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Abstract

Energy is an important geopolitical driver, and energy security is an emerging field with growing interest in its measurement. This Chapter is a guide to energy security research that aims to estimate a quantitative energy security index with a geopolitical focus, by providing an in-depth dynamic geopolitical look into the history, evolution, dimensions, data, estimation, taxonomy, and forecasts of energy security. Discussion is complemented with examples from the area of the Southeastern Mediterranean and the Middle East. The Chapter commences with documenting the state of the art of the research literature on energy security. In particular, the definitions, the dimensions, the associated geopolitical issues, the policies, and the quantitative simple indicators and complex indexes of energy security are examined. An alternative to a full panel data approach for research that aims to calculate a quantitative energy security index would be to focus on specific milestone time periods such as the first oil crisis of the 1970s, the first Gulf War of 1990–91, the Russian-Ukrainian disputes (2005–09), and the present time. The Chapter discusses how empirical geographical, energy, socioeconomic, environmental and geopolitical data could be collected, and a novel geopolitical energy security index could be developed with reference to appropriate statistical techniques. A Cluster Analysis of the data and security index values of each milestone time period could provide a dynamic taxonomy of countries, based on their energy security profile, which could be depicted on geopolitical maps. Of particular interest would be to see how countries shifted from one cluster to another over time. Following Cluster Analysis, it is suggested that a case study analysis of the energy security profile of key countries (such as Germany, Russia, Iran, Iraq, Saudi Arabia, the United States, Canada, Venezuela, China, India, and Japan) could complement the quantitative approach, and provide an in-depth appreciation of countries, the energy security issues they face, the policies they adopt to address them, and how well the obtained clustering and energy security values capture this knowledge. It is also proposed that any energy security index research include a small number of interviews with energy experts from the government, the academia, and the professional arena. It is advised that these interviews include open-ended questions on the concept of energy security, its evolution through the milestone time periods, the energy security index, the clusters, the geopolitical maps, and energy security policies. Finally, it is proposed that any energy security index research be complemented with forecasts that take into account socioeconomic and geopolitical data, the energy security index values, the dynamic taxonomy, as well as information gleaned from the interviews.

Conceptualizing and Measuring Energy Security: Geopolitical Dimensions, Data Availability, Quantitative and Qualitative Methods

John A. Paravantis, Athanasios Ballis, Nikoletta Kontoulis and Vasilios Dourmas

> *It is even probable that the supremacy of nations may be determined by the possession of available petroleum and its products.*
>
> —Calvin Coolidge, US President (1872–1933)
>
> …"*patterns of oil peace*" *would be drawn up by governments because oil was too serious an affair to be left to oilmen…*
>
> —Frankel [24]
>
> *Without data, you're just another person with an opinion.*
>
> —W. Edwards Deming (1900–1993)

Abstract Energy is an important geopolitical driver, and energy security is an emerging field with growing interest in its measurement. This Chapter is a guide to energy security research that aims to estimate a quantitative energy security index with a geopolitical focus, by providing an in-depth dynamic geopolitical look into the history, evolution, dimensions, data, estimation, taxonomy, and forecasts of energy security. Discussion is complemented with examples from the area of the Southeastern Mediterranean and the Middle East. The Chapter commences with documenting the state of the art of the research literature on energy security. In particular, the definitions, the dimensions, the associated geopolitical issues, the policies, and the quantitative simple indicators and complex indexes of energy security are examined. An alternative to a full panel data approach for research that aims to calculate a quantitative energy security index would be to focus on specific milestone time periods such as the first oil crisis of the 1970s, the first Gulf War of 1990–91, the

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Russian-Ukrainian disputes (2005–09), and the present time. The Chapter discusses how empirical geographical, energy, socioeconomic, environmental and geopolitical data could be collected, and a novel geopolitical energy security index could be developed with reference to appropriate statistical techniques. A Cluster Analysis of the data and security index values of each milestone time period could provide a dynamic taxonomy of countries, based on their energy security profile, which could be depicted on geopolitical maps. Of particular interest would be to see how countries shifted from one cluster to another over time. Following Cluster Analysis, it is suggested that a case study analysis of the energy security profile of key countries (such as Germany, Russia, Iran, Iraq, Saudi Arabia, the United States, Canada, Venezuela, China, India, and Japan) could complement the quantitative approach, and provide an in-depth appreciation of countries, the energy security issues they face, the policies they adopt to address them, and how well the obtained clustering and energy security values capture this knowledge. It is also proposed that any energy security index research include a small number of interviews with energy experts from the government, the academia, and the professional arena. It is advised that these interviews include open-ended questions on the concept of energy security, its evolution through the milestone time periods, the energy security index, the clusters, the geopolitical maps, and energy security policies. Finally, it is proposed that any energy security index research be complemented with forecasts that take into account socioeconomic and geopolitical data, the energy security index values, the dynamic taxonomy, as well as information gleaned from the interviews.

1 Preamble

Energy has been essential throughout human history, crucial for economic development and human security. According to the latest BP Statistical Review of World Energy [8], global primary energy consumption increased by 1% in 2016, following a growth of 0.9% in 2015 and 1% in 2014. Yet, energy is an economic, ill-distributed and expensive good, subject to price fluctuations, with repercussions in many domains of life. With energy being the "*precondition of all commodities, a basic factor equal with air, water, and earth*" (E. F. Schumacher, Nobel laureate economist, 1977), energy security is paramount to human security [77], and has become an increasingly popular concept for policy makers, entrepreneurs and academics. Energy security can be viewed as a public good for societies, and its insufficient provision may be associated with disruptions of the supply of oil, gas and electricity, and severe consequences for societies, economies and individuals. Consequently, energy security is a political issue combining the concepts of high and low politics.

Concerns about energy security first arose in the early 1970s in Europe, Japan and the US, as the first oil crises uncovered the vulnerability of developed economies to oil price shocks. The International Energy Agency (IEA) was created in 1974 by the countries of the Organization for Economic Cooperation and Development

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(OECD), so as to promote energy security among its member countries, through collective response to physical disruptions of energy supplies (e.g. by holding stocks equivalent to at least 90 days of net oil imports). Energy security became a matter of national security for many developed countries in the aftermath of the oil shocks of 1973. The late and great International Relations theorist Kenneth Waltz argued that there is a continuity of strategies of the major western states in energy geopolitics, and he predicted that the oil shocks, provoked by the Arab export embargo, would not cause a change of power in the West [83]. The current global attention to energy security is mostly explained by the new emerging giants of the world economy and their rising energy demand.

Energy security is a field dominated by a traditional approach to security, and means different things to different countries. The differentiation is based on their geographical location, their natural resource endowment, the status of their international relations, their political system, their economic disposition [55], and their ideological views and perceptions [58]. Approaches to energy security may differ between countries, depending on the structure of the energy system and historical experiences. This is observed in the various strategies chosen by the different member states within the European Union (EU), e.g. the degree of reliance on Russian gas and the diverse historical experiences from the Cold War that have led to different approaches to energy security ([51], as cited by Johansson [40]).

Energy security is argued to be part and parcel of security, and thus it should be high on the policy agenda of countries across the world. The Copenhagen School of security studies has described a four-level approach to international politics: the international (system), the regional (sub-system), the national (unit), and the internal (sub-unit) [16]. Energy security needs to be investigated at these four levels: globally, to ensure adequacy of resources; regionally, to ensure that networking and trade can take place; at a country level, to ensure national security of supply; and finally at a consumer level, to ensure that consumer demand is satisfied.

Yet, as it will become evident in the rest of this Chapter, part of the challenge is (1) to conceptualize energy security in a concrete way, and (2) measure it and formulate a quantitative energy security index that would be helpful in solving geopolitical problems. In this respect, this Chapter aims to be of use as an in-depth guide to: conceptualizing energy security; collecting data on various energy indicators; synthesizing a wide array of energy related variables and indicators into a geopolitical energy security index; using such an index to develop a dynamic geopolitical taxonomy of countries over time; examining key countries in depth; utilizing experts to assess gained knowledge; and compiling energy security forecasts.

Some of the background research leading to this Chapter has been published [67].

1.1 Structure of Chapter

The rest of this Chapter is structured as follows:

- Section 2 reviews the energy security research literature, with subsections covering the definitions, the history, the geopolitics, the dimensions, and the indexes of energy security.
- Section 3 presents in an organized manner a number of important research questions that were extracted from the energy security literature; these research questions could guide research aiming to develop an energy security index as well as suggest specific tasks that could be achieved with its use.
- Section 4 achieves a number of objectives, while at the same time outlining appropriate statistical techniques for addressing the research questions presented previously, and presenting examples from the Southeastern Mediterranean and the Middle East. Some of these tasks are: list sources for collecting data on a wide variety of energy security indicators; discuss historical time periods that could be focused upon; dissect energy security into components that should be accounted for in any attempt to measure it; discuss the role of Cluster Analysis (CA) in establishing groups of countries with a similar energy security level, and observe how countries change from one group to another, and how regional hotspots are formed and moved over time; examine case studies of key countries, to complement a quantitative with a qualitative approach; conduct (a small number of) key interviews with energy (security) experts to firm up the concept of any new geopolitical energy security index; and use all these tools to develop energy security forecasts.
- Finally, Sect. 5 wraps up the Chapter by presenting a few closing comments.

2 Review of Energy Security Literature

The research literature on energy security is organized around the concept of security, which, whether approached from a realist or a liberalist standpoint, is based on similar ontological and epistemological assumptions. Energy security is understood to be closely linked with national security, and greatly influenced by fossil fuels, particularly oil. It is also closely related to microeconomic and macroeconomic developments [15].

Energy security may be divided into security of supply, and security of demand [55] or into physical security (uninterrupted supply), price security, and geopolitical security. Much of the literature relates the term energy security to the security of supply. According to Kruyt et al. [47], energy security is often used as a synonym for the security of energy supply, particularly by researchers adopting an economic perspective [38, 40, 42, 49]. According to IEA [33], energy security is related to the security of supply and its physical availability. Even if energy security is a term which includes the economic competitiveness of energy, its environmental sustainability and a wide variety of geopolitical issues, the literature usually focuses on the unterrupted physical availability of energy at an affordable price [64].

2.1 *Brief History of Energy Security*

Energy security has played an important role in the 20th century. According to Yergin [90], Winston Churchill believed that oil supply security was essential to fuel his army during the First World War, and was an important concern for Germany and Japan as they invaded the Soviet Union (USSR) and Indonesia during the Second World War. During these wars, energy security was often implicitly used as a synonym for national security.

According to 2013 United Nations (UN) energy statistics, the world energy demand increased from 1676 million tons of oil equivalent (Mtoe) in 1950 to 4197 Mtoe in 1969 [18]. The dominance of oil was assured by its liquid form, which made it the only viable fuel for transportation and the emerging automobile market: solid fuels had to be burned to raise steam, and only then could they drive an engine [24]. Globally, economic growth, improved living standards, motorization, and electrification pushed energy demand in all sectors, and the international energy trade increased from 331 Mtoe in 1950 to 1513 Mtoe in 1969. Oil exporting countries formed the Organization of Petroleum Exporting Countries (OPEC) in part to address the distribution of wealth derived from oil exports. In that period, security of energy supply was not a priority in many developing countries because companies supplied cheap oil and, thus, stability. At the same time, in many developing countries the majority of the population did not have access to modern energy. In 1969, 72% of the electricity was consumed in OECD countries that had only 20% of the world total population.

It was during the 1970s that energy security arose as a problem in the research literature. In the first oil crisis of 1973, oil embargoes by the Organization of Arab Petroleum Countries (OAPEC) shook the oil importing countries to the core, while the second oil crisis shot up international oil prices above $30 per barrel, which amounted to $100 per barrel in 2015 values [18]. The year 1974 was a milestone for the energy security concept, and as a response to the 1973 oil embargo, the OECD established the IEA. During that period, international energy security still largely meant oil security. According to IEA [36], in 1979 oil shared as much as 86% of the world energy trade, and the Middle East supplied 58% of the internationally traded oil. Consequently, by the end of 1970, energy security was a high priority issue on the policy agenda, in view of its significance for the entire economy.

The concern for energy security was somewhat reduced in the 1980s, as a result of the supply expansion and lower demand for energy. Global oil imports decreased by 25% during the first half of the decade [19]. Oil was in part replaced by natural gas and nuclear energy, especially for power generation. According to IEA [36], while the world energy demand increased by 20% per year during the 1980s, the share of oil shrank from 42 in 1980 to 37% in 1989 for primary energy supply, and from 20 in 1980 to 12% in 1989 for power generation.

The early 1990s were marked by the First Gulf War (https://history.state.gov/departmenthistory/short-history/firstgulf) and the collapse of the Soviet Union (https://history.state.gov/milestones/1989-1992/collapse-soviet-union). Energy security gained momentum after that, when global resources became scarce, in the face of a growing global demand for energy. At the time of the First Gulf War (1990–1991) and the dissolution of the Soviet Union (1991), new concepts emerged, and the concern for energy security began to gain prominence in global discourse [90]. According to 2013 UN energy statistics (https://unstats.un.org/unsd/energy/yearbook/2013.htm), power demand in non-OECD countries grew much faster than that of the OECD countries, although 63% of electricity was still consumed within OECD. Global warming issues became gradually institutionalized throughout the decade. The Kyoto Protocol was signed in 1997, and was the first international treaty to outline emission targets for combating global climate change. Implementation required participating members to create policies and measures to reduce and offset domestic emissions, and increase absorption of greenhouse gases.

As mentioned by Yergin [91] and Hancock and Vivoda [31], the energy security issue re-emerged in the 2000s, driven by the rising demand in Asia, disruptions of gas supplies in Europe, and the pressure to decarbonize energy systems. In 2005 the Russian federation cut down the supply of gas to Ukraine on the premise that they were not ready to accept the new prices. As a result, the supply of gas towards western European was also shortened. The Russian-Ukrainian crises of 2006 and 2009 showed that the main supplier of the EU was not only unreliable, but capable of using energy resources as a geopolitical weapon as well. A more recent revival of interest in energy security was stirred by high oil prices (in the period up to 2008), as well as geopolitical supply tensions [33]. At the same time, terror attacks led to the wars in Afghanistan and Iraq. The Arab Spring and the Islamic State created further tensions and instability. Finally, in 2011 the Fukushima nuclear accident revived important questions about the safety of nuclear energy.

So, the meaning of energy security expanded over time. Deviating gradually from the origin of the wording that suggested stable energy flow, the fair price element was added in the 1970s and 1980s. Recently, energy security became closely entangled with other energy policy problems, such as providing equitable access to modern energy, and mitigating climate change [27].

2.2 Defining Security and Energy Security

When one tries to define energy security, the question of what the term security means in general emerges. The Walzian notion of security asserts that the issue of security stems from the anarchical structure of society [83]. Neoclassical realism, as expressed by Morgenthau [63] and Klare [44], considers energy as a geopolitical tool to pursue state goals, and adds an element of hard power with overlapping military, political and economic dimensions.

According to Winzer [84], the attempts to define energy security have varied over time because of challenges in the realm of energy policy. Different countries may define energy security differently, in relevance to their own energy situation, and their vulnerability to energy supply disruptions. Countries not only differ in their definition of energy security, but also in the way they address energy security challenges [55].

Some authors [91]; IEA [33] point out that the term of energy security is not clearly defined; consequently there is no universal concept of energy security. Taking into consideration the absence of a clear definition [47]; APERC [4], energy security has become an umbrella term for different policy goals [84]. A multiplicity of concepts and dimensions enter the realm of energy security. Chester [12] aptly described energy security as "*slippery*" and "*polysemic*". The diversity of definitions is shaped by the perspective and nature of different countries, and their place in the energy chain and the complex global energy system.

