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A broadened typology on energy and security

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ABSTRACT

A broadened typology describing the interconnection between energy and security is developed in this paper, with the aim of improving understanding of the relationship between energy and security by applying different research and policy perspectives. One approach involves studying energy as an *object* exposed to security threats, using concepts such as security of supply or security of demand. Another approach involves studying the role of the energy system as the *subject* in generating or enhancing insecurity. The latter approach includes studying the conflict-generating potential inherent in the economic value of energy, the risk of accidents and antagonistic attacks to energy infrastructure and the security risks related to the negative environmental impact of the energy system. In order to make a comprehensive analysis of the security consequences of proposed energy policies or strategies, all these aspects should be taken into account to varying degrees. The typology proposed here could be a valuable tool for ensuring that all security aspects have been considered.

1. Introduction

Energy is an essential commodity for a well-functioning society. The availability of low cost energy has historically been one of the main factors contributing to economic development and an improved standard of living. At the same time, energy contributes heavily to several of the most important environmental problems, especially climate change. The modern energy system has developed into a network of energy interconnections (global, regional and local) and the economic values involved in the transactions are huge.[1]

The concept of energy security is frequently highlighted in policy texts and in academic literature, but with different connotations depending on the professional, political and geographical background of the user, see e.g. Refs. [2,3]. Energy security is often implicitly used as a synonym for security of supply, particularly by researchers applying an economic perspective, see e.g. Ref. [4]. Security of supply is defined broadly as adequate, affordable and reliable supplies of energy. However, in other forums, the relationship between energy and security is seen from the perspective that energy can be an important contributor to conflicts and other security threats. These two perspectives are seldom combined in analysis. However, Hoogeveen and Perlot [5] touch upon this in identifying the two fears, dating back to the 1970s oil crisis, that create the grounds for EU energy security policy, namely the risk of regional tensions leading to a disruption in oil and the fear that energy will be wilfully used as a weapon, cf. also [3]. Similarly, Chaudry et al. [6], referring to the UK DECC, state that energy security can be divided into physical security (uninterrupted supply), price security and geopolitical security.

Security of supply plays an important role in energy policy, together with industrial competitiveness and sustainability, see e.g. Ref. [7], and it also overlaps other policy arenas such as environmental policy, security policy, foreign policy and business and trade policy. Energy as a contributor to conflicts and other security threats is usually dealt with in foreign policy and security policy (in its wider definition also including critical infrastructure protection).

The aim of this study was to establish and elaborate a broad typology for categorising energy and security issues that would allow us to include both perspectives mentioned above. Recent related efforts elaborating on parts of this field can be found for example in Refs. [6,8,9]. The typology could be a useful tool when analysing various policy initiatives. One important area would for example be when analysing climate mitigation strategies. Energy security aspects are sometimes discussed in climate policy studies but the aspects included are usually limited. Using the typology proposed here could be a useful framework for providing a fuller picture of the impact of climate policies, positive or negative, to security.

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[1] Blyth [1] estimates the total value of global energy consumption to be about 7% of Gross World Product (GWP).

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This paper takes its starting point in various existing security concepts (which are seldom explicitly discussed in existing energy security studies) and the different threats to security that can be identified. Following from that, two main approaches to energy and security (energy system as *object* to security threats or as *subject* generating or enhancing insecurity) are developed.

2. Security concepts and their relevance for energy

One way to define security is as the absence of threats, but security can scarcely be understood without relating it to an actor, activity, technology or system. Furthermore, security can have both an objective and a subjective dimension. While the objective dimension can include factors that can be measured against external criteria, the subjective dimension can be defined as the individual perception of being safe (secure). Subjective security, which might be of great importance for policy, does not have to be correlated to changes in the indicators used for measuring objective security [10].

