategies is low. Coal, which accounts for more than 80% of electricity generation in Kazakhstan, is mostly combusted in power plants that are more than 50–60 years old. Turkmenistan consumes on average 3755.30 of total energy per capita in 1991 and 4401.11 in 2018 (IEA, 2019). Turkmenistan similar to Kazakhstan has a large number of inefficient production facilities that

**Table 5**  
Energy security dimensions in normalized value (1991).

	Resources & Dependency	Intensity & Sustainability	Cost & Poverty	Total
AZE	-1.260583	0.756401	-2.019063	-2.523245
IRN	0.779086	2.092063	0.153696	3.024845
KAZ	0.293037	-1.330588	2.427323	1.389772
RUS	3.870920	-2.909689	2.330895	3.292126
TKM	-0.690246	0.064715	-2.270054	-2.895584
UZB	-2.992214	1.327098	-0.622798	-2.287914

\* Here and further table shows positive and negative converted normalization values, where positive normalization Z-score means better energy security situation compare to other case-studies.

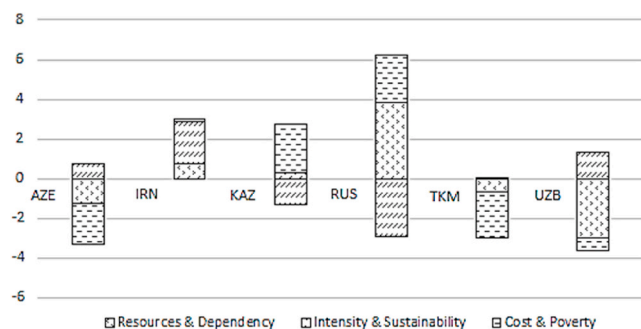


Fig. 4. Energy security dimensions (1991)\* Here and the further graph shows positive and negative converted normalization values, where positive normalization Z-score means better energy security situation compare to other case-studies.

Table 6  
Energy security dimensions in normalized value (2018).

	Resources & Dependency	Intensity & Sustainability	Cost & Poverty	Total
AZE	0.245847	-0.164573	1.566536	1.647810
IRN	3.785906	0.433671	1.214932	5.434509
KAZ	1.372159	0.169741	0.668269	2.210169
RUS	4.849115	-0.759318	-0.938815	3.150982
TKM	-2.379674	0.215442	-1.195048	-3.359279
UZB	-3.213400	0.105036	-1.315874	-4.424238

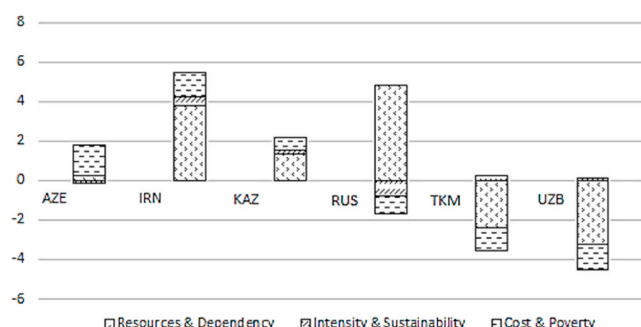


Fig. 5. Energy security dimensions (2018).

remained not renovated after collapsing the Soviet Union. Most of these facilities were constructed in the 1960s. In Iran, energy intensity is 68% higher than the global average consumption (Afsharzade et al., 2016). Iran’s economy is highly energy intensive, which along with the low energy prices has resulted in over-consumption of energy and low efficiency (Afsharzade et al., 2016). In the case of Russia, the energy intensity indicator has slightly improved since 1991, however, this level of energy intensity is still high compare to OEAD countries. At the same time, significant energy saving potential exists (WB, 2015).

In 1991, Iran was the most energy efficient and sustainable country with a coefficient of 2.092063 (Table 5). Due to the nature of the economy, Russia and Kazakhstan had the worst energy efficient indicators, -2.909689 and -1.330588, respectively. In 2018, Iran worsened energy intensity and sustainability indicators, however, the country remains in better rank compare to other Caspian Sea countries (Table 6).