Countries may be divided into three groups: producers/exporters, who wish to ensure reliable demand for their commodities; consumers, who commonly aim towards diversity of energy supply to maximize their security; and transit states, who are the essential bridges connecting producers/exporters with their markets [55]. Given the above differentiation among countries, there are two important concepts for energy security: security of supply (for the consumers), and security of demand (for the exporters). For energy exporting countries, the security of demand is equally important to the security of supply [40].

According to Sovacool [74], there are at least 45 different definitions of energy security that share a great deal of similarity among them, and lead to difficulties in terms of the operationality of the concept. Ang et al. [3] identified 83 energy security definitions in the literature. As pointed out by Cherp and Jewell [11], a classic definition of energy security is provided by Yergin [89], who visualized energy security as the assurance of "*adequate, reliable supplies of energy at reasonable prices,*" adding a geopolitical component by qualifying that this assurance must be provided "*in ways that do not jeopardize national values or objectives*". Yergin's definition identifies "*national values and objectives*" as the assets that safeguard energy security.

The IEA, a pioneer institution in energy security and the most important multinational platform, defines energy security as the "*uninterrupted availability of energy sources at an affordable price,*" and considers it to have a long-term and a short-term aspect. The IEA has restated the definition through the years to characterize energy security as the adequate, affordable and reliable supply of energy. Long-term energy security relates to "*timely investments to supply energy in line with economic developments and environmental needs*". Short-term energy security relates to "*the ability of the energy system to react promptly to sudden changes in the supply-demand balance*" [35, 39, 43].

In 2000, the European Commission [21] referred to energy supply security as "*the uninterrupted physical availability of energy products on the market, at a price that is affordable for all (private and industrial) consumers, while respecting environmental concerns and looking towards sustainable development*". This was an extension of the IEA definition, involving the inclusion of environmental and sustainability issues.

Definitions of energy security [4, 21, 33, 91] mainly use the term availability to imply stable and uninterrupted supply of energy. Other authors [41, 85] use the term reliability for energy infrastructure. Accessibility has been at the center of the energy security debates and policy approaches into the 21st century [45]. So, as an extension to the original IEA definition of energy security, the Asia Pacific Energy Research

Centre (APERC [4] highlighted the four As of availability, affordability, accessibility (to all), and acceptability (from a sustainability standpoint), and defined energy security as "*the ability of an economy to guarantee the availability of the supply of energy resources in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy*". Cherp and Jewell [11] compared the 4 As to the five As of access to health care (availability, accessibility, accommodation, affordability and acceptability). The first two As (availability and affordability) constitute the classic approach to energy security (20th century), while the latter two (accessibility and acceptability) reflect certain contemporary concerns (21st century) e.g. fuel poverty and global climate change.

2.3 Energy Security Since the 20th Century

Chester [12] and Vivoda [82] highlight the polysemic and multi-dimensional nature of energy security. Chester suggested that the term has risen highly on the policy agenda of governments because there is a complex system of global markets, a vast cross-border infrastructure network, and a small group of primary energy suppliers. Manson et al. [57] have described the energy security as a dynamic concept, with a perspective that depends on the time frame analyzed.

Energy security studies have changed in scope and focus over time, evolving from classic political economy studies of oil supplies for industrialized democracies, to a research field addressing a much wider range of energy sectors and energy security challenges [11]. The sources that Cherp and Jewell cite show that, in the 1970s and 1980s, energy security signified the stable supply of cheap oil, and threats to energy security included threats of embargoes, and price manipulation by exporters. Contemporary energy security studies: go beyond OECD oil importers; include nations at all levels of developments (that extract, import and export); address perspectives on energy security of non-state actors, including, individual regions, utilities, consumers, and global production networks; examine a variety of energy sources and carriers; address environmental issues such as climate change; address equity issues, mainly providing equitable access to energy; and address a wider range of threats.

Chester [12] described the energy regime after the Second World War, highlighting some important characteristics. During that time, there was a growing dominance of fossil fuels, particularly of Middle Eastern oil, which in 2008 accounted for one third of world energy use. Oil was cheap until the oil shocks of the 1970s, effectively triggered by the OPEC. As a consequence, energy security became synonymous with the need to reduce dependence on oil consumption.

The 1970s economic crisis took place at a time when production was internationalized against a backdrop of rampant inflation, persistently high unemployment, growing government expenditures, declining productivity, shrinking revenues, and smaller profits margins. Accepted management strategies failed to restore the growth of the 1950s and 1960s. In the 1980s, the need for the introduction of greater competition and less government involvement was strongly advocated for the electricity, telecommunications, and gas grids, so the energy markets took the path towards restructuring and liberalization. Monopolies were broken up, and new pricing schemes were introduced. This restructuring was promoted by the OECD, the World Bank, the International Monetary Fund (IMF), and international trading agreements.

In the meantime, nuclear energy was developed rapidly. By the end of the 1970s, 25 countries were generating electricity from nuclear power (including the US, the UK, France, Germany, and the former Soviet Union). The public acceptance of nuclear energy was hit by the Three Mile Island (USA 1979) and the Chernobyl (USSR 1986) accidents. The growth of nuclear energy was slowed down by high capital costs, lengthy construction times, problems with decommissioning older nuclear plants and disposing their radioactive waste, reactor safety, and concerns about the potential use to produce nuclear weapons [54]. By 2006, nuclear energy accounted for around 15% of the world's electricity generation, compared to 41% for coal, and 20% for gas. Interestingly, the current climate change debate has rekindled interest in nuclear energy as an energy source that is low in carbon dioxide emissions (more concerns will be discussed in Sect. 4.3.4 of this Chapter).

Consequently, the emergence of nuclear power reduced the role and geopolitical significance of coal. While oil had become the dominant fuel by 1930 mainly due to its importance in transport, it replaced coal as the industry's primary energy source in the 1950s. It is worth pointing out that these two energy sources are very different economically [24]: on the one hand, while locating coal seams is relatively easy (i.e. cheap), bringing coal to the surface is very costly; on the other hand, while locating oil is very difficult (with one fourth to 95% of exploratory holes failing to yield oil), once located oil rises to the surface under its own steam. In the meantime, the advent of supertankers and the development of pipeline networks lowered the price of oil and natural gas. Gas accounts for about a quarter of global energy consumption [86], a dominance which has been catalyzed by the development of a global market for Liquefied Natural Gas (LNG). The geopolitical problem is that natural gas resources are concentrated in a handful of countries, with the former Soviet Union and the Middle East holding about three quarters of known world reserves [8].

Presently, developing nations are characterized by escalating energy demands. Of these, China and India ("*Chindia*") have emerged as major geopolitical players, key energy consumers, and major energy producers. Interestingly, China's growth has taken place hand in hand with a rapid growth in China's coal consumption, and an increase in its share of coal in world energy use. As of 2017, the cost of coal was comparatively low, as oil and natural gas prices had escalated and remained high. The political instability in supplier countries, rapidly increasing oil prices, the increasing frequency of disruptions to gas supplied from Russia to Europe, terrorist attacks, and extreme weather events (e.g. the Hurricane Katrina that hit the Gulf coast of the US in 2005) often followed by electricity blackouts, constitute additional energy security risks.

2.4 Energy Security and Geopolitics

The consequences of the two oil crises of the 1970s uncovered the degree of vulnerability and dependence on fossil fuels of the industrialized Western world. Conant and Gold [13] made the first systematic study of energy issues, from a geopolitical perspective, asserting that "*the country having control over resources will control those who rely on the resources, which will lead to a profound transformation of International Relations*".

Energy geopolitics gained momentum after the 1990s, when global resources (mainly fossil fuels) became scarce in the face of a growing world demand for energy. These changes in the global energy geopolitical situation after the Cold War were documented by Mitchell et al. [61]. The term "*new geopolitics*" was used to reflect factors such as the end of the Cold War, the transformation of the international energy trade by the Russian oil and gas resources, and the increase of the importance of natural gas and related technology developments.

Despite the fact that the concept of energy security has varied across different time periods, it remains central to the study of geopolitics and the global agenda. Esakova [20] presented the relationships in the energy sector, as interdependencies between energy producers and energy importers. Due to the interdependence of energy markets and energy prices, energy producers are also highly interconnected among themselves [40]. The same applies to energy importers, who are often forced to cooperate in order to ensure collectively their energy security. Exporting and energy importing states normally have contradictory interests: the first group is interested in the security of energy demand, while the latter seek the security of energy supply.

The concept of energy security is central to the study of geopolitics. Vivoda [82] pointed out the following issues that have made energy security an emerging area of focus in international relations: high energy prices; the increasing demand for geographically concentrated resources; the threat of resource scarcity and depletion in the foreseeable future; and concern for the likely social and political effects of climate change.

Citing several literature sources, Johansson [40] suggested that ongoing or potential conflicts over small islands or water areas (such as the South China Sea and the Arctic Region) may be attributed to the existence of valuable energy resources. Furthermore, it is pointed out that US military activities in the Middle East (such as in Iraq) may be motivated by the Carter Doctrine, enunciated by President Jimmy Carter on January 23rd, 1980: "*An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force.*" (http://www.presidency.ucsb.edu/ws/?pid=33079).

Johansson [40] has also argued that the development of large-scale solar power in North Africa for import to the EU, may create dependencies with security policy implications for Europe. Furthermore, Johansson has suggested that the presence of abundant energy and natural resources in poor countries may create regional insecurity, a phenomenon known as the resource curse.

Citing 2009 BP data, Vivoda [82] argued that the following 10 largest regional economies consume 61% of the world's energy, producing 54% of the world's Gross Domestic Product (GDP), and emitting 66% of the world's carbon dioxide (CO_2): United States, Canada, Mexico, Russia, China, India, South Korea, Japan, Australia and Indonesia. These data show a major geopolitical disconnect: the world's top four oil consumers (China, Japan, India and the US) account for 42% of the world's oil demand, but control only 4% of global oil reserves. Vivoda asserted that energy security concerns among these four major powers have the potential to cause power competition so intense that may translate into open confrontation, especially in the Asia-Pacific region, the world's fastest growing energy consumer and a strategically vulnerable region of paramount importance for global stability and development. Vivoda also observed that the world's top ten regional economies are characterized by very different energy efficiency and carbon intensity values, citing as examples: Japan being four times as efficient as Russia, and four times as efficient as China; the economies of Russia, China and India being five to six times as carbon intensive as Japan; and the inefficient use of energy (with a high carbon intensity), creating energy-related pollution in Russia, China and India. Consequently, the growth of energy use in the Asia-Pacific region, particularly in China and India, is likely to have profound impacts on the energy landscape, and may have major geopolitical consequences.

2.5 Dimensions of Energy Security

The historical discourse on energy security has shown that it encompasses a number of dimensions. According to Kruyt et al. [47], the bulk of the recent literature on energy security seeks to classify energy security concerns into dimensions, even if this classification has been criticized for lacking transparency, being systemically unjustified, and arbitrary [10].

The IEA considers energy security to have three components: reliable and uninterrupted supply; affordable and competitive supply; and accessible or available supply (http://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity). Furthermore, the IEA has proposed the following characteristics for energy security measurement: physical availability that accounts for geopolitical energy security; pipe-based import dependence; power system reliability; and market power [12]. A study by the U.S. Chamber of Commerce [81] presented four dimensions of energy security: geopolitical (energy imports, particularly from politically unstable regions); economic (high energy intensity and trade imbalances); reliability (adequacy and reliability of infrastructure); and environmental (related to the carbon intensity of energy systems).

In the words of Cherp and Jewell [10]: "*there are three perspectives on energy security, namely those of sovereignty, robustness and resilience*". Alhajji [1] differentiated between six dimensions of energy security: economic, environmental, social, foreign policy, technical and security. Vivoda [82] listed seven salient energy security dimensions (environment, technology, demand side management, socio-cultural or political factors, human security, international elements like geopolitics, and the formulation of energy security policy) and 44 attributes of energy security.

Sovacool and Mukherjee [77] considered energy security to comprise five dimensions that may be broken down into 20 components, as follows:

- *availability*: security of supply and production, dependency, and diversification;
- *affordability*: price stability, access and equity, decentralization, and low prices;
- *technology development*: innovation and research, safety and reliability, resilience, energy efficiency, and investment;
- *sustainability* (i.e. environmental component): land use, water, climate change, and air pollution;
- *regulation*: governance, trade, competition, and knowledge of sound regulation.

To this end, Sovacool and Mukherjee have assembled 320 simple indicators and 52 complex indexes of energy security.

In a study for the evaluation of energy security in the Asia-Pacific region, Sovacool [74] listed 20 dimensions of energy security identified by experts. For each dimension (availability, dependency, diversification, decentralization, innovation, investment, trade, production, price stability, affordability, governance, access, reliability, literacy, resilience, land use, water, pollution, efficiency, and greenhouse gas emissions) a number of metrics and indicators was presented.

Putting energy security dimensions into perspective, Radovanović et al. [69] pointed out that it is not possible to develop a unique methodology of assessing energy security because each country has a different wealth of energy resources. The use of these resources differs in: the type and intensity at different points of development; climate; geopolitical position; demographic indicators; economic growth; and strategic priorities, which depend on the historical, social and political social conditions [12]. Furthermore, Radovanović et al. argued that all countries try to improve their energy security by increasing energy efficiency, improving the stability of energy systems, reducing energy vulnerability, and increasing self-sufficiency.

Key energy security models, indicators and indexes are reviewed next.

2.5.1 Energy Security Models

The *IEA Model of Short-Term Energy Security* (MOSES) [39] is designed to analyze short-term energy security in IEA member countries, and it functions as a tool to understand the energy security profiles, and identify energy policy priorities. The MOSES model looks at resource adequacy, diversity, flexibility, asset performance, and sustained emergency events [43]. MOSES uses 35 indicators each of which relates to one of the dimensions and is meant to indicate a "*level of risk*" or the "*adequacy of resilience*" of the energy sources under investigation [35, 39].

MOSES has produced some interesting results. Energy security, in terms of diversity of supply of crude oil and oil products, is the highest in Denmark, Estonia, France and Italy. In terms of natural gas, Hungary, Ireland, Finland and Sweden are at the

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greatest risk. Relatively lower risk is reported for Austria, Luxembourg, Greece, Slovakia and Czech Republic, and the lowest for Denmark, Italy, Estonia, France and the United Kingdom. When it comes to natural gas, the same research took storage capacities (expressed as a percentage of annual demand) into account for the assessment of energy security. Results indicated that Estonia, Switzerland, Luxembourg, Norway, Finland and Sweden are at the greatest risk in this respect. Medium level of risk was reported by the United Kingdom, the Netherlands, Germany, Italy, Spain, France and Czech Republic. The lowest risk is reported by Austria, Hungary and Slovakia. When it comes to coal, not a single European Union country has more than 60% of coal from its own reserves, so the risk was determined indirectly, by considering the adequacy of importing infrastructure. The highest level of risk in this regard is reported by Finland and Switzerland [69].

The *Risk of Energy Availability*: *Common Corridors for Europe Supply Security* model (REACCESS) [71] is a unique world model that links three sub-models: the Pan European TIMES multi-regional model (PET36); the global multi-regional TIMES Integrated Assessment Model (TIAM-World); and the REACCESS Corridor (RECOR) model, representing the technical-economic details of all energy corridors, which bring energy from all resource-rich locations to consuming regions. REACCESS is a large partial equilibrium model of the global energy system representing 51 regions: the 36 countries of PET36 plus the 15 regions of TIAM-World remaining after the EU region is excluded from consideration.

2.5.2 Energy Security Indicators and Indexes

The conceptualization and formulation of energy security dimensions is the first step for an analysis of energy security. These dimensions must be complemented by indicators which should relate to the dimensions, and seek to quantify the identified energy security risks and concerns [10]. The aggregation of indicators into composite indexes allows a comparison between energy security risks and policy trade-offs.