Threats and crises can be man-made (deliberate and accidental) or follow from natural causes [11]. Furthermore, threats to a system can be both external and internal. Energy policies can deal with both internal and external security threats. For example, the energy security policy of the EU, see e.g. Ref. [12], deals with both internal threats (e.g. poor infrastructure and inefficient markets) and external threats (e.g. dependence on unreliable imports).

In the security discourse a distinction is often made between national or state-centric security and human security. National security traditionally deals with the protection of the national state and its functions, while human security focuses on the security of individual citizens, see e.g. Ref. [13]. The United Nations Development Programme [14] introduced two main aspects of human security: safety from chronic threats such as hunger, disease and repression; and protection from sudden and harmful disruptions in the pattern of daily life. The UNDP has furthermore defined seven different categories of human security; environment, economic, food, health, personal, community and political security. There is a link between the state-centric and human concept in that the state often (but not always) plays an important role in preserving human security and vice versa [15]. In addition to the concepts of national and human security the stability of the international state system is important in a globalised world, since instability can pose threats to important flows of goods and people necessary for providing national and human security.

Another concept of relevance is societal safety [16], which could be defined as society's ability to maintain critical social functions, to protect the life and health of citizens and to meet citizens' basic requirements in a variety of stress situations. It deals with extraordinary stresses and losses that require a response beyond routine capacities and operations. According to Ref. [16], societal safety includes other concepts such as national security, human security, sustainable development and incident management. Another concept of relevance for energy and currently stressed in policy is critical infrastructure protection (see e.g. Refs. [17–19]), which is often used within the civil protection policy arena. Energy is often highlighted as one of society's vital functions and critical infrastructure together with health protection, the payment system, etc.

Energy and security can be discussed using all these approaches to security. In our further analysis we found it fruitful to view energy and security field from two different angles. In the first, the energy system can be seen as an object that should be protected from external security threats thus enabling it to provide the services necessary for most societal functions. In the second the energy system is viewed as a subject and one of several factors that, in a broader sense, could pose threats to human, national and societal security, see Fig. 1. In the following sections these two perspectives are elaborated upon in more detail.

3. Energy system as object: securing energy supply and demand

Energy security in the meaning of securing a well-functioning energy system has at least two aspects, security of supply and security of demand. The relative importance of these aspects depends on the role of the actor or the country within the energy economy.

3.1. Security of supply

For most actors and countries, security of supply is the most important aspect and is also the field most commonly discussed in

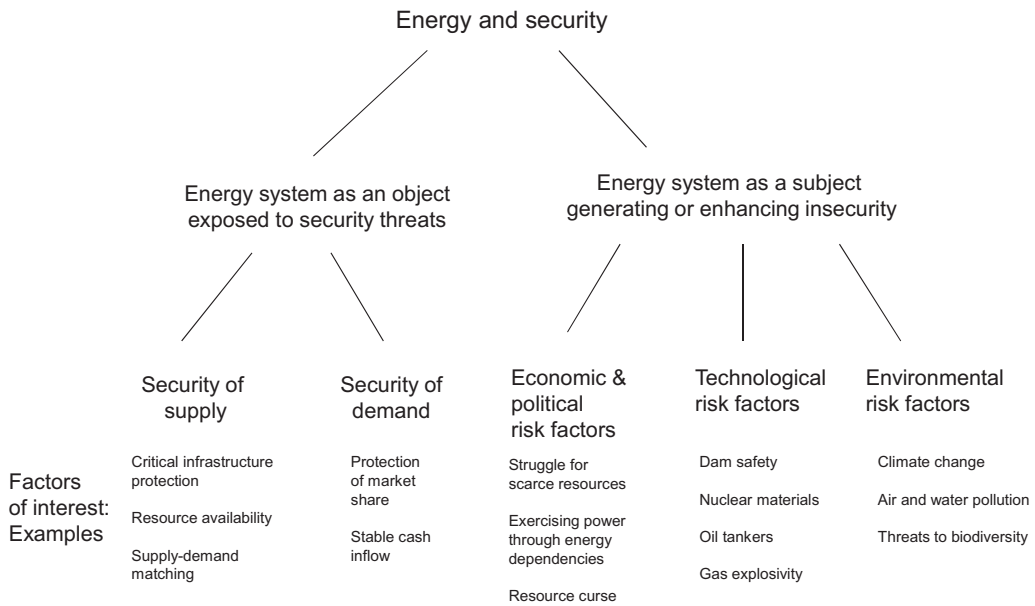

Fig. 1. The analytical structure used in this paper to study the relations between energy and security.