5.3. Cost & Poverty

The energy security performance in the Caspian Sea region in relation to energy poverty indicator, all Caspian Sea countries demonstrated an improvement. Caspian Sea countries have 293 million people, while

according to official statistics, the population share without access to electricity is less than 1% (WB, 2019). Azerbaijan has reduced energy poverty from 3.8 in 1991 to 1.6% in 2018, Kazakhstan - from 1.7 in 1990 to 1.1% in 2018. Regarding energy prices, the increase in electricity prices for industry and household sectors has been observed in all Caspian Sea countries, while electricity prices are still lower international average in all Caspian Sea countries. The energy security performance in the Caspian Sea region in relation to price for gasoline, diesel fuel, liquefied petroleum gas has become worse. Kazakhstan has experienced a rise in the price of both gasoline and diesel fuel, because of unexpectedly high demand for gasoline and diesel fuel in Russia itself. Kazakhstan is largely depending on gasoline and diesel fuel from Russia. Four key Russian oil companies - Rosneft, Gazprom Neft, Lukoil and Tatneft - export on average 480.000 metric tons of high-octane kerosene per year to Kazakhstan, meanwhile, three Kazakhstani refineries (Pavlodar, Atyrau, and Chimkent) produce around 520.000 metric tons of fuel per year (IEA, 2019). In contrast, the total domestic demand in Kazakhstan is about 1200.000 metric tons. The same situation can be observed in Azerbaijan, where Baku oil refinery with production approximately 600.000 metric tons of gasoline does not satisfy the domestic demand, the significant amount of fuel products come from Russia.

In 1990, Russia and Kazakhstan were the most energy price secure country (2.330895 and 2.427323), followed by Iran (0.153696). In 2018, Iran and Kazakhstan remain the most economically secure states, 1.214932 and 0.668269, while Turkmenistan and Uzbekistan had the worst indicators (Table 6).

5.4. Low-carbon energy

Regarding alternative energy supply, renewable energy indicators demonstrated improvement in Azerbaijan, Kazakhstan, and Uzbekistan. Kazakhstan increased renewable energy supply in total final energy consumption from 1.4 in 1991 to 1.5% in 2018, Azerbaijan – from 0.7 in 1991 to 2.3% in 2018, Uzbekistan – from 1.3 in 1991 to 2.8% in 2018. Overall, the potential of renewable in all countries in the Caspian region is high. For Kazakhstan, the estimated potential of wind energy is about 760 GW (REN21, 2019). Kazakhstan receives 2200–3000 h of sunlight per year, which equals 1200–1700 kW per m<sup>2</sup> annually (REN21, 2019). Kazakhstan has set a target of raising the share of renewable resources in electricity production from 3% by 2020 to 50% by 2050 (Koshim et al., 2018). In Azerbaijan, the figures are 1500–2000 kWh per m<sup>2</sup> (Vidadili et al., 2017). The technical potential for wind electricity generation was estimated at approximately 4.500 MW (REN21, 2019). Azerbaijan aims to increase the share of RES in the total energy sector by 20% at 2020 and share of RES in the total final energy consumption by 9.7% in 2020 with 2500 MW installed capacity of renewable-based generation equipment in 2020 (Vidadili et al., 2017). For Iran, the amount of actual solar radiation hours in the country exceeds 2800 h per year, the technical potential of solar electricity was estimated to be 14.7 TWe (Najafi et al., 2015). Wind energy density was reported for Iran is 275 W per m<sup>2</sup> (Tofigh and Abedian, 2016), the technical potential for wind electricity generation was estimated at approximately 60.000 MW (Bahrami and Abbaszadeh, 2013), for biomass 700 PJ (Tofigh and Abedian, 2016). The Iranian renewable energy roadmap has a renewable energy target providing 1–5 GW to total power generating capacity each year through 2022 (Khojasteh et al., 2017; Tofigh and Abedian, 2016). In the case of Russia, the total technical bioenergy potential is estimated at 2225.4 PJ (Namsaraev et al., 2018). Despite huge renewable energy potential, this potential is not fully used due to a number of specific barriers that resource-rich countries are facing so far (Koshim et al., 2018; Karatayev et al., 2016).

5.5. Energy security performance

In general, energy security index shows that Azerbaijan, Iran, Kazakhstan have improved energy security since 1990 (Table 7, Fig. 6).