The interest in measuring energy security results not only from its rising prominence, but also from its increasing complexity. Many indicators are available in the literature, based on the perspective of the user [64]. The literature on the indicators of energy security is quite extensive [28, 33, 49, 53, 78] and may be a useful tool for monitoring, measuring, and evaluating the current and future effects of energy security on the economy, the society, and the environment. Indicators for energy security are necessary to link the concept with model-based scenario analyses in the context of addressing policy issues related to affordable energy and climate change [47].

Chester [12] suggested that there are quantitative and qualitative approaches to the measurement of energy security. Threats to energy security are short-term (operational), and long-term (related to adequacy of sources, transit, storage and delivery). The literature reviewed by Chester suggests that the quantifiable energy security indicators have the potential of being analytically helpful, and are necessary to assess the consequences of alternative development scenarios.

Various studies [43, 69, 77, 78] have proposed a wide variety of energy security indexes, either to compare performance among countries or to track changes in a country's performance over time. In these studies, some indicators are first identified based on specific considerations or theoretical framework. This is followed by data collection, normalization, weighting, and aggregation of the chosen indicators to give one or more composite energy security indexes. A quick review of these studies has shown that there are large variations in the choice of indicators [3]. Radovanović et al. [69] applied Principal Component Analysis (PCA) to assess the impact of individual indicators on an energy security index and found energy intensity, GDP per capita, and carbon intensity to have the greatest impact on energy security (more on this in Sect. 4.4).

Sovacool [74] defined an index with 20 dimensions and 200 attributes. In a subsequent work, Sovacool and Mukherjee [77] reduced the number of dimensions to five and the number of attributes to 20. Sovacool et al. [78] applied the index to a set of countries, and found that Japan had the highest energy security index among the 18 countries considered. The impact of the Fukushima nuclear accident on Japan's energy system and economy, hints at the (often unexpected) difficulties that may be encountered when attempting to construct robust energy security indexes.

Ang et al. [3] reviewed 53 studies that dealt with energy security indicators, and found the number of indicators examined to vary from a few to more than 60. About two-thirds of the studies employed no more than 20 indicators. Their research identified that there are two major types of studies that use energy security indicators: those that deal with performance over time, and those that compare performance among countries, with no significant difference in the number of indicators used.

Turning to specific indexes, the *Herfindahl-Hirschmann Index* determines the degree of a certain country's dependence on a certain supplier, and may be used as an indicator that indirectly points to the energy security of a country [69]. The *Supply/Demand Index for the long-term security of supply* (SD Index) [73] has been designed on the basis of expert assessments on all possible relevant aspects of the security of supply, and covers demand, supply, conversion, and transport of energy in the medium to long-term [47]. It is a composite indicator (i.e. an index) that comprises 30 individual indicators, and considers the characteristics of demand, supply and transport [69]. According to Kruyt et al. [47], the basic difference with other indicators, is that the SD Index attempts to grasp the entire energy spectrum, including conversion, transport, and demand (taking into account that a decrease in energy use lowers the overall impact of supply disruptions).

The *Oil Vulnerability Index* (OVI) [30] is an aggregated index of oil vulnerability, based on seven indicators: ratio of value of oil imports to GDP; oil consumption per unit of GDP; GDP per capita; oil share in total energy supply; ratio of domestic reserves to oil consumption; and exposure to geopolitical oil supply concentration risks, measured by net oil import dependence, diversification of supply sources, political risk in oil-supplying countries, and market liquidity. According to Radovanović et al. [69], the OVI is a comprehensive composite indicator that manages to consider economic indicators, import dependence, and political stability.

The *Vulnerability Index* [26] is a composite indicator which considers five indicators: energy intensity; energy import dependency; ratio of energy-related carbon emissions to the total primary energy supply (TPES); electricity supply vulnerability; and lack of diversity in transport fuels [69]. The six-factor *Risky External Energy Supply* [49] is entirely supply-oriented, and considers solely the level of diversification, with particular emphasis given to the assessment of transport safety of energy generating products [69].

The *Aggregated Energy Security Performance Indicator* (AESPI) [59] has been developed by considering 25 individual indicators representing social, economic, and environmental dimensions. The indicator (essentially an index) ranges from zero to 10, and requires time series data for its estimation. The advantages of AESPI is that, it not only assists in knowing the past energy security status of a country, but also helps in assessing the future status considering the energy policies and plans, thus enabling monitoring the impacts of policies.

The *Socio-economic Energy Risk* is a composite index that considers the following indicators: energy source diversification, energy resource availability and feasibility, energy intensity, energy transport, energy dependence, political stability, market liquidity, and the GDP [69].

The *US Energy Security Risk Index* [81] is an index based on 83 individual indicators assessing geopolitical indicators, economic development, environmental concerns and reliability [69].

The *Energy Development Index* (EDI) [39] is composed of four indicators, each of which captures a specific aspect of potential energy poverty: per capita commercial energy consumption (which serves as an indicator of the overall economic development of a country); per capita electricity consumption in the residential sector (which serves as an indicator of the reliability of, and consumer's ability to pay for, electricity services); share of modern fuels in total residential sector energy use (which serves as an indicator of the level of access to clean cooking facilities); and the share of population with access to electricity. This index was intended as a simple composite measure of the progress of a country or region in its transition to modern fuels, and of the degree of maturity of its energy end use [32].

The *Energy Security Index* is composed of two indicators (ESI_{price}, ESI_{volume}) that measure the energy security implications of resource concentration, from the viewpoint of both price and physical availability [33]. ESI_{price} is a composite measure of the diversification of energy sources and suppliers, and the political stability of exporting countries, while ESI_{volume} is a measure of the level of dependence of natural gas imports.

In what constitutes an interesting concept, the "*energy trilemma*" is defined as balancing the trade-offs between three major energy goals, namely energy security, economic competitiveness, and environmental sustainability [3]. The dimensions of energy trilemma are defined by WEC [85] as follows:

- *Energy security*: Effective management of primary energy supply from domestic and external sources, reliability of energy infrastructure, and ability of energy providers to meet current and future demand.

- *Energy equity*: Accessibility and affordability of energy supply across the population.
- *Environmental sustainability*: Encompasses the achievement of supply and demand-side energy efficiency, and the development of energy supply from renewable and other low-carbon sources.

The Energy Trilemma Index, formerly known as the *Energy Sustainability Index*, was first introduced in 2009, ranking close to 90 countries. This ranking has been expanded to include 130 countries and greater detail about the performance of countries on the specific trilemma dimensions by adding a balance score, and an index watch list to indicate countries that are expected to display trend changes in the next few years [3]. The Index 2.0 methodology uses a set of 34 indicators and approximately 100 data sets to rank countries on their trilemma performance (compared to 23 indicators and 60 data sets in the previous index methodology; WEC [85]).

Finally, the *Energy Architecture Performance Index* (EAPI) was proposed in 2010 by the World Economic Forum (WEF), and was modified the next year into the *Energy Sustainability Index* [87]. EAPI is a composite index based on a set of indicators divided into three basic categories (energy security, energy equity, and environmental sustainability), the so-called *Energy Trilemma Index* [69].

More on some of these indexes this will be graphed and discussed in Sect. 4.4.

3 Methodology

In a seminal work, O'Neill [65] discusses social scientist authors setting up game theoretic models, but failing to follow through with the mathematics, thus failing to use game theoretic tools to advance their research. O'Neill calls this approach "*proto-game theory*". In a similar vein, much energy security research addresses the development of energy security indexes, but fails to achieve much with them (beyond e.g. sorting countries according to the value of some energy security index) in way of solving real geopolitical problems.

According to Ang et al. [3], research on energy security may follow either a qualitative or a quantitative approach, with the former relying on theory and geopolitical considerations, and the latter focusing on the analysis of mostly numerical indicators [92]. This Chapter explains how these two approaches may be combined by outlining methods that would allow the formulation and estimation of an energy security index (with a geopolitical slant) by: analyzing various types of data; resorting to CA and tracking clusters of countries over time; analyzing case studies; and incorporating the opinions of energy experts through interviews. Such approaches would help solve geopolitical problems and develop forecasts, taking into account the diversity of country interests over space and time, and the polysemic nature of energy security that has risen near the top of the agenda of the international community.

3.1 Research Questions

The tasks that a researcher would have to pursue in an endeavor to develop and use a geopolitical energy security index are formulated and presented below in the form of grouped research questions.

1. *Literature*: What is the state of the art of the research literature on the topic of energy security? How has the definition of energy security changed over time? What are the dimensions of energy security? What has the role of energy security been in the foreign policy of energy-exporting, energy-importing, and energy-transition countries? What geopolitical issues has it been mostly associated with? Are there important aspects related to energy security that current research methods have failed to capture?
2. *Milestones*: Which specific time periods could be regarded as important milestones in the history of energy security? What were the socioeconomic and geopolitical characteristics at these times? How was energy security conceptualized at each milestone time period, and what specific data should be taken into account? While continuous annual data could be collected for the estimation of an energy security index (which would be quite demanding), the authors of this Chapter believe that the establishment of a few distinct milestones that were associated with important geopolitical events would be more fruitful, for better calibration of the results and a more focused (and thus efficient) utilization of the energy security index.
3. *Data*: What (online) sources may be used for collecting data for the development of an energy security index? What kind of data are contained in these sources? What data types may be collected? Which areas of the world or specific countries appear to not be well covered, and at which time periods? What kind of analyses may be run with these different types of data? What problems should one be aware of? What statistical software is suggested for these analyses?
4. *Index*: How may an energy security index be formulated and estimated, based on the data collected in the context of the previous research question? Based on the published literature, what issues might hinder the development of an energy security index geared towards geopolitical considerations, and how can they be overcome? What socioeconomic and geopolitical data would be required to estimate an energy security index? How may different types of data be of use in addressing specific types of research questions? What would the values of an energy security index (annual or at the milestone time periods) be for most countries of the world? How have they changed over time? Beyond observing how energy security is associated (perhaps causally) to major geopolitical events, how could the milestone time periods be used otherwise to bring added value to the research? How do other energy indicators and indexes compare, e.g. which aspects are better covered, and which aspects are not well addressed by them?
5. *Clusters*: Having formulated and estimated an energy security index, it is proposed that one of the most useful things that could be done with it, would be to cluster analyze the countries of the world across different time periods according

to the values of the energy security index and possibly some complementary socioeconomic and geopolitical indicators that were left out of the index; this, to the knowledge of the authors of this Chapter, has not been attempted in the published literature. Related questions might include: Could the countries of the world be organized fruitfully into similar groups, based on various socioeconomic, geopolitical characteristics, and the values of the energy security index? How many such groups exist at each milestone time period (or annual time series)? Have countries moved from one group to another over time? Depicting these findings on a dynamic map (that would involve the use of a Geographical Information System or GIS software tool), which were the geopolitical hotspots from an energy security perspective (at each milestone or time period), and how have they changed and moved over time? Which energy policies have been pursued by energy import countries, energy export countries, and energy-transition countries, to address the issues of the energy security challenges they face? How are such energy policies related to the foreign policy of these countries? Can any insights be drawn as to why countries under comparable international conditions prioritize energy security differently (as observed in Sect. 2)?

6. *Cases*: The results of any quantitative analysis could be complemented with the study of individual cases. To this end, selected key countries could be analyzed as case studies that could showcase the application of the entire approach in geopolitical issues. Different countries could be selected at different milestones, in part aided by the clustering of countries, and other specifics of the statistical analyses. A full longitudinal statistical analysis could also be employed, although this would be more demanding in data (as will be seen in Sect. 4.2). Questions that could be addressed during the examination of case studies include: How has the participation of these key countries in energy security clusters changed from one milestone time period to another, i.e. have they shifted from one group to another over time? Have the energy security related policies of these countries changed over time? Does the involvement of an energy security index shed light on the analysis of these policies, and does it help determine the efficacy of energy security policies over the milestone time periods (or a complete time series)?
7. *Experts*: To add more perspective from a qualitative approach, an energy security researcher could turn to a group of energy experts in order to seek answers to questions such as: How may a small group of energy security experts be defined (i.e. what is an "energy security" expert)? What criteria should be used for selecting and including individuals to the group? What would the resulting identity of these experts (including government officials, academics and professionals) be? What would their opinion be of the concept of energy security, perhaps with emphasis on the milestone time periods (which would be easier to poll compared to registering their view for a complete time series)? How would they judge the energy security policies that the case-study countries have followed over time? Finally, what would their opinion of the energy security index be, and would they agree with the findings that would have resulted from its usage?
8. *Forecasts*: The final issue to address in an energy security research could be the issue of forecasts. A research work that would have developed an energy security

index and responded to the previous questions, would probably want to address the following issues: How may energy security forecasts be developed? How are the energy security index values expected to vary in the foreseeable future, and what are the corresponding geopolitical implications? How may such forecasts take into account global climate change, and any surrounding uncertainties?

Attention now shifts to a detailed discussion of the research tasks that would have to be undertaken to answer some of the aforementioned questions.

4 Analyses and Results

This section details the analyses that would have to be run to address the research questions outlined in the previous section.

Research question 1 (*Literature*) has been addressed in Sect. 2 of this Chapter, so this section commences with research question 2 (*Milestones*), i.e. the task of defining appropriate key time periods for energy security research.

4.1 Milestone Time Periods

Vivoda [82] has argued that the definition and dimensions of energy security are dynamic and evolve as circumstances change over time. Furthermore, energy security regimes tend to be transformed or even weaken over a period of time. Therefore, taking time into account is important in energy security research.

To address the second research question (*Milestones*), it is recommended that an energy security researcher focus on a small number of distinct and well defined milestones that were characterized by important energy events in the post-1970s world (the energy world before 1970 was vastly different; [24]). An examination and analysis of such milestones should look at the socioeconomic and geopolitical dynamics that culminated at those times.

Four such milestones are proposed and described in the following sections: the first oil crisis of 1973–74, the Gulf War of 1990–91, the period of the Russia–Ukraine gas disputes, and the present (2018, at the time of writing).

4.1.1 Milestone 1: First Oil Crisis (1973–74)

The first oil crisis was caused by a number of measures that were coordinated by the members of the Organization of Arab Petroleum Exporting Countries (OAPEC), and were directed at the countries that had supported Israel in the Yom Kippur War (1973).

The year 1974 has been a milestone for the energy security concept. As a response to the 1973 oil embargo, the Organization for Economic Cooperation and Development (OECD) established the IEA. During that period, the concept of international energy security still largely meant oil security. Back then, it was all Middle Eastern oil: IEA [36] data show that oil shared as much as 86% of the world energy trade in 1979, while the Middle East supplied 58% of the internationally traded oil.

This is, without doubt, a very important first milestone that should be taken into consideration in energy security research that aims to develop a geopolitical energy security index.

4.1.2 Milestone 2: Gulf War (1990–91)

Energy geopolitics and the concept of energy security gained momentum after the 1990s, when global resources became scarce in the face of a growing world demand for energy. Concurrently, the first Gulf War (1990–1991) and the dissolution of the Soviet Union (1991) took place (as mentioned previously), new concepts emerged, and concern for energy security began to gain prominence in the world's discourse [90].

As mentioned, global warming issues were gradually institutionalized throughout the decade, while the signing of the Kyoto Protocol in 1997 marked the starting point of countries considering the concept of energy security coupled with environmental protection and sustainable development.

4.1.3 Milestone 3: Russia–Ukraine Gas Dispute (2005–9)

The Russia-Ukraine gas disputes refer to a number of periods of tension that occurred around the beginning of the 21st century, against a constant backdrop of rather complicated intergovernmental relations between Russia and Ukraine.

Energy security has played an important role in Russian-Ukrainian relations since Ukraine became independent in 1991. The two major crises that stick out in the bilateral gas relationship occurred in 2006 and 2009. During both of these disputes, Russia halted the supply of gas through Ukraine, which is the basic energy-transition country between Russian gas and the EU.