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Table 1
Areas worth protecting, threats to security of supply and primary, secondary and tertiary causes of these threats. The list is not intended to be exhaustive.

Areas worth protecting, examples	Threats, examples	Primary causes, examples	Secondary causes, examples	Tertiary causes, examples
- Human health - Economic growth - Public safety - Trust in political system - Trust in energy companies	- Energy interruptions - Price shocks - Long-term high price levels	- Technical errors - Handling errors - Weather events - Antagonistic events (terrorism, blockades, etc.) - Imbalance between supply and demand - Lack of physical energy resources	- Lack of investment in maintenance - Lack of education - Lack of investment in physical security - Lack of investment in search and exploration - Lack of investment in alternative energy	- Poorly functioning markets - Inadequate regulation - Unstable political conditions in producer countries - Unstable political conditions in countries key for distribution - Unsuccessful development of alternative energy sources

the literature. The starting point for this discussion is a notion of the important role of energy for the functioning of modern society. Oil and gas often play a central role due to its pivotal position in the global energy system. Definitions of energy security in the meaning of security of supply usually include an availability aspect (stable and uninterrupted supply) and a price aspect (see e.g. Refs. [20–22]). A variant, energy services security [23], is based on the recognition that it is not energy per se but the energy services it provides that is important for the consumer or society as a whole. Much interest is directed to the availability of global and national energy resources, the functionality of energy infrastructure, energy diversity and the development of functioning and transparent markets (see e.g. Ref. [24]).

Security of supply (or energy services) depends on a chain of well-functioning infrastructure and networks stretching from energy extraction through transportation, transformation, refining and distribution all the way to energy end use. Potential natural or human threats to the functioning of the system occur all along these chains. The importance of a well-functioning network has made energy dependency a central concept in the energy security discourse. However, there is no exact definition of energy dependency and there is also an ongoing discussion as to the degree of importance that should be attributed to this factor (see e.g. Refs. [25,26]), and whether gaining energy independency is important for increasing security of supply.

The threats to security of supply can be of differing characters in terms of type of negative effect, time-frame and cause of the threat. The main negative effects that threaten the interests and values of nations and individual consumers are energy interruptions, see e.g. Refs. [27–29], and price increases resulting from long or short term imbalances between supply and demand (see e.g. Ref. [26]).

Two different time aspects are relevant for dealing with threats to the security of supply, namely the *level of permanence* of a disturbance and the *prior warning time* expected before a disturbance.

First, the longer the disturbance, the greater are the expected consequences. The acceptance for short-term effects and the strategies to deal with these are significantly different to those attached to longer interruptions and imbalances. For example, a short-term price spike can be more easily assimilated in the economy than longer periods of high prices eating up more of the economy's resources. Similarly, an electricity blackout of a few seconds causes much less impact and is generally more accepted than a blackout lasting for many hours and even days. Furthermore, for shorter fuel supply interruptions, energy reserves could be released to reduce price hikes but this method would be less feasible for long-term imbalances.