According to obtained data, Iran has made progress improving its energy security by 2.409663 points for the studied period of 1991–2018 and this country has a leading position in energy security index, caused by availability of fossil fuel resources, cheap energy prices, and high level of access to energy services. However, Iran performed poorly on intensity & sustainability dimension of energy security (Table 8). Russia and Kazakhstan are more similar in their levels of energy security, with the overall energy security index being around 3.150982 and 2.210169. Both these countries have best performance on Resource & Dependency indicators, however, Russia showed poor performance on the Cost & Poverty dimension of the energy security (Table 8). In 1990, Azerbaijan had a negative energy security coefficient,  $-2.523245$ . In 2018, Azerbaijan improved its indicators with a score 1.647810. Uzbekistan has the lowest level of energy security indicators. In terms of availability, Uzbekistan has significant natural gas reserves in the Caspian Sea region, while the country's performance on Intensity & Sustainability and Cost & Poverty indicators of energy security is low. The key energy security issues in Uzbekistan and Turkmenistan are associated with high energy prices, high level of carbon emissions, the highest energy intensity among Caspian Sea countries.

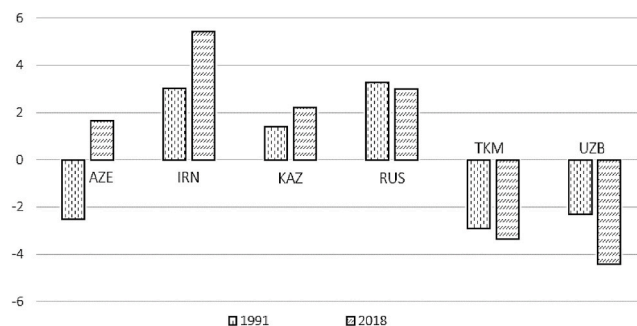
## 6. Conclusion and policy implications

ES is considered as a complex multidimensional issue in both importing and exporting countries. However, the view on ES is different from country to country. Some countries (Kazakhstan, Russia) see ES as a means of availability and affordability of energy resources for social and economic prosperity, and others (Azerbaijan and Iran) as a technology and infrastructure opportunities for providing economic development and achieving geopolitical goals. ES in Uzbekistan and Turkmenistan needs to be understood in the context of the environmental dimension. Based on elements of ES reflected in policy documents energy security in the context of resource-rich energy-exporting countries of Caspian Sea region can be defined as sufficient level of presence of non-renewable resources of oil, gas, coal, nuclear and electricity first of all for domestic use and then for international export with expected maximum economic and social development benefits, progress towards exploiting low carbon source, pro-active scenario planning, and minimum environmental impact during production, transportation, transformation, and end-use application. The proposed definition is broad and has similarities with definitions provided in (e.g., Yao and Chang, 2014). Yao and Chang (2014, p. 272) suggested that national ES in whatever importing or exporting countries is based on “affordable energy resources with an adequate amount of fossil fuels, nuclear energy, and renewable resources, technologies applicable to energy harnessing and utilization, and, at the same time, addresses social and environmental concerns”. According to Yao and Chang (2014), the key elements of ES include energy resource availability (fossil fuel and renewables), energy production, energy transportation and demand, energy consumption, energy use efficiency and technologies, energy prices, and energy-related environmental pollution.

The assessment of ES in Caspian Sea countries has been conducted by using 18 individual indicators to quantitatively measure three dimensions of energy security: Resources & Dependency, Intensity & Sustainability, Cost & Poverty. These dimensions reflected in the

**Table 7**  
Energy security score change (1991–2018).

	1991	2018	Changes
AZE	-2.523245	1.647810	4.171055
IRN	3.024845	5.434509	2.409663
KAZ	1.389772	2.210169	0.820397
RUS	3.292126	3.150982	-0.141144
TKM	-2.895584	-3.359279	-0.463695
UZB	-2.287914	-4.424238	-2.136324