Ukraine is a key factor in the global energy arena because half of Russia's total gas exported to Europe is transmitted through the Ukrainian pipeline system [37]. As a result of the above disputes, several European countries lost gas supplies, and the matter of diversifying the energy sources and transportation routes emerged as an important concern in the EU. The most severely affected countries were in Southeastern Europe, most of which relied completely on Russia for gas, and at the time did not have sufficient alternative energy sources [68].

The 2009 dispute is considered the most serious of all. The crisis of 2009 became a battle of self-image for both Russia and Ukraine in Europe; Russia's reputation as a supplier to Europe and Ukraine's reputation as a transit country were seriously damaged. The 2009 dispute ended with an agreement, where the heads of Gazprom and Naftogaz (the national oil and gas company of Ukraine) signed supply and transit contracts covering the ten-year period 2009–19.

The milestone of Russia-Ukraine gas disputes is important from an energy security perspective. The security of gas supply has a totally different meaning than the security of supply of oil. Gas is mainly sold on the basis of long-term bilateral contracts, and shipped through dedicated pipelines, which often cross several countries; with oil, the main issue is that there is no global market for an interchangeable product [50].

4.1.4 Milestone 4: Present (2018)

Presently, energy technologies keep advancing, the awareness of climate change and sustainability issues are on the increase, and the facets of energy security are being reshaped (as evidenced by the review of the literature). The global attention to energy security may be explained by the new emerging giants of the world economy (China and India included) and their rapidly rising energy demand.

As the geopolitical changes that commenced in the 20th century continue in the 21st century, and constitute a basic dynamic component of the concept of energy security, the present time (2018) is proposed as an appropriate final milestone that should be considered.

4.2 Data

To adopt a marketing approach to data science (as it bears to research in the field of energy security), there are primary data, secondary data, and marketing intelligence [56]. Primary data are originated by a researcher for the specific purposes of a particular research task, may require a longer time frame to collect, and are often more expensive to generate. Secondary data are usually of a quantitative nature, are collected for purposes other than those of the researcher that accesses them, and are oftentimes used by many researchers. Marketing intelligence may be defined as "*qualified observation of events and developments in the marketing environment*" [56] and may, for instance, refer to expert opinions in the case of energy security. Such marketing intelligence usually is of a qualitative nature, suffers from poor structure, and since it is opinion based may be characterized by varying credibility. It is much easier to evaluate the accuracy of secondary data than marketing intelligence [29], i.e. the opinion of experts. While marketing intelligence is used systematically by companies such as Microsoft, IBM and Coca Cola, it is also employed by companies in the field of energy, such as General Electric [56]. The rest of this section is devoted to secondary data, although mention of primary data will be made later on (when discussing expert interviews in Sect. 4.7).

Secondary data are easily accessible (usually online), and may be obtained quickly and inexpensively. Yet, with secondary data, a researcher may not be aware or information such as the margin of error or the response rate (in cases where secondary data were collected with a survey). In fact, a variety of accuracy issues plague all types of secondary data [29]: observational errors; approximations and roundoffs; selectivity bias created by nonresponse (for data that were collected by survey); biases created by different sampling methods; a high level of aggregation (often due to confidentiality). Therefore, the reliability, dependability and generalizability of data may be questionable [56]. Furthermore, secondary data may not be current enough (for the purposes of the research at hand). Nevertheless Malhotra and Birks [56] advise that secondary data be examined as an option before deciding where primary data must be generated and collected. Accuracy may be a particular concern with dynamic global phenomena that affect geopolitics and energy security. Multiple sources of secondary data may be sought and compared, to overcome issues of accuracy and possibly fill in missing cases.

Sources of secondary data include published materials, online and offline (electronic) databases, and syndicated services [56]. Researchers should try to obtain secondary data from original rather than acquired (surrogate) sources (i.e. sources that reproduce data obtained from other secondary sources). Many variables may be included in such databases, and it is very important to be clear on their definition and units of measurement. Occasionally, a researcher may need to convert a variable from one system of units to another, or change its time frame (which may not always be feasible).

There is an accelerating tendency for secondary data to be available in electronic format including the Internet and offline electronic sources such as CD or DVD-ROMS [56], with physical media perhaps being phased out over time. The Internet in particular has emerged as the most extensive source of secondary data. While not all online secondary data are free, the Internet is replete with such collections that include diverse energy related data, including supranational entities (like the European Union), national and government sources (like the Hellenic Statistical Authority), international organizations (like the International Energy Agency or the United Nations), national organizations (like the CIA) and businesses (like British Petroleum). There are even thematic lists, directories and indexes of secondary sources, including reputable periodical publications and newspapers, e.g. *The Financial Times Index* or the *Foreign Affairs* list of energy related articles (https://www.foreignaffairs.com/topics/energy?cid=int-gna&pgtype=hpg).

International trade, national accounts, demography, population, socioeconomic data, industry, energy, environment, and other information are all available to an energy security researcher, in a variety of online secondary sources [56]. All an energy security researcher has to do is locate and select the data required, taking into consideration the expertise, credibility, reputation and trustworthiness of the data provider. Such a list of reputable and inclusive list of free online sources of global secondary data related to the many dimensions of energy security is displayed in Table 1, sorted alphabetically (with the exception of Eurostat, as a source of predominantly regional data, i.e. on European Union member and affiliated countries).

Table 1 Online sources of energy data

Source	Contents	Link
British Petroleum (BP)	The BP *Statistical Review of World Energy* contains data on: primary energy; oil; natural gas; coal; nuclear energy; hydroelectricity; renewable energy; electricity and CO_2 emissions	https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
Central Intelligence Agency (CIA)	*The CIA World Factbook* contains data on: geography; people and society; government; economy; communications; transportation; military and security; terrorism and transnational issues. Especially on energy issues, it contains data on: electricity; crude oil; refined petroleum; natural gas; and CO_2 emissions from energy consumption. Country information much qualitative information in each category, so this source would be a good complement to case studies	https://www.cia.gov/library/publications/the-world-factbook/
International Energy Agency (IEA)	The IEA *Atlas of Energy* contains data on: CO_2 emissions from fuel combustion; electricity; oil; coal; natural gas and renewables. In addition, it contains energy indicators and energy balance data	http://energyatlas.iea.org/#!/topic/DEFAULT
Organisation for Economic Co-operation and Development (OECD)	The *OECD database* contains data on: agriculture; development; economy; education; energy; environment; finance; government; health; innovation and technology; jobs and society. Energy data include: CO_2 emissions; natural gas; oil; coal; renewables; electricity; energy prices and taxes; and world energy statistics	http://www.oecd.org/statistics/listofoecddatabases.htm; https://data.oecd.org/searchresults/?r=%2Bf%2Ftype%2Findicators&r=%2Bf%2Ftopics_en%2Fenergy
United Nations Development Program (UNDP)	The *Human Development Reports* contains data on: health; education; income/composition of resources; inequality; gender; poverty; work; employment and vulnerability; human security; trade and financial flows; mobility and communication; environmental sustainability and demography. The Human Development Report Office releases five indices each year: the Human Development Index (HDI), the Inequality-Adjusted Human Development Index (IHDI), the Gender Development Index (GDI), the Gender Inequality Index (GII), and the Multidimensional Poverty Index (MPI)	http://hdr.undp.org/en/countries

(continued)

Table 1 (continued)

Source	Contents	Link
United Nations (UN) Data	Contains data on most countries of the world, including: general information; economic indicators; major trading partners; social indicators; environment and infrastructure indicators; and some energy data	http://data.un.org/en/index.html; https://unstats.un.org/unsd/energy/default.htm
World Bank Open Data	Contains many development data sets on: agriculture and rural development; aid effectiveness; climate change; economy and growth; education; environment; energy and mining; external debt; financial sector; gender; health; infrastructure; poverty; private sector; public sector; science and technology; social development; social protection and labor; and trade and urban development	https://data.worldbank.org; https://data.worldbank.org/indicator?tab=all; https://data.worldbank.org/country
World Data Atlas	These data contain data on: agriculture; climate statistics; demographics; economy; education; environment; food security; foreign trade; health; land use; national defense; poverty; research and development; telecommunication; tourism; transportation; water and world rankings. Data include indicators on total energy, electricity, renewables, oil; gas and coal	https://knoema.com/atlas; https://knoema.com/atlas/topics/Energy
World Nuclear Association	Contains profiles on countries that use nuclear power, including: energy policy; nuclear facilities; research and development; regulatory framework and non-proliferation. Profiles include much textual and qualitative information, so this source would be a great complement to case studies	http://www.world-nuclear.org/information-library/country-profiles.aspx

The majority of the data to be used for the estimation of an energy security index is expected to be of a secondary nature, although some primary (mostly qualitative) data may be of use as well (as in the case of case study and energy expert approaches that will be discussed in Sects. 4.6 and 4.7).

Turning to the types of data, three major categories are generally used in various statistical and econometric analyses: (1) cross-sectional, (2) time series, and (3) pooled data, including balanced and unbalanced panel or longitudinal data [29].

Cross-sectional data are data that are collected at the same time, e.g. a survey of households in an area, a census of the population in a country, or a Gallup poll among the countries of the European Union. As Gujarati and Porter [29] mention, cross-sectional data may suffer from heterogeneity, and may require appropriate mathematical transformations to correct.

Time-series data may be collected daily (e.g. stock prices), weekly (e.g. various economic figures such as the money supply), monthly (e.g. the inflation rate, the unemployment rate or the Consumer Price Index), quarterly (e.g. the Gross Domestic Product or GDP of a country), annually (e.g. the government budget), every five years (such as the census of manufacturers) or even every 10 years (such as the population census in a country) [29]. Some data may be available both quarterly and annually, such as the GDP or consumer expenditure. The analysis of time-series data presents special problems in econometric analyses, mostly because time series must be tested for stationarity (i.e. no upward or downward trending and steady variance over time) prior to any analysis such as regression modeling; if found to be nonstationary, they must be corrected with appropriate mathematical techniques, depending on the type of nonstationarity established (for a practical example, see [66]).

Pooled data combine the characteristics of cross-sectional and time-series data, as for every time unit there is an entire cross-sectional data set (instead of a single observation), e.g. the annual GDP of European Union countries over the last 10 years. If the same cross-sectional units are surveyed over time, the pooled data are called panel data; if all the units have the same number of observations, the panel data are balanced, otherwise the panel data are unbalanced [29]. The terms panel and longitudinal data are used interchangeably, although it may be argued that the concept of panel data analysis is broader [25].

Variables used in econometric research (like most related to energy security), belong to the following four broad measurement scales (in decreasing amount of useful information contained in them: ratio, interval, ordinal and nominal [29]):

1. With *ratio* scale data, both the ratio of two values, and the distance between them are meaningful. Such data may be ordered (in an ascending or descending) manner, so comparisons between their values may be made, while the value of zero denotes the absence of any quantity of such data meaningfully. All in all, ratio-scaled data are numeric data that contain the most information. Personal or family income or GDP are examples of ratio scaled data.
2. *Interval* scaled data are also numeric data with values that may be ordered (in an ascending or descending manner), but while the distance between two of their values is meaningful, their ratio is not, i.e. they lack a meaningful definition of the location of the value of zero. Time is such a data type, and taking years as an example, it would be meaningless to claim that 2000 AD is twice as big as 1000 AD. Temperature scales also belong to this data type, and it is easy to realize that different scales (such as Celsius, Fahrenheit and Kelvin) place the location of zero degrees at a rather arbitrary point.
3. Although *ordinal* data may not necessarily be numeric, they can certainly be ordered (in an ascending or descending manner) but this is pretty much all one can do with them. Age classes (e.g. 0–17, 17–35, 35–50, over 50 years of age), income classes (e.g. low, medium and high) or grading systems (such as A, B, C, D, and F for fail in the US grading system).

4. Finally, *nominal* scale data contain the least amount of information, and just represent different values of a variable that cannot even be ordered in a meaningful manner. Gender (e.g. male, female) and marital status (e.g. single, married, divorced, separated) are examples of nominal scaled data.

It is worth making a special mention to dummy variables that are used in statistical and econometric analyses to indicate the presence or absence of a certain quality or characteristic. In the case of energy security research, one may use a dummy variable to indicate, for instance, the membership of a country in OPEC or the IEA, with the value of one indicating membership, and the value of zero indicating nonmembership. Dummy variables may also be employed to represent a nominal variable with more than one categories. For instance, if a researcher has arrived at a clustering scheme that groups countries into three energy security clusters, then one may employ two (i.e. one less than the number of clusters or categories) dummy variables to indicate the membership of each observation into a cluster. Assuming that these two dummy variables were named D2 and D3, here is how it would work: if both D2 and D3 were zero, the corresponding observation would belong to the first cluster; if D2 was equal to one, and D3 was equal to zero, then the corresponding observation would belong to the second cluster; finally, if D2 equalled zero and D3 equalled one, the corresponding observation would belong to the third cluster. It is important to remember that if the number of categories of a nominal variable equals N, then one need only define N − 1 dummy variables to represent them; in fact, if all N dummy variables were defined and included in a multiple regression model, perfect multicollinearity would prevent the model from being estimated.

Although the issue of which software tools to use in energy security research (that includes analysis of secondary data with the aim of estimating an energy security index) is rather subjective, some advice may be useful. The authors of this Chapter use *Microsoft Excel* exclusively for data entry and manipulation, and find Excel great because almost all statistical packages may open Excel files. *Minitab*, in the opinion of the authors, is hard to beat for graphing, basic statistical analyses and multiple regression modeling (http://www.minitab.com). The freely available *SAS University Edition* (https://www.sas.com/en_us/software/university-edition.html) is outstanding for carrying out specific analyses, such as Poisson and Negative Binomial regression of count data [2]. Finally, *IBM SPSS* (https://www.ibm.com/analytics/spss-statistics-software) is a great tool for many types of multivariate statistical analysis, including Two-Step Cluster Analysis that can accommodate a mixture of quantitative and qualitative data [62].

4.3 Measuring Energy Security

Having discussed the data that are usually involved in energy security research, attention now turns to the specific socioeconomic and geopolitical data that should be collected, in order to compute an energy security index.

As it has probably become evident from the literature review, the measurement of energy security is not a straightforward issue, as there is uncertainty over the definition of the concept [92]. Different approaches to measuring energy security have been developed in the literature [69], although even the simplest definition (“*the uninterrupted availability of energy sources at an affordable price*” by the IEA) illustrates how complex can any attempt of measurement be. Despite the multitude of dimensions, indicators, and models, the concept of energy security (especially its geopolitical role) is relatively novel, and there are no well-replicated scales for measuring it [14].

Measuring energy security helps remove ambiguity, but encounters numerous complications. As an example, energy security oftentimes focuses on specific energy sources, and talk is made of oil security or coal security. In fact, if one centers on certain aspects of energy supply (such as electricity supply, nuclear power, or gasoline powered automobiles), developing and least developed countries are automatically excluded from consideration since they have poor electricity networks, limited nuclear power units, and non-motorized forms of transport. Another way to go about it, is to consider isolated quantitative variables (such as electricity supply, percent of population with access to electricity, or energy intensity) that are often sectoral in nature, e.g. household energy consumption or share of commercial energy in total energy use. Alternatively, one may estimate composite indicators, such as industrial efficiency, transportation productivity, and environmental quality [77], although these are nontrivial to estimate in a meaningful and accurate way.