Second, with a long prior warning time the potential disturbance and its consequences can more easily be mitigated by proactive behaviour. For example, dramatic sudden price increases could have more serious consequences than a slow increase, to which economies can adjust over time [3]. If there is an appropriate response to signals, the longer term issue of a necessary diminishing role of fossil fuel resources could be handled through investments in other energy sources, energy efficiency improvements, etc.[2]

The threats to security of supply can be viewed as multi-level effects, see Table 1. First, there are primary causes leading to interruptions or market imbalances. They could consist of inadequate production capacity, technical or operational errors, weather events or antagonistic behaviour such as terror attacks, blockades, wars, etc. These primary causes could affect all parts of the energy chain, but the consequences for the consumer would vary depending on their location. Effects appearing near the consumer would pose a greater risk of supply interruption, for example through blackouts in the case of electricity. Disturbances at fuel extraction facilities, refineries or electricity production plants, etc., which are situated far from the consumer, would be less likely to lead to interruptions in a well-functioning market but, due to the resulting imbalances between supply and demand, could instead lead to price effects, creating a new balance between supply and demand.

These direct causes often depend, at least partly, on indirect causes. Indirect causes could include lack of new investment in capacity and quality, lack of maintenance of existing systems, lack of education, lack of physical protection and political unrest. On a higher level, malfunctioning markets and other institutions, as well as inadequate regulation, could be underlying causes leading to inadequate investments in for example capacity, functionality and protective measures. Furthermore, unclear legal status of geographical areas could hinder the exploitation of resources, see e.g. Refs. [37,38]. Lack of transparency and lack of trust in the reliability of countries for exploration are often stressed as being of great importance for impeding further oil exploration in many areas, as well as for enhancing price volatility [39,40]. The lack of economic distribution of the wealth emanating from energy exploitation could lead to politically unstable conditions, which might hinder the development of energy extraction within countries, see also next chapter. Measures and strategies, both proactive and reactive, that mitigate the risk of disturbance comprise in themselves an important field for energy and security studies, but are not included in this paper. It should be noted, however, that these strategies and measures could target primary, secondary as well as tertiary causes.

Security of supply is analysed using both quantitative and qualitative methods. In the literature, much effort has been devoted to developing and using various indicators to compare different energy systems with regard to security aspects (see e.g. Refs. [4,21,26,41–46]), and to evaluating strategies for strengthening security of supply, see e.g. Refs. [28,47,48]. The indicators include for example import dependency ratios, diversity indices (including

[2] There are different views in the literature as to whether the reduced role for fossil fuels (especially oil) will primarily be driven by resource constraints or by climate policy and whether the pre-warning time is enough for managing the balance between supply and demand, see e.g. Refs. [30,31,32,33,34.35,36].

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both energy sources and market suppliers) and economic estimates of the cost of disturbance (blackouts as well as price hikes).

3.2. Security of demand

For energy exporting countries, security of demand may be equally important to security of supply. Both the economy in general and the national budget can be heavily dependent on income from energy exports, cf. [5]. The role of the energy sector in this case is comparable to that of other important industrial sectors, with the difference that the energy sector in a few countries totally dominates the economy. For example, the oil industry contributes 45% of GDP in Saudi Arabia, 80% of budget revenues and 90% of exports [49]. For budgetary reasons it is of great interest for exporting governments that income remains stable, and thus price volatility is a great concern (cf. [39]), as is keeping transportation routes functioning.

Stable prices and open transportation routes form mutual interests shared with the energy consuming countries. However, conflicting views between producers (e.g. OPEC) and consumers may arise regarding price levels and optimal exploration rates, cf. [50]. Consuming countries wish to keep energy prices at as low level as possible without hampering the development of enough supply to meet demand. The producing countries on the other hand gain from keeping the price as high as possible as long as it does not lead to significant losses in demand. Climate policy is also often seen as a major threat to the security of demand of oil-exporting countries as it would give incentives for energy efficiency and expansion of renewable energy. Persson et al. [51] have, however, challenged this reasoning as being too simplistic as climate policy would lead to even greater cost increases for unconventional oil and synthetic diesel from coal which, in a world of dwindling oil resources, might set the long-term price for liquid fuels. Thus the price on oil would go beyond an applied CO_2 fee, increasing the rent on conventional oil.