**Fig. 6.** Energy security score change (1991–2018).

**Table 8**  
Changes in energy security dimensions (1991–2018).

	Resources & Dependency	Intensity & Sustainability	Cost & Poverty
AZE	1.506430	-0.920975	3.585599
IRN	1.527404	-1.658392	1.061235
KAZ	0.686776	1.500329	-1.759054
RUS	0.071444	2.150372	-3.269710
TKM	-1.689428	0.150727	1.075006
UZB	-0.221186	-1.222062	-0.693076

definition of ES for resource-rich energy-exporting countries. Based on the analysis, between 1990 and 2018, the Caspian Sea countries experience a stable rise in the availability of all fossil fuel reserves except coal resources and RES in total energy production and consumption. All Caspian countries rely on fossil fuels to a great extent for their electricity generation and final energy consumption, while renewable energy potential is largely unused. Despite the fact that all Caspian countries are provided with fossil fuel sources, all these countries committed to the transition to low-carb energy systems (Table 9). The renewable energy targets are included in a number of strategic national documents. All Caspian countries adopted national climate and energy targets, however, as it can be seen now, Azerbaijan and Russia failed to achieve its 2020 RES targets, the current contribution of RES including a hydro project in Azerbaijan is 9.7% and in Russia is 4.5% (Jan., 2020), while countries' targets are 20% and 4.5% by 2020, respectively. The cost of electricity production in Azerbaijan and Russia based on renewable energy sources is still high. The core requirement for the growth of RES in all Caspian Sea countries is extensive government involvement in the promotion of renewable energy technologies. The market financing of RES projects like in EU countries is still impossible. There is a continued need to support scientific and technological developments and create conditions for the formation of an accessible and non-barrier RES market taking into account the countries' domestic priorities. This is as much a factor of energy security as it is climate mitigation action and with the volatile markets for hydrocarbons exposing resource-rich nations to such volatile financial risks, building and maximizing renewables capacity utilizing export revenues during high price periods would contribute strongly to future energy security and domestic resilience.

In terms of limitations, in our opinion, this research can be advanced in a number of ways. We indicated that using the Z-score approach does not provide information on the relative importance of each component of the developed index. The role of each indicator to general energy security performance might be examined in future studies by applying the Analytic Hierarchy Process (AHP). The AHP is both quantitative and qualitative analysis methodology that uses to order and rank the importance of each indicator and has the potential to assist decision-makers in making choices (Vaidya & Kumar, 2006; Bruderermann et al., 2015). Furthermore, the study focuses on Russia and the Caspian Sea region, however a comparison of results obtained from other resource-rich energy-exporting countries will provide additional insight, since climate change and energy security are nowadays global agenda.



**Table 9**  
Climate and renewable targets of Caspian region.

	Climate targets	Renewable targets	Policy actions
AZE	−35% by 2030 (level 1990)	20% RES in electricity by 2020, 9.7% in TPES	State program on the development of renewable energy sources for 2012–2020, Feed-in Tariffs for wind and small hydro projects
IRN	−12% by 2030 (level 2014)	1–5 GW to total power generating capacity each year through 2022	Minimum tariff rates for investors, the Budget for Purchasing Renewable Energy Electricity, Renewable Energy Development Fund, Feed-in Tariff, Renewable Portfolio Standards
KAZ	−40% by 2050 (level of 2012)	50% RES in electricity by 2050	Auctions, Feed-in Tariff, Carbon Emissions Trading scheme, energy efficiency certificates, National 2050 Low Carbon Energy Transition Programme, Roadmap 2050 for RES, Law on Green Economy
RUS	−25% by 2030 (level of 1990)	4.5% RES in electricity by 2020	Climate doctrine and action plan, National security strategy, State program on energy efficiency and power industry development
TKM	Conditional 2030 targets: zero growth in emissions and possible reduction trajectory between 2015 and 2030	No mandatory targets on renewable energy	National Strategy of Turkmenistan on Climate Change, National Strategy of Social and Economic Transformation of Turkmenistan until 2030
UZB	No concrete targets on GHG reduction	10–20% RES in electricity by 2030	National Decree on Measures to Develop Alternative Energy Sources and Energy saving technologies

Furthermore, some problems associated with ES, for example, the energy pricing model in the industry and household sectors have to be explored much further to be adequately rigorous.

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### Declaration of competing interest

No conflict of interest exists.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.resourpol.2020.101746>.

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