Cherp and Jewell [11] have suggested that energy security be conceptualized as an instance of a more general construct of security. A good basis for approaching security has been provided by the seminal work of Baldwin [5], who argued that military, economic, social and environmental instances of security constitute different forms of security, not fundamentally different concepts. Cherp and Jewell suggested that Baldwin makes a distinction between “*acquiring new values,*” which is not related to security, and “*protecting existing values,*” which lies at the heart of the concept of security. The latter approach in the literature focuses on the dynamics of separate indicators, and offers a rather limited possibility for comparative assessment of multiple countries in term of energy security through quantitative analysis [92].

Secondary literature sources are used typically for the estimation of an energy security index. Collected socioeconomic and geopolitical data at a country (or region) level and each milestone time period may be entered in a single Excel file that will essentially be a flat database. Further to socioeconomic and geopolitical data, this flat database may include simple indicators, functions and combinations of simple indicators, and composite indexes collected from the Internet or the literature (even by direct communication with the authors of the original source, if necessary). A composite index is formed when individual indicators are compiled into a single index, on the basis of an underlying model of energy security. The analysis of these empirical data must commence with graphical depiction and numeric measures of location and dispersion. Such a descriptive analysis of the collected data will help concretize the theoretical framework and provide a wealth of information for case studies.

Table 2 Countries (and regions with a state-like status) of the Southeast Mediterranean and the Middle East

Country	Label
Bahrain	Bah
Cyprus	Cyp
Djibouti	Dji
Egypt	Egy
Eritrea	Eri
Greece	Gre
Iran	Irn
Iraq	Irq
Israel	Isr
Jordan	Jor
Kuwait	Kuw
Lebanon	Leb
Libya	Lib
Oman	Oma
Qatar	Qat
Saudi Arabia	Sau
Somalia	Som
Sudan	Sud
Syria	Syr
Turkey	Tur
United Arab Emirates	UAE
West Bank	WB
Yemen	Yem

In the next sections, an attempt is made to organize and discuss briefly thoughts and notions, mostly drawn from literature findings, as to the nature of the data that need to be collected and organized as a researcher tries to measure the conceptual components of an energy security index. Some examples from the area of the Southeast Mediterranean and Middle East are included, with country (and region) abbreviations used for labeling points on graphs as in Table 2.

4.3.1 Geographical Components

According to Correlje and van der Linde [15], the geographic distribution of oil, gas and coal reserves should be considered in energy security research. Furthermore, the location of a country in an oil producing area such as the Middle East, Russia, the Caspian, the Persian Gulf, and Africa, should be represented (possibly by dummy variables). Considering that even though the Middle East has vast gas resources, its political climate is not much better than Russia and the Caspian Sea as far as investments are concerned, it could be that interaction terms of location and political climate may be useful in energy security research.

Variables that are of a geographic nature, may be found in the sources of Table 1, and may be of use in energy security research include: area of a country, broken down into land and sea parts (in km^2); land boundary and coastline of a country (in km); percent of the area of a country that is agricultural or forestry; and dummy variables indicating the location of a country, e.g. in the Middle East or Africa.

To look at a few examples, Fig. 1 shows that the area of Southeast Mediterranean and the Middle East contains four large countries that appear to the left of the chart: Saudi Arabia, Sudan, Libya, and Iran. The area also contains quite a few very small countries such as Djibouti, Israel, Kuwait, Qatar, Lebanon, Cyprus, the region of the West Bank, and Bahrain.

Looking at the coastline of countries in the Southeast Mediterranean and the Middle East affords an entirely different picture, as shown in Fig. 2. Greece and Turkey have the longest coastlines by far, while Jordan and the West Bank are entirely landlocked. The length of a coastline may act as a surrogate variable for access to marine resources, so it may prove to be important in energy security research.

Figure 3 charts the percent of the area of a country in Southeast Mediterranean and the Middle East that is agricultural land. It may be seen that Sudan is an exclusively agricultural country; 70–80% of the area of Saudi Arabia, Syria, Eritrea, Djibouti and Somalia is agricultural; and Greece and Lebanon are very similar in that just over 63% of their area is agricultural land. The rest of the countries have less than half of

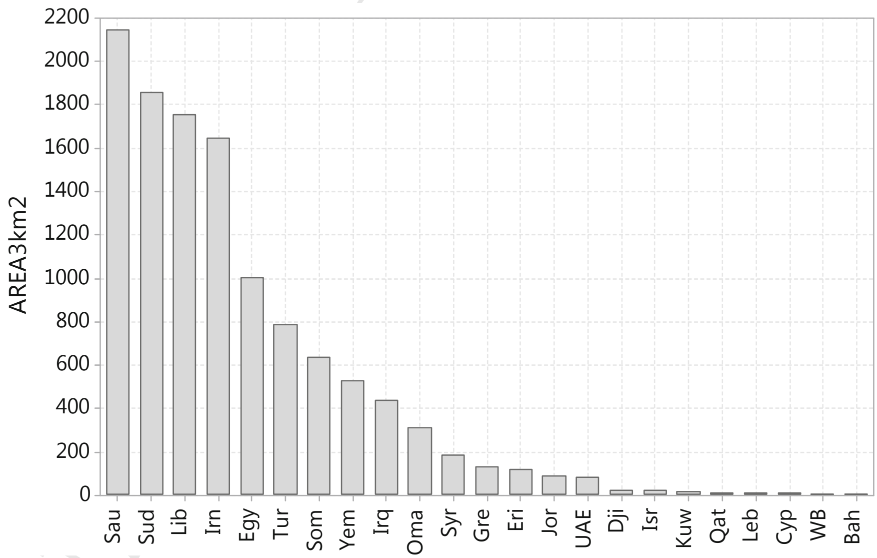

Fig. 1 Bar chart of the area of countries in the Southeast Mediterranean and the Middle East (AREA3km2: area in thousand km^2)

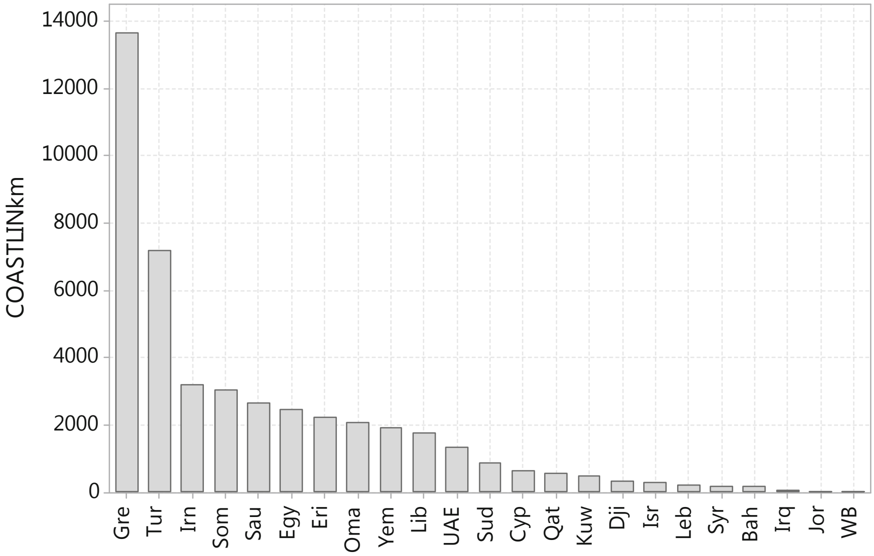

Fig. 2 Bar chart of the coastline of countries in the Southeast Mediterranean and the Middle East (COASTLINkm: length of coastline in km)

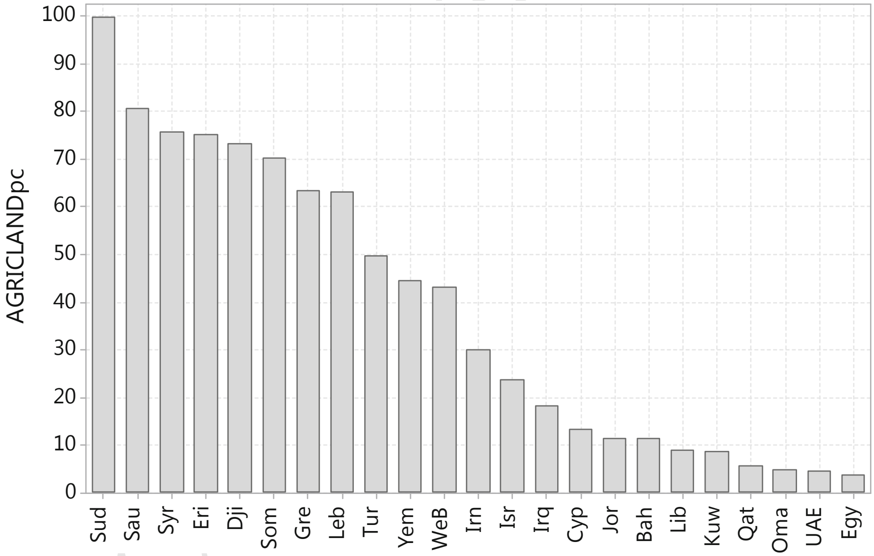

Fig. 3 Bar chart of the percent of agricultural land of countries in the Southeast Mediterranean and the Middle East (AGRICLANDpc: agricultural land in percent of total area)

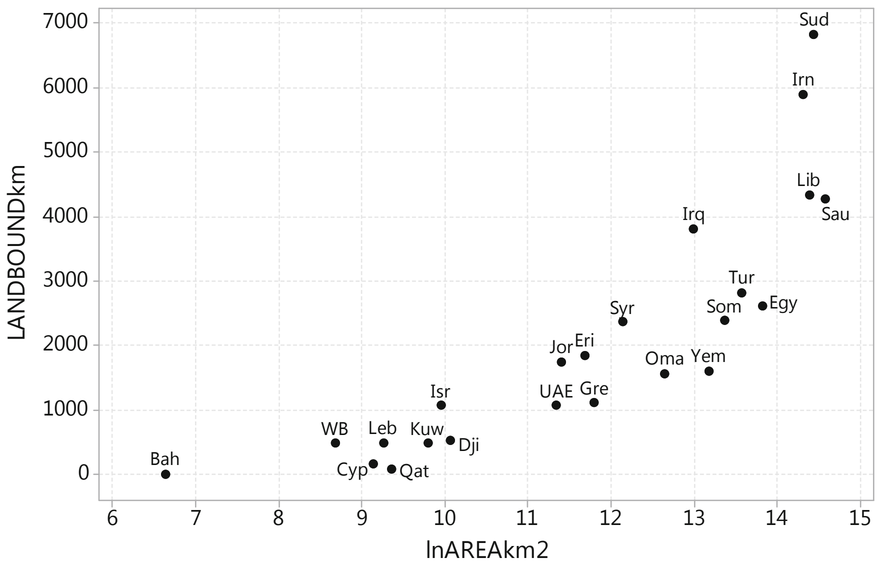

Fig. 4 Scatterplot of the land boundary of countries in the Southeast Mediterranean and the Middle East as a function of their area (LANDBOUNDkm: land boundary of a country in km; lnAREAkm2: natural logarithm of the area of a country in km^2)

their area devoted to agriculture, with some energy resource rich countries (such as Kuwait, Qatar, Oman, and the United Arab Emirates) having very little agricultural land.

Finally, a look at data transformations that may have to be carried out is presented in Fig. 4, where the size of the land boundary in km (LANDBOUNDkm) is shown to be nonlinearly related to the natural logarithm of the area of a country in km^2 (lnAREAkm2). The natural logarithm is preferred to decimal logarithms because it allows a more natural interpretation of the coefficients in regression models in terms of percentage changes and elasticities [79].

While some of the variables that were examined graphically in this section may not be strongly related to the concept of an energy security index, they could be useful in a case study approach to energy security (which is discussed in Sect. 4.6). The graphs also hint at possible clusters of countries with similar geographical characteristics [22], and in this respect may guide (in part) a Cluster Analysis.

4.3.2 Socioeconomic Components

Thinking hard about economic variables that should be taken into account in an energy security index should be an important part of such research.

Turning to literature findings on socioeconomic characteristics, Corner et al. [14] argue that high concern about energy security (as a foreign policy issue) was found

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in a summary of international public opinion (by the World Council on Foreign Relations), with significant support for energy conservation and investment in renewable energy sources. The same authors cited a UK national survey that indicated a high degree of support for government subsidies of renewable energy technologies as well as attaining energy independence. Of the renewable energy sources, solar and wind power appear to be perceived as being able to deliver reliable and secure energy [72].

Probably the most important element that is included in all definitions of energy security is the availability of energy to the economy [47]. As a consequence, many countries consider energy security to be a major priority of their energy policies. Energy security is often used implicitly as a synonym for the security of supply, particularly by researchers adopting an economic perspective, such as Kruyt et al. [47] and Johansson [40]. So, energy security is closely related to micro and macroeconomic developments [15].

A minimum supply of energy is essential for the functioning of the economy, thus energy security is and will continue to be an issue [48]. The cost of energy is an important factor in the inflation rate as well as in the competitive position of the economy of a country [15]. On the relationship between energy prices and energy consumption, Radovanović et al. [69] have argued that when energy prices increase, the consumption does not decline, while when energy prices decrease, energy consumption increases significantly. On the affordability of energy prices, Deese [17], as cited by Cherp and Jewell [11], writes that affordable prices do not cause "*severe disruptions of normal social and economic activity*".

Consuming countries wish to keep energy prices low, as long as this does not remove incentives for the development of supply); producing countries gain when prices are high, as long as they do not cause big reductions in demand [40]. Imports from OECD and non-OECD countries could be tallied and involved in the economic components of the energy security index [15]. Investments as well as Foreign Direct Investments (FDS) in the oil, gas and coal industry could also be taken into account [15].

The existence and number of independent bilateral agreements with producer countries could be indicated by a dummy or other quantitative variables [15], possibly including quantitative measures of economic instability. As a related thought, in countries like Nigeria, there are conflicts over economic rents and oil exploitation, which in turn cause political and social rivalry [15] that should be accounted for in energy security research.

Socioeconomic variables that could be found at a country level in the sources of Table 1 include: population and percent of urban population; life expectancy; health expenses, physicians, and hospital beds; education expenses and literacy rate; unemployment and inflation rate; GDP and GDP per capita, in current or Purchasing Power Parity (PPP) terms; house and government consumption as percent of GDP; imports and exports as percent of GDP; the contribution of agriculture, industry and services to the GDP (as percentages); size of labor force; percent of the population that is below the poverty line; as well as taxes and public debt as percent of the GDP.

To consider some examples, do bigger countries tend to have a larger population? It turns out that, to get a near linear relationship for countries in the Southeast

Mediterranean and the Middle East, one has to take the natural logarithm of both variables, as shown in Fig. 5. The physical meaning of such a log-log relationship is this: the slope of a regression line passing through the points of the scatterplot of Fig. 5 (not shown) would be equal to the percentage change in population (expressed in thousands) every time the area (expressed in km^2) was increased by one percentage point [79]. Incidentally, Fig. 5 shows the three largest and most populated countries in the area at the top right of the scatterplot: Egypt, Turkey, and Iran. Similarly, the scatterplot reveals that Israel, Lebanon, Kuwait, West Bank, Qatar, Cyprus and Djibouti are countries that have relatively similar area and population characteristics (although it should be kept in mind that the axes are in logarithm units, so points that appear near may in fact have very different numerical values).

Figure 6 shows the percentage of the population living in urban areas for countries in the Southeast Mediterranean and the Middle East. It is shown that Kuwait and Oman are almost exclusive urbanized, many countries have an urban population ranging from about two thirds to 90%, while countries like Somalia, Egypt, Eritrea, Yemen and Sudan have an urban population that is less than 50% of the total.