4. Energy system as subject: a generator of insecurity or threat multiplier

Energy could act as a generator of insecurity in several ways. The security effects can be divided into those that are mainly a result of the economic importance of energy, the physical and technical characteristics of the energy carriers and the environmental consequences of energy use, cf. Fig. 1. All these aspects are discussed further below, see also Table 2.

Table 2
Values worth protecting, energy-generated threats and potential causes of these. The list is not exhaustive.

Values worth protecting, examples	'Energy-generated' threats, examples	Causes, examples
- Peace - State stability - Democratic institutions - National influence - Human health - Economic assets - Natural environment	- Struggle over resource-rich areas - Energy blockades - Energy as a factor in political negotiations - Internal wars and conflicts - Accidents (hydro, nuclear, oil) - Terrorism (hydro, nuclear, oil) - Criminal acts (blackmail, etc.) - Climate change	- Economic value of energy - Dependence on specific energy supplier - Uneven distribution of wealth - Lack of investment in technology and competence - Lack of physical protection - Carbon dioxide emissions

4.1. Economic and political risk factors

International conflicts arising from the competition for scarce resources could be attributed to the economic aspects of energy. Thus, ongoing or potential conflicts over small islands or water areas, for example in the South China Sea and the Arctic Regions, are often attributed to the existence of potentially valuable energy resources, see e.g. Refs. [3,37,52–56]. Furthermore, it has often been argued that US military activities in the Middle East, e.g. Iraq, are motivated by the urge to control the energy supply, taking its starting point in the so-called Carter doctrine [57]. The opposite standpoint is also found in the literature; with arguments that there is no economic rationale for trying to take control of the oil in Iraq by military means, see e.g. Ref. [58]. Others argue that US intervention, rather than securing its own energy interests, forms part of securing generic interests of global capitalism as a whole [59].

Furthermore, the economic value of energy can encourage and enable countries to strengthen their geopolitical position. This can be based on their role as dominant supplier, prominent investor and/or consumer, see e.g. Refs. [37,60]. One example of a country trying to exercising the power of a prominent supplier is Russia. A significant amount of literature deals with the security policy implications of its energy relations with neighbouring countries including the EU, see e.g. Refs. [24,25,61–63]. Some analysts also report that Chinese investments are sometimes exchanged for political support on general political stances in the global arena, see e.g. Ref. [64]. In addition, blockades directed towards energy suppliers have been used from time to time (e.g. in relation to Iran and Iraq) with the purpose of achieving political goals. Renewable energy sources are often seen as less risky from a security policy perspective. There is a discussion, however, whether for example the development of large-scale solar power in North Africa, largely for import to the EU, would create new dependencies with security policy implications for Europe, see e.g. Ref. [65].

One important aspect of the energy and security connections is the regional insecurity that abundant energy resources (and other natural resources) can help generate, often in poorer countries (often called the 'resource curse'). The underlying reasons can be uneven distribution of wealth, corruption and reduced incentives to build functioning institutions.[3] Examples of this can be found for example in Nigeria and Ogaden in Ethiopia [24,57,67]. Concerns have more recently been raised that the on-going large scale expansion of biofuels could create new conflicts when large scale plantations substitute small-scale framing creating potential conflicts between international companies and local communities (For example, Van den Horst and Vermeylen [68] discuss the consequences for indigenous and minority communities of the on-going biofuel expansion).

Finally, the economic value of energy as well as its technological characteristics (see below) could attract the attention of terrorist groups [69], but whether energy infrastructure is an attractive target for terrorists can be discussed. For example, Toft et al. [70] see only minor incentives for terror groups to attack energy infrastructure, as such attacks generate limited attention among the public, while other more newsworthy targets are also less well protected than energy installations.

[3] Humphreys [66] presents six mechanisms by which resource (not only energy) abundance can create civil conflicts: i) the greedy rebels mechanism ii) the greedy outsiders mechanism iii) the grievance mechanism iv) the feasibility mechanism v) the weak states mechanism and vi) the weak networks mechanism.

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4.2. Technological risk factors

The second area of security and safety threats emanating from energy systems is grounded in the physical and technological properties of energy, generating various risks of natural/technical hazards and antagonistic threats. Damage to hydroelectric dams, oil tankers, gas depots and nuclear plants, emanating from technical and operating errors, can have devastating effects on both nearby and more distant areas, see e.g. Refs. [71,72]. As mentioned above, these plants are also potential targets for terror groups [69,70]. Furthermore, with nuclear energy there is an associated risk of proliferation of nuclear weapons, as the capacity to enrich nuclear fuel is closely related to the capacity to produce nuclear weapons, and the plutonium produced as a by-product in reactors is a viable resource for nuclear weapon production, see e.g. Refs. [73–76]. Nuclear waste could also be a target for criminal groups (possibly to sell illegally or as an object for blackmailing activities) or terrorists [77].

4.3. Environmental risk factors

Finally, security aspects are frequently discussed in relation to climate change, see e.g. Refs. [13,78]. In these cases climate change is often argued to act as a threat multiplier, enhancing existing stresses for many societies. As fossil fuel combustion is the most important contributor to climate change, energy is here indirectly a potential source of insecurity. Climate policy measures to reduce fossil fuel use may also generate conflicts among nations, creating new security risks, see e.g. Refs. [13,79,80].

Other risk factors of relevance are the effects of air pollution which poses a severe threat to human health and thus human security, not the least in developing countries where small-scale wood burning causing many deaths etc [81]. Energy exploitation also puts stress on water resources is also an important aspect not the least with the expansion of non-conventional fuels produced from tar sands and oil shale, see e.g. Gavrilova et al. [82].

Large-scale expansion of biomass could in the future be a new stress factor to biodiversity, see e.g. Ref. [83]. This could be the case even if the biomass plantations themselves have little negative impact on biodiversity (or even be locally advantageous compared to current land-use practises), through secondary effects where current land-use forms are moving to other and more extensively managed lands (so-called indirect land use change) [84].

5. Discussion

The typology developed above is one way to structure the field of energy and security. It could support a comprehensive evaluation of various energy systems or policy initiatives with regard to energy and security aspects. Policy initiatives that will have an impact on the relationship between energy and security can be found in a broad range of policy areas, such as energy policy, foreign and security policy, civil protection policy, environmental and climate policy. The typology developed stresses the fact that energy and security can be viewed from several different perspectives. One main dividing line lies between security issues, where the energy system is an object of security threats, and where it is a subject that generates or enhances insecurity.

The boundary between the different perspectives is not clear-cut, however. For example, at the same time as regional conflicts could sometimes be partly a consequence of the availability of energy resources and poor distribution of the wealth generated, those conflicts could hamper the exploitation of available resources and hence affect security of supply. In a similar way, the potential attractiveness of energy infrastructures for terror attacks, if exercised in reality, would not only lead to direct security effects and potential casualties, but would also indirectly affect energy markets.

With a broad approach to security, most disturbances could be framed as security issues, at least if they are of significant magnitude. Use of security as a concept for framing an energy issue can have several different motives. One motive may be to give the energy issue a higher priority within politics, since the securitisation of an issue such as energy can enable it to be excluded from the normal decision-making process [85]. Conversely, the traditional security actors might want to find new areas of potential conflicts and threats, which could motivate a continuous flow of resources into the security sector. In line with this argument, Moran and Russell [86] stress that overemphasis on the possibility of great power conflicts in the energy field favours important, and generally conservative, institutional interests within the defence establishment of developed states, particularly in the US. Furthermore, although a conflict discourse around energy is widespread, some studies instead highlight the mutual benefits of cooperation between consumers and producers [87]. According to those authors, the suppliers' quest for supply security is met by the producers' quest for demand security.