As another example, the level of taxation in countries in the Southeast Mediterranean and the Middle East is graphed in Fig. 7. It may be concluded that Libya, Greece and Kuwait draw 45–50% of their GDP from taxes, which one may argue constitutes a hindrance to investment and innovation. Cyprus, Djibouti, Eritrea, Iraq and Oman draw around 30–35% of their GDP from taxation. Israel, Saudi Arabia

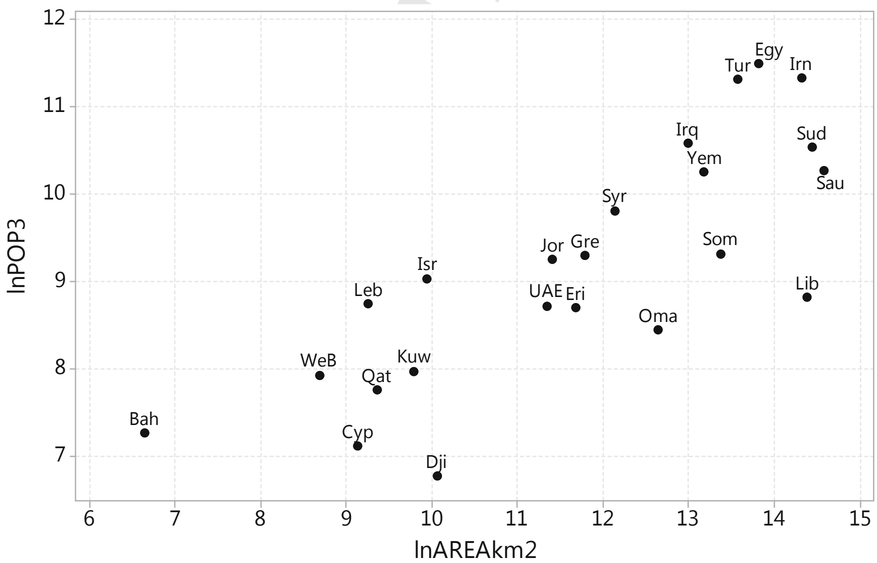

Fig. 5 Scatterplot of the population of countries in the Southeast Mediterranean and the Middle East as a function of their area (lnPOP3: natural logarithm of population in thousands; lnAREAkm2: natural logarithm of area in km^2)

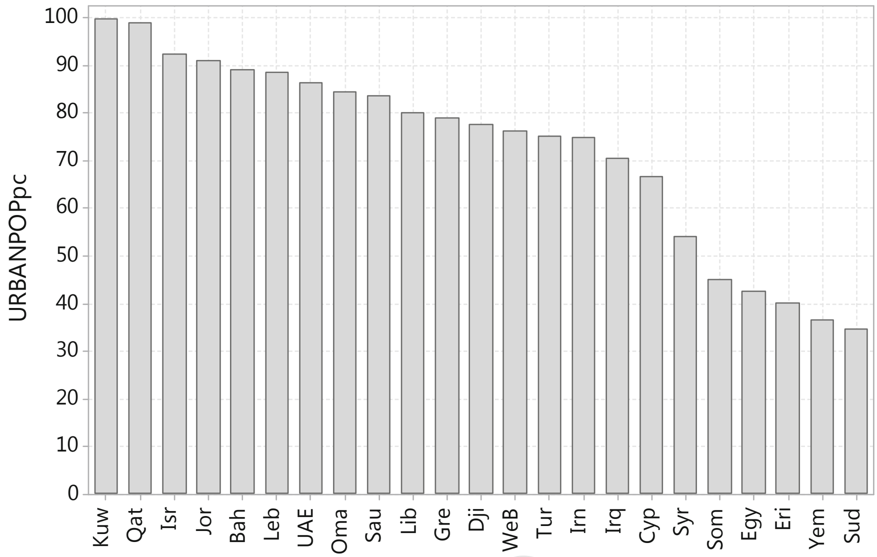

Fig. 6 Bar chart of percent of population residing in urban areas of countries in the Southeast Mediterranean and the Middle East (URBANPOPpc)

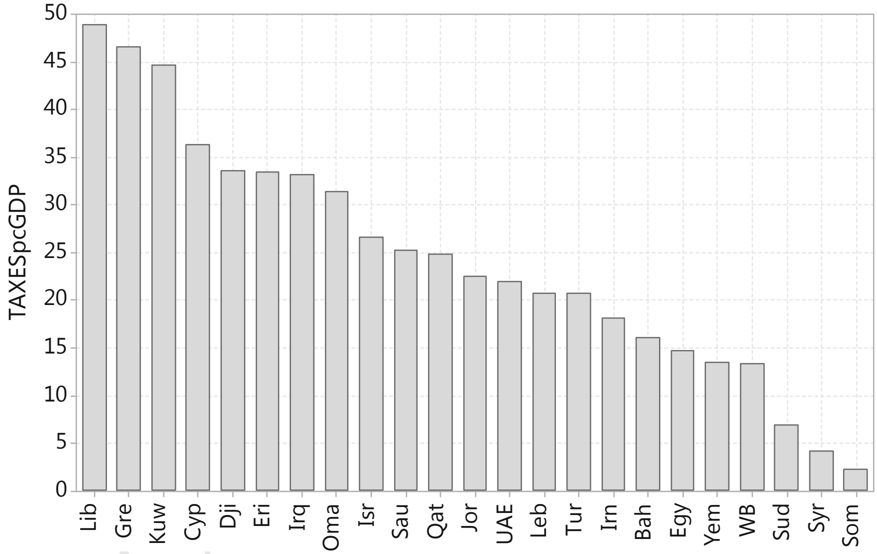

Fig. 7 Bar chart of taxation as percentage of GDP of countries in the Southeast Mediterranean and the Middle East (TAXESpcGDP)

and Qatar draw around one quarter of their GDP from taxation. One could go making analogous observations about groups of countries with similar levels of taxation.

Exports minus imports expressed as percent of GDP is graphed in the bar chart of Fig. 8. Interestingly, oil and gas rich countries (such as the United Arab Emirates, Bahrain, Iraq, Qatar, Saudi Arabia, Kuwait and Oman) are characterized by a surplus of exports. On the other hand, one sees countries struggling with their economies and political situation (such as the West Bank, Yemen and Djibouti) to have a large deficit of exports (compared to their imports). So, this particular indicator may be an interesting metric in the sense as it appears to be associated with energy exports of countries in the Southeast Mediterranean and the Middle East.

How is average life expectancy (of countries of Southeast Mediterranean and the Middle East) related to the number of physicians per population? An answer is given in Fig. 9, which shows that: Somalia has the lowest life expectancy (below 55 years of age); Yemen, Djibouti and Sudan have a life expectancy of about 65 years of age (although Sudan has a much larger number of physicians per population); and most other countries are clustered together, with a life expectancy ranging from below 75 to less than 85 years of age. Israel has the highest life expectancy, and it achieves this without the near double number of doctors per population that Greece has.

Turning to technology diffusion, as a last example in the socioeconomic section, Fig. 10 shows that there is a rather weak linear relationship between the Internet users per 1000 inhabitants and the cellular phone subscribers per 1000 inhabitants of the countries in Southeast Mediterranean and the Middle East. It is interesting to note that energy rich countries, such as Kuwait, the United Arab Emirates, Bahrain,

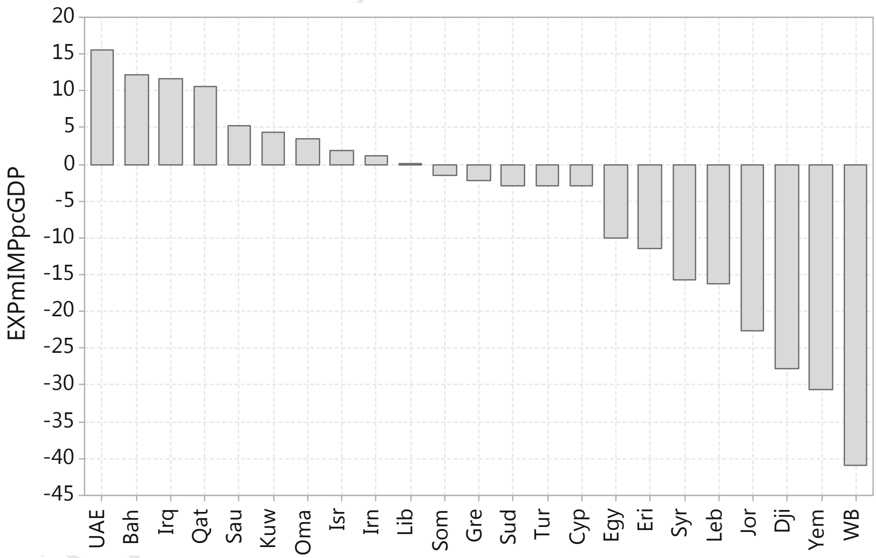

Fig. 8 Bar chart of exports minus imports as a percentage of the Gross Domestic Product (GDP) of countries in the Southeast Mediterranean and the Middle East

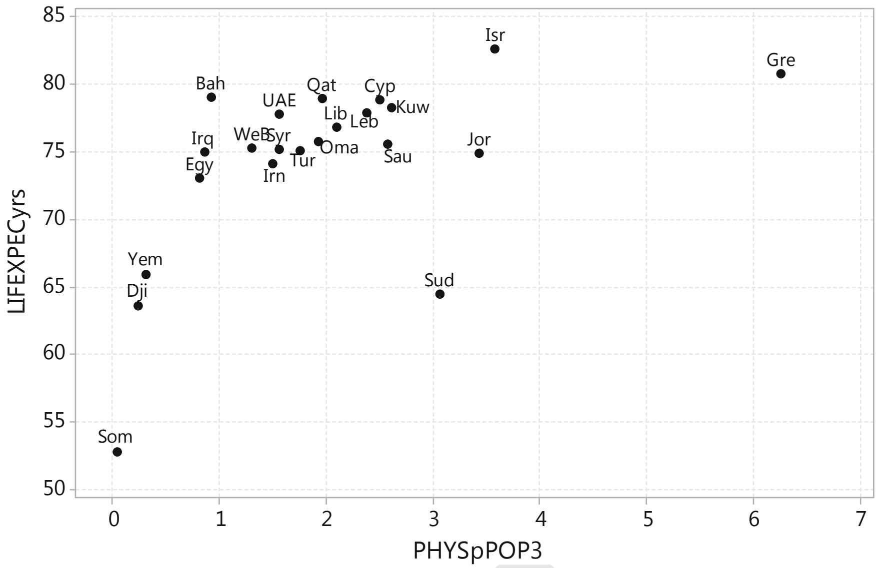

Fig. 9 Scatterplot of the life expectancy of countries in Southeast Mediterranean and the Middle East as a function of the number of physicians per population (LIFEXPECyrs: average life expectancy in years for the entire population, including both genders; PHYSpPOP3: physicians per 1000 inhabitants)

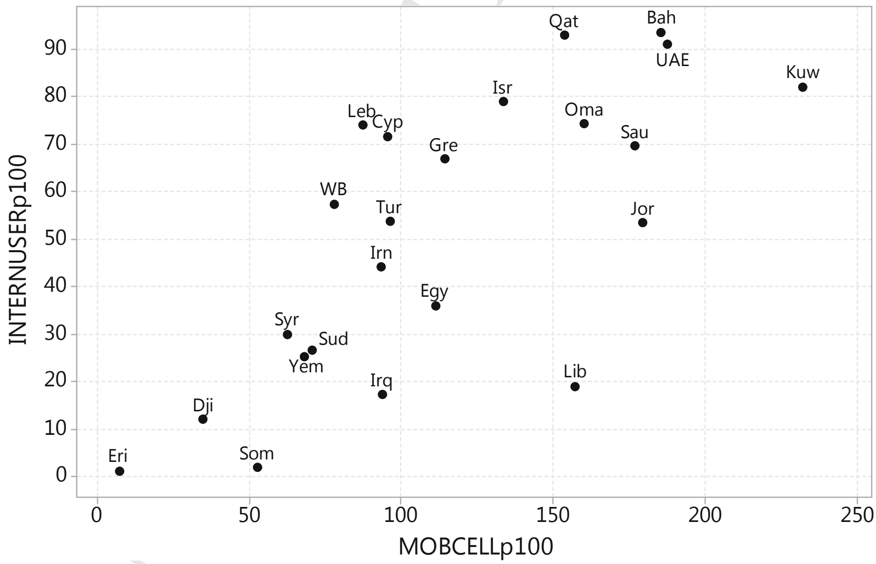

Fig. 10 Scatterplot of the number of internet users of countries in Southeast Mediterranean and the Middle East as a function of the number of mobile/cellular phone subscribers (INTERNUSERp100: Internet users per 100 inhabitants; MOBCELLp100: mobile/cellular phone subscribers 1000 inhabitants)

Oman, Qatar and Saudi Arabia have over 1.5 cellular subscriptions per individual—in fact Kuwait has over two. Bahrain, Qatar and the United Arab Emirates have over 90 Internet users per 100 people. At the other end, countries like Djibouti, Somalia and Eritrea have very low usage of Internet. As a general observation though, cellular phone diffusion is (much) bigger than Internet usage, so perhaps a (large) part of Internet access is now carried via cellular connections (especially in certain countries).

4.3.3 Institutional and Political Components

Turning to institutional and political components, organizations that should be considered in the context of energy security include the World Trade Organization (WTO), IEA, OPEC, and IMF. Relevant regional free trade organizations include the European Union (EU), the North American Free Trade Agreement (NAFTA), the Southern Common Market (MERCOSUR), and the Southern African Development Community (SADC) [15].

Although the US maintains a transatlantic relationship with the EU, cooperating on issues of energy security, at the same time it discourages independent EU energy initiatives, e.g. the Euro-Arab dialog that took place in the 1970s. Therefore, political difficulties should be taken into account in the development of an energy security index, with possible interactions with oil producing country [15].

The ability of a country to develop its own means of deterrence, and the actual deterrence capacity both relate to energy security. The case of Iraq, a central player in the global energy landscape, makes one think that an indicator variable showing whether a country is a fragile or failed state, could be incorporated in the political component of energy security research. Competition for scarce resources between consumer countries could cause conflict, so there is a risk that key producing regions slip into chaos—this should also be accounted for.

Delving deeper to the political component of an energy security index, the presence of a centralist political structure, lack of effective political institutions, and a weak civil society are also indicator variables that could be considered. The presence of elites, and the concentration of bigger amounts of wealth in smaller portions of the society (measured by the corresponding Gini coefficient), should also be considered. Taking corruption into account is important because large oil and gas revenues generate political pressures and corruption [15].

Institutional and political variables that could be found at a country level in the sources of Table 1 include: type of government; years of being an independent state; and the Gini coefficient for family income, which along with the percent of households with income at the lowest and highest 10% could act of surrogate variables for the effectiveness of democratic institutions.

For countries in the Southeast Mediterranean and the Middle East the type of government is tabulated in Table 3.

One could pool similar categories and come up with a more summary description, such as 10 republics and democracies, seven monarchies, one theocratic republic, and

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Table 3 Type of government in countries of the Southeast Mediterranean and the Middle East (CIA Word Factbook characterization)

Type of government	Number of countries	Average years independent
Absolute monarchy	3	168
Parliamentary republic	3	120.3
Presidential republic	3	62
Federal parliamentary republic	2	73
In transition	2	48.5
Constitutional monarchy	1	48
Constitutional monarchy (emirate)	1	58
Federation of monarchies	1	48
Parliamentary constitutional monarchy	1	73
Parliamentary democracy	1	71
Presidential republic (highly authoritarian)	1	73
Semi-presidential republic	1	42
Theocratic republic	1	40

one authoritarian state presenting as a presidential republic. Looking at the years of independence per government type (rightmost column of Table 3), one may conclude that absolute monarchies and republics tend to be the countries enjoying the longest status as independent states; on the other hand, there are countries that have been in transition for decades.