The approaches to energy and security can differ between countries depending on the structure of the energy system and historical experiences. This can be illustrated by the various lines chosen by the different member states within the EU, where e.g. the degree of reliance on Russian gas and historical experiences from the Cold War have led to different approaches to energy security, see e.g. Ref. [88]. Historical experiences may also affect the relative priority given to energy security compared with environmental factors.

Within energy policy, the security aspect of energy is only one aspect. The competitiveness of the industry is a central area of interest in most countries. Energy security priorities, such as increasing the reliability of the energy system, might incur extra costs, which could be negative from the perspective of competitiveness. Thus, finding a balance between security-enhancing measures and efficient energy systems is an area that requires further research. Some measures, such as cost-effective energy efficiency improvements and creating stable conditions for investment in new production facilities can serve the purposes of both energy security and competitiveness.

Measures that reduce the climate impact of the energy system could have an effect on security of supply and vice versa. For example, restrictions in the use of coal, due to its negative impact on the climate, could lead to even greater dependencies on more concentrated resources such as natural gas. Climate policy could also pose restrictions on some strategies for diversifying energy supply, such as replacing petroleum with non-conventional oil, as the latter usually produces significantly higher emissions per unit of final energy. However, removing obstacles for energy efficiency can be advantageous for security of supply, competitiveness and climate.

Much of the literature on energy and security focuses on the current or near-term situation and on oil and natural gas. Although current dependencies will also be relevant in the future, new dependencies will most likely develop. New international flows of renewable energy in the form of biofuels, hydrogen and electricity could create new security issues. At the same time as new long-distance energy flows are developed, distributed production systems could develop in parallel, with both potential security advantages and disadvantages. The implementation of new policy regimes could generate new security issues by imposing restrictions on nations using fossil fuels that can be assumed to be necessary for their development or, in other nations, by hampering their possibilities to harvest the economic value of their fossil fuel resources [13,79].

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The typology developed in this paper can prove useful in supporting a broader analysis of the security consequences of future policy regimes, not the least climate policy. For example, in Ref. [89] an earlier version of the typology was used for identifying security aspects related to a future major expansion of renewable energy sources. The study showed both positive security aspects of renewable energy (e.g. the independence of exhaustible resources), several similarities with current systems regarding the dependence of well-functioning technical systems and potential reasons for concern regarding how to handle variable electricity production, dependence of new potentially instable regions, and the strain on food security and biodiversity of an increased use of biomass.

Furthermore in an on-going project,[4] the scenarios in the EU energy roadmap [90] and other relevant scenarios are analysed using the typology presented here. Although energy security is analysed shortly in the impact assessment of the EU energy roadmap, this analysis is limited to a few, mainly quantifiable, aspects of energy security. A better understanding of the relations between energy and security could enhance the opportunities for developing national and supranational policy strategies with a good balance between environmental, economic and security objectives. In addition to applying the typology, a further development of specific methodologies (quantitative and qualitative) is important in order to deepen the understanding of various security aspects relating to energy system transformations (see e.g. Ref. [91]).

6. Conclusion

In this paper, a typology is presented that describes the relation between energy and security in a way that integrate several perspectives found in the literature, perspectives that are often treated separately from each other. Through this integration, the typology can be useful as a theoretical basis for a broad analysis of security aspects of various energy systems designs and energy policies.

The main structural feature of the typology is the dividing line drawn between security issues, where the energy system is an *object* of security threats, and where it is a *subject* that generates or enhances insecurity to society. Each of these parts is further divided in smaller elements. The security issues related to when energy systems is seen as an object are divided in security of supply and security of demand, whereas the security issues related to when the energy system is seen as a subject are divided in economic and political, technological, and environmental risk factors. As for most typologies, the division between the various elements is