4.3.4 Energy Components

Coming to potential energy components of an energy security index, clean coal and safe nuclear power will continue to play an important transitional role in the energy mix [9] and help offset dependence on imported gas [15]. So the contribution of each energy source to the energy mix of each country should be taken into account. Strategic coal, oil and gas reserves [6] as well as the ratio of reserves to production of the present and near future, should also be taken into consideration. In particular, the oil and gas consumption growth, and the investments to construct new or replace existing production capacity should be considered in the analysis.

Given that the US purchases crude oil from over 60 different countries [15], a work researching energy security should keep track of the number of countries that a country purchases oil, gas, and coal from. This adds a significant degree of complexity, but (together with the fact that much of the global oil production originates in countries that are characterized by internal instability) hints at the need of possibly defining and using energy fragility variables.

The incorporation of a nuclear energy component in an energy security index seems obvious since nuclear power can be an economical and reliable way of generating large amounts of base load electricity without producing CO_2 emissions. With nuclear power, the marginal cost of electricity is low, but construction, decommissioning, and waste disposal costs are high [85]. A total of 31 countries already have nuclear power and a number of them, including India and China, are looking to build new nuclear power units, while 20 countries are reported to be looking to develop nuclear power [88].

As pointed out by Corner et al. [14], the long-time association of nuclear energy with destroying power and world-making, sets nuclear apart from other technological systems in the mind of the public, what Masco [60] called the "*nuclear uncanny*". In the words of Winzer [84]: "*For some people the goal of energy security is the reliable provision of fuels and the role of nuclear energy is one of enhancing security. For others, energy security is concerned with a reduction of hazards from accidents and proliferation and the expansion of the nuclear industry is a potential threat to energy security*".

Corner et al. [14] argue that public attitudes towards nuclear energy constitute a reluctant acceptance [7] that should be interpreted against the following background: (a) high levels of awareness and concern about climate change, coupled with (b) an emerging concern about energy security (which remains poorly defined). Nuclear energy has been viewed as a potential method of addressing these two issues since the late 1990s [80], yet there is a clear preference for renewable energy over fossil fuels, as sources for electricity generation.

A comprehensive summary of up-to-date objections to nuclear power was made by Levite [52]. In his informed opinion, one could cite the following reasons for supporting nuclear power: ubiquity of fuel; exceptional form of energy for use as a base loader of the electrical grid; environmental benefits (mainly reduction of CO_2 emissions); manageable proliferation risks; improving operational performance record; safety standards improving since Chernobyl; and alternative energy sources also plagued by limitations and risks. Yet, Levite asserts that nuclear power is now in free fall, mainly due to the following shortcomings: lack of standardization; absence of harmony in (the update of) core regulatory requirements; cost management and financing challenges; enduring challenges of handling spent fuel; proliferation risks, to be added to safety and security issues; decommissioning overhang; and industry mentality and corporate myopia. Levite furthers his arguments against nuclear power by arguing that the problems that plague nuclear power now occur against a backdrop of: abundance of alternative energy supplies (such as shale, wind and solar); rapidly declining costs of the renewables (especially wind turbines and solar panels) that also possess better political appeal; significant improvements in storage capacity and affordability; daunting nuclear decommissioning overhang; political paralysis in confronting the storage challenge; a meltdown in the US nuclear leadership; and failure to come up with working industry solutions.

As expected, a wide variety of energy variables may be found in the sources of Table 1. These include: crude oil exports and imports (in barrels per day or bpd); refined oil production and consumption (in bpd); refined oil exports and imports (in

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bpd); gas production and consumption (in m^3); gas exports and imports (in m^3); electricity production and consumption (in kWh); electricity exports and imports (in kWh); installed capacity for electricity production (in kW); the contribution of each energy source (including coal, oil, gas, nuclear, hydro, solar, wind, geothermal, biofuel, and waste) expressed in GWh as well as percentage of the energy mix. Energy infrastructure variables may be found as well, such as gas and oil pipeline network (in km), although in general these data are incomplete and not up to date. Finally, pertinent socioeconomic variables such as population without electricity, and percent of electrification at urban centers, rural areas, and country average, may also be found in those sources.

The electricity energy mix of most countries in the Southeast Mediterranean and the Middle East is presented in Table 4. Quite a few observations may be made on the data presented there. For one, it may be argued that countries with a more varied energy mix (such as Greece and Turkey) would tend to be more energy secure. Also, there are unlikely countries whose energy resource endowment is such that energy security would appear to be easy to achieve, such as Sudan (with two thirds of its energy coming from hydro sources). Countries that use a single energy source predominantly (such as Cyprus, Eritrea, and Lebanon, all of which use oil almost exclusively) would have an energy security that would depend strongly on the availability of oil imports (and their own production of oil). In particular, countries that use (imported) natural gas almost exclusively would clearly have an energy security that would also depend strongly on its continued physical availability and affordability. Naturally, one should be careful with the data, e.g. countries like Qatar or Oman use natural gas almost exclusively because they have an abundance of it, and are exporting countries.

In the case of many EU countries (not shown on the table) that import the majority of the natural gas from Russia, this would mean that they would remain energy secure as long as Russia continues to supply its European market smoothly. Situations such as the Ukrainian crises (that were discussed in Sect. 4.1.3) or other unforeseen geopolitical considerations that would affect Russia, would also affect its European (and other) gas customers, more so in the case of small countries (like Greece) and less so in the case of bigger players (such as Germany) that are able to secure better terms. It is this very concern that the EU is currently trying to address with its much touted project of Energy Union, in a manner that would safeguard the energy security of its members and combat climate change, which the EU regards as a priority.

A final look at an energy variable is given by Fig. 11, which charts the energy self-sufficiency of the countries of the Southeast Mediterranean and the Middle East. On the one hand, countries that appear very secure from a self sufficiency point of view include: Qatar and Kuwait (with a self sufficiency between 450 and 500%); Iraq (with a self sufficiency between 350 and 400%); and the UAE, Oman and Saudi Arabia (with a self sufficiency around 300%). On the other hand, countries that appear quite insecure from a self sufficiency point of view include: Lebanon, Jordan, and Cyprus (with a near zero self-sufficiency); Greece, Turkey and Israel (with a self sufficiency less than 50%); and Syria (with a self-sufficiency of around 50%).

Table 4 Electricity energy mix of countries in the Southeast Mediterranean and the Middle East (percent of GWh; no data on Djibouti, Somalia, and the West Bank)

Country	Coal	Oil	Gas	Biofuel	Waste	Nuclear	Hydro	Geo-thermal	Solar PV	Solar thermal	Wind
Bahrain	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	0.0	91.2	0.0	1.1	0.0	0.0	0.0	0.0	2.8	0.0	4.9
Egypt	0.0	21.0	70.7	0.0	0.0	0.0	7.4	0.0	0.1	0.0	0.7
Eritrea	0.0	99.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Greece	42.6	10.9	17.5	0.4	0.2	0.0	11.9	0.0	7.5	0.0	8.9
Iran	0.2	14.4	79.3	0.0	0.0	1.0	5.0	0.0	0.0	0.0	0.1
Iraq	0.0	71.9	24.4	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0
Israel	45.8	0.7	51.6	0.1	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Jordan	0.0	50.6	48.4	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.6
Kuwait	0.0	63.6	36.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lebanon	0.0	97.4	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0
Libya	0.0	46.3	53.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oman	0.0	2.6	97.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Qatar	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saudi Arabia	0.0	44.2	55.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sudan	0.0	35.5	0.0	0.0	0.0	0.0	64.5	0.0	0.0	0.0	0.0
Syria	0.0	29.1	68.6	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Turkey	29.1	0.8	37.9	0.5	0.0	0.0	25.6	1.3	0.1	0.0	4.5
United Arab Emirates	0.0	1.2	98.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Yemen	0.0	60.2	39.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

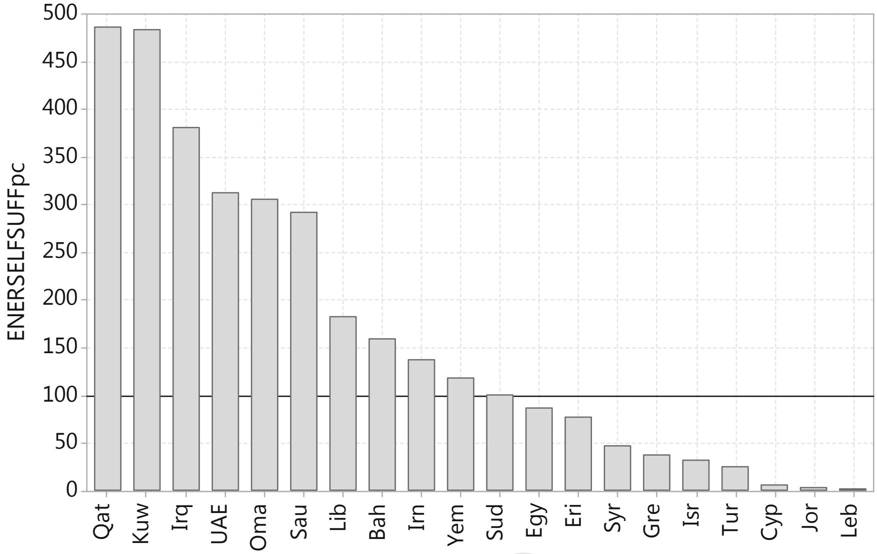

Fig. 11 Bar chart of energy self sufficiency expressed as a percentage for countries of the Southeast Mediterranean and the Middle East (reference line drawn at 100% energy self sufficiency)

Part of the challenge in defining (and calculating the values of) an energy security index is exactly this: how does one put together these opposing influences, e.g. variety in the energy mix versus self-sufficiency, in order to construct an index that would be a useful tool in analyzing geopolitical situations.

4.3.5 Environmental Components

Turning to environmental variables, although air pollution became a big concern in industrialized countries during the 1950s, 1960s and 1970s, global warming and awareness of climate change remained low. In the 1980s, the World Health Organization (WHO) established the Intergovernmental Panel on Climate Change (IPCC) to provide a scientific view of climate change. In 1997, the Kyoto Protocol was signed to set binding obligations on industrialized countries to reduce emissions of greenhouse gases. In 2011 a new value was included in the basic definition of energy security by IEA, the "*respect for environmental concerns*".

Although there is little doubt that environmental concerns should be accounted for, in a definition of energy security, the way to formalize their inclusion is not as obvious and may, in fact, be fruitful to address this task via qualitative approaches (e.g. with case studies and expert interviews, mentioned in Sects. 4.6 and 4.7 correspondingly).

Environmental (including geomorphological and ecological) variables that are found in the sources of Table 1 include: land and water area of a country (in km^2); land boundary and coastline of a country (in km); agricultural and forest land in a

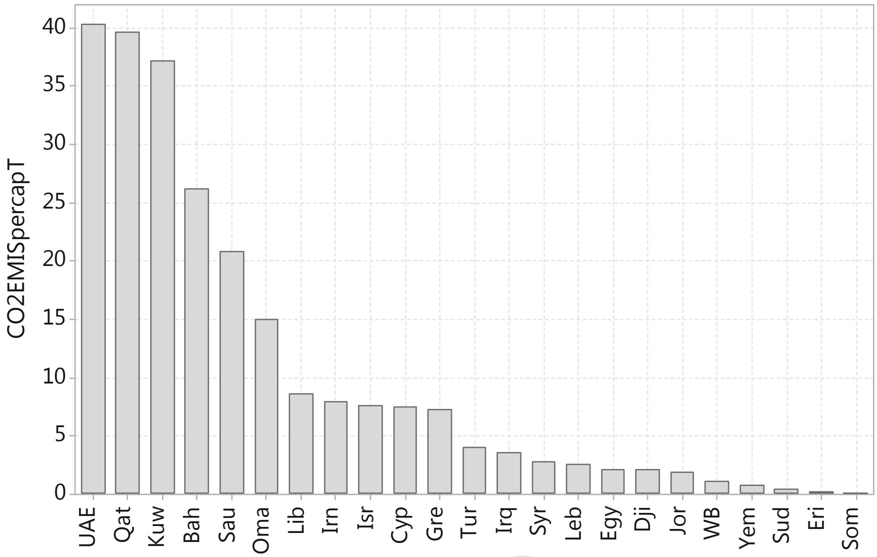

Fig. 12 Carbon dioxide (CO_2) emissions per capita in metric tons (CO2EMISpercapT) for countries of the Southeast Mediterranean and the Middle East

country (in percentages); contribution of fossil fuels and renewable energy sources to electrification in a country (in percentage); and CO_2 emissions of a country (in metric tons).

This last variable, CO_2 emissions per capita (in metric tons), is depicted in Fig. 12. It may be concluded that fossil-fuel producing countries such as the United Arab Emirates, Qatar and Kuwait, are major producers of CO_2 emissions on a per capita basis (between 35 and 50 tons per capita). Libya, Iran, Israel, Cyprus, and Greece are remarkably similar in their CO_2 emissions per capita (between five and 10 tons per capita). Finally, poor countries such as Somalia, Eritrea and Sudan have near zero CO_2 emissions per capita.

4.4 *Creating a Geopolitical Energy Security Index*

According to Sovacool [74], creating an energy security index involves: conceptualizing energy security; putting the existing definitions in the proper frame; collecting and consolidating data on previous energy security metrics; and scoring the results, so that a better index is obtained. The evaluation of such a new index may be based on the following criteria:

- *Suitability*: How well does the index measure the relevant aspects of the energy security framework?

- *Transparency*: How transparent and objective is the index? Is expert judgment required?
- *Availability of data*: Are sufficient and robust data available to compile the index?
- *Ability of forecast* (self-evident).

Common shortcomings of indices include [76]:

- *Topical focus*, i.e. studies centering on pressing concerns (such as electricity supply, nuclear power, and automobiles) instead of striving to be applicable not only in developed countries, but also in developing or least developed countries (with patchy and incomplete electricity networks, limited nuclear power units, and non-motorized forms of transport).
- *Scope and coverage* as many indices are sector-specific, and focus on security of supply rather than security of demand.
- *Continuity*, as very few studies have assessed energy security performance over time.

Motivated by the above observations, an energy security index should attempt to include as many countries as possible, certainly all member states of the UN, taking into account the full complexity of the global environment, where energy decisions are taken at the political level [24] and global geopolitical consequences unfold. Such an energy security index should take into consideration both security of supply and demand, and it should attempt to measure energy security across a range of political systems and geopolitical priorities. Finally, an energy security index should provide the element of continuity by assessing energy security during the milestone time periods (if not along a complete time series).

Turning to the scope and nature of an energy security index, such research should strive to address Sovacool's [75] remark that "*metrics for energy security will always have this tension between comprehensiveness and understandability, but the most important aspect of any energy security index is for it to be simple, meaningful, and accessible – usability is better than perfectibility.*"

The creation of a composite energy security index would normally include the following activities [3]: the energy security definition is framed; any specific focus areas are set; the appropriate simple indicators and selected; the required data are collected; the simple indicators are normalized; the normalized indicators are weighted; and the weighted and normalized simple indicators are aggregated into a (composite) index. The normalization step may resort to a minimum-maximum scale, the distance to a reference, or other standardization techniques; the weighting may use equal weights, recognize the relative importance of different fuel types, use PCA to sort out overlapping information, obtain expert opinions, or resort to Data Envelopment Analysis.

Further to what has been presented in previous sections, common simple indicators for developing an energy security index have included [46]: the reserve/production ratio, which shows the remaining amount of unexploited resources a country possesses; the Total Primary Energy Supply (TPES), which accounts for the indigenous production from primary sources, the import/export balance, the availability in

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international marine bunkers, and any stock changes; the reserve/consumption ratio, which provides an indication of how much energy a country may use, if in a pinch; and the reserve margin of generation capacity.

The development of a new quantitative energy security index with an emphasis on geopolitical considerations could be done by collecting quantitative data, categorical data, and qualitative data and indicators that highlight the causative connection between energy security and geopolitical events. The steps of normalization, weighting, and aggregation should take into consideration the (previously outlined) state of the art in the research literature. A significant contribution would be achieved if such an energy security indicator reflected—in a novel way—the energy security realities across time, geopolitical priorities, and political systems.

An example of such a research work is provided by Radovanović et al. [69], who used the following indicators to construct an energy security index (ESI): energy intensity (EI); final energy consumption (FEC); Gross Domestic Product per capita (GDPpc); share of nuclear and renewable energy (SRN); energy dependence (ED); and carbon intensity (CI). PCA was used to determine the coefficients in the following final equation of their energy security index:

$$\mathrm{ESI} = 20 \times (\mathrm{EI}) + 20 \times (\mathrm{FEC}) + 10 \times (\mathrm{GDPpc}) + 20 \times (\mathrm{SRN}) - 20 \times (\mathrm{ED}) - 10 \times (\mathrm{CI})$$

In a newer effort, Radovanović et al. [70] used an expanded list of variables (adding energy dependence, electricity prices, and sovereign credit rating) to estimate values of a Geo-Economic Energy Security Index for many European countries from 2004 to 2013. Such panel data may be used for further statistical analysis, especially in reference to case studies and expert opinions.

Turning to specific energy and environment-related indexes, the 2018 Environmental Performance Index (EPI, a collaborative effort of the Yale Center for Environmental Law and Policy, the Center for International Earth Science Information Network of Columbia University, and the World Economic Forum) was used to rank 180 countries on 24 performance indicators across ten issue categories covering "*environmental health and ecosystem vitality*" (https://epi.envirocenter.yale.edu/downloads/epi2018policymakerssummaryv01.pdf). The EPI has been touted as a scorecard highlighting "*leaders and laggards in environmental performance*". Low scores of the EPI may indicative a need for, e.g. cleaning up air quality, protecting biodiversity, or reducing greenhouse gas emissions.

Values of the 2018 EPI for the countries of the Southeast Mediterranean and the Middle East are plotted against the United Nations Human Development Index in Fig. 13. It may be seen that countries like Eritrea, Djibouti and Sudan score low on both indexes. On the other hand, countries like Israel, Greece, Cyprus and Qatar appear to be clustered together at the highest value range of both indexes. Quite a few other countries are located in the middle range of both indexes, with countries like Iraq doing relatively well on the HDI, but poorly on the EPI.

Another index of interest is the INFORM global risk index, a tool for understanding the risk of humanitarian crises and disasters (http://www.inform-index.org/Portals/0/InfoRM/2018/INFORM2018-WithCovers.pdf). It is composed of three

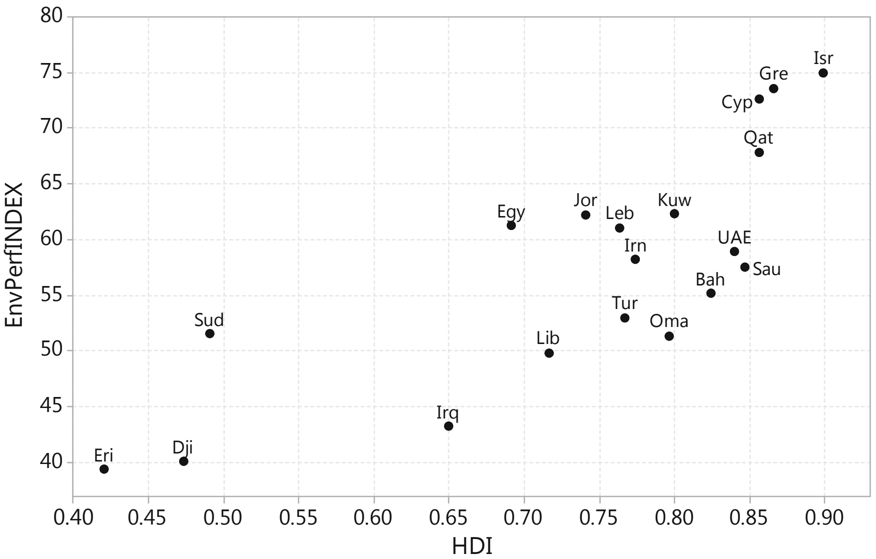

Fig. 13 Scatterplot showing the Environmental Performance Index (EnvPerfINDEX) as a function of the Human Development Index (HDI) for countries of the Southeast Mediterranean and the Middle East

dimensions: hazards and people's exposure to them; vulnerability; and lack of coping capacity (i.e. lack of resources to help people cope with the hazards). INFORM uses 50 different indicators to create a risk profile for every country, ranging from zero to 10, where: values less than two indicate very low risk; values from 2 to 3.5 indicate low risk; values from 3.5 to 5 indicate medium risk; values from five to 6.5 indicate high risk; and values over 6.5 (and less than 10, its maximum) indicate very high risk.

The Environmental Performance Index is plotted against the INFORM index for countries of the Southeast Mediterranean and the Middle East in Fig. 14. As expected, they appear to be negatively correlated: high values of the Environmental Performance Index appear to be associated with low values of the INFORM index and vice versa. Quite a few interesting observations may be made. First, Israel, Greece and Cyprus are clustered together at the top and middle-left of the figure, indicating that these three countries are similar in having a good level of environmental performance and relatively low global risk. On the other hand, countries like Djibouti, Eritrea, Iraq, Libya and Sudan, combine high levels of global risk with low levels of environmental performance. Energy producing countries such as Qatar, Kuwait, the United Arab Emirates, Saudi Arabia, Bahrain and Oman have reasonably low global risk and relatively average environmental performance.

A last look is shown by Fig. 15, where energy self-sufficiency (expressed as a percentage) is plotted against carbon dioxide emissions per capita. The data exhibit a moderately linear relationship, with more countries clustering at the lower left of

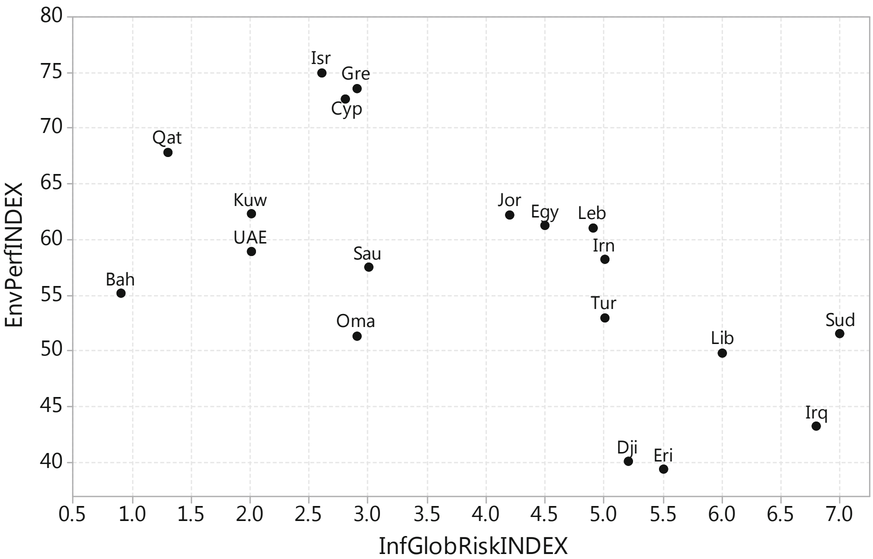

Fig. 14 Scatterplot showing the Environmental Performance Index (EnvPerfINDEX) as a function of the Inform Global Risk Index (InfGlobRiskINDEX) for countries of the Southeast Mediterranean and the Middle East

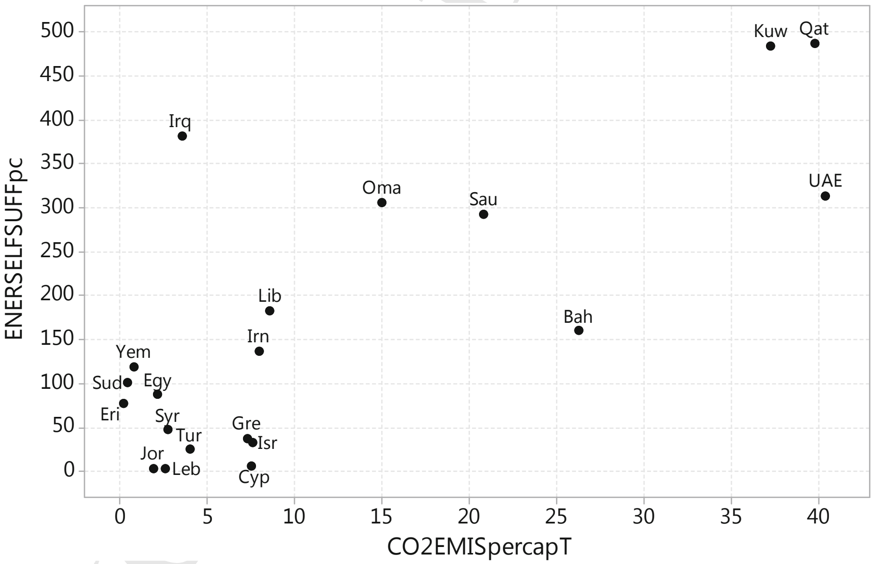

Fig. 15 Scatterplot showing the energy self-sufficiency as a percentage (ENERSELFSUFFpc) as a function of carbon dioxide (CO_2) emissions per capita in metric tons (CO2EMISpercapMt) for countries of the Southeast Mediterranean and the Middle East

the scatterplot. It is evident that countries with a very high self sufficiency, such as Qatar and Kuwait, are also characterized by high CO_2 emissions per capita. On the other hand, there is a very wide variation of CO_2 emissions for countries that are the mid range of self sufficiency, e.g. the United Arab Emirates, Saudi Arabia, Oman, and Iraq. Poor countries such as Eritrea and Sudan have near zero emissions of CO_2 per capita.

4.5 Using Cluster Analysis

The aim of this important step of the analysis in an energy security research work will be to produce country classifications by: forming groups of similar countries at each milestone time period; examining how countries change classification by moving from one group to another over time; and observing how energy security profiles of entire regions (and hotspots) have changed from the 1970s until today.

To formulate the groups, CA [22] may be run on a variety of socioeconomic and geopolitical variables as well as values of the formulated energy security index. Although it is expected that empirical degrees of freedom considerations, such as those proposed by Formann [23], as cited by Mooi and Sarstedt [62], will limit the number of variables that may be employed by CA, the aim would be to derive well-defined cluster solutions, which will constitute an innovative energy security taxonomy of countries over time. PCA may be employed to extract a small number of Principal Components out of (significantly more) well correlated variables, and thus manage to have more variables represented (even indirectly) during CA. Fuzzy clustering techniques or complexity dynamics may also be taken into consideration. Data quality and missing data consideration along with a priori expectations (as to which variables should characterize the profile of a country) could be taken into consideration, and may help with the final selection of variables to be used for clustering.

The classification that will result from the CA will provide information from which insight and knowledge may be gained as to: (a) the significance of the energy security index; (b) the factors that put a country in a specific cluster; and (c) the policies that are correlated with any changes in the classification of a country. Qualitative information that were left out of the CA (e.g. by not being represented by dummy variables) may also be associated with the classification, in an effort to gain additional understanding of the components of energy security over time. The clusters of each milestone time period may also be depicted on global or regional maps of energy security (also proposed by Vivoda [82]), the configuration and dynamics which, may generate additional geopolitical insight and highlight the location and movement of energy security hotspots over time.

Vivoda [82] has stressed the importance of constructing energy security typologies, i.e. clusters, which (it is asserted) are better than lists of variables and complex interrelations. The construction of typologies allows for the classification of countries, e.g. developing countries that are net energy importers, such as China and

India, have a significant degree of similarity across many dimensions and attributes of energy security, and are structurally different from developed energy importers (such as Japan and South Korea) and energy exporters (such as Russia and Australia).

4.6 Looking at Case Studies of Key Countries

The estimation of an energy security index and the results of CA could be complemented usefully by a case study analysis of a relatively small number of key countries, possibly including: Germany, Russia, Iran, Iraq, Saudi Arabia, the United States, Canada, Venezuela, Nigeria, China, India and Japan. If a researcher decided to concentrate one's efforts on the Southeast Mediterranean and the Middle East, plenty of ideas are present in the material present in previous sections; in particular, examining Turkey, Israel, Greece and Cyprus would be very important.

Different countries may be examined at different milestones, if this is recommended by the produced classification or grouping of countries, especially the calculated values of the energy security index at the milestone time periods. Since such key countries would be analyzed in depth, it would be interesting to see if they moved from one energy security cluster to another over time, and what policies were associated with such moves.

Since case studies may examine a broad spectrum of (quantitative and qualitative) energy security concerns, they may help explain why countries under comparable international conditions prioritize energy security differently. In this fashion, a case study approach would complement nicely the quantitative methods discussed in previous sections.

4.7 Carrying Out Interviews of Energy Experts

Conducting interviews with energy experts is a research method that has been combined with other methods in the field of energy security [77].

The interviewees could range from academic and policy experts on energy security to public officials from different government departments and bodies. Snowball sampling could be employed to augment the set of experts selected initially, i.e. at the end of each interview, experts could be asked to nominate other potential interviewees (and help provide contacts and access).

The interviews could be based on a questionnaire of open-ended questions, and would be used to complement quantitative data analyses, and provide more texture and depth to the knowledge that will have been gained thus far. The qualitative data produced by the interviews could be of use both from a theoretical and an empirical perspective. By construction, the theoretical approach will have a normative ambition, and will strengthen the comprehension of the main issues at stake. In particular, the interviewees could be polled on their opinion of the concept of energy security, with emphasis on the milestone time periods. The interviewees could also be asked to critique the energy security index and judge the classification, energy security policies, and geopolitical energy hotspots depicted on the dynamic maps throughout the milestone time periods.

The degree of involvement of expert opinions in the developed index would help provide a reality check and ensure its transparency [74].

4.8 Forecasting Energy Security

An energy security index research could be complemented by energy security forecasts.

The use of formal statistical methods would be contingent on data availability. If the socioeconomic and geopolitical energy security data were available on a yearly basis (which, at this point and with the experience gained in collecting such data by the authors of this Chapter, appears nontrivial) then formal modes (such as time series regression combined with atheoretical methods such as ARIMA) could be used to produce forecasts. If only data for the examined milestone time periods were available, forecasts would have to be developed based on a qualitative approach (and with a greater involvement of the experts).

Taking into account global climate change and energy mix transitions would be of particular importance in developing robust energy security forecasts. It would be particularly interesting to see how the energy security index values affect the forecasts, see how the state of energy security affairs is forecast to vary in the foreseeable future, and gain an understanding as to what geopolitical implications are likely to occur.

Importantly, energy security could be examined in the context of storylines, such as the *Markets and Institutions* (idealistic scenario) and the *Regions and Empires* (realistic scenario) examined by Correlje and van der Linde [15]: in a *Markets and Institutions* world, Russia becomes integrated in the EU market, while in a *Regions and Empires* world, Russia develops its own empire. Depending on which storyline prevails, the EU may need to transform itself [15] from an economically driven project into a project that is driven by geopolitics and the strategic use of state and economic power (possibly at the cost of significant political hardship and internal conflict).

5 Closing Comments

An extensive examination of the current energy security indicators and indexes in the literature has shown the differentiation among studies, and the need to integrate additional indexes in the framework for the analysis of geopolitical problems.

Many previous studies on energy security have focused on the security of supply. This Chapter has shown how future energy security research could add to the state of the art by combining quantitative and qualitative approaches in a way that is innovative and characterized by a more holistic geopolitical perspective.

The outcomes of such research could, in the long run, help address the issues of energy security in the years to come that may be characterized by energy transition, economic uncertainty and environmental hardship.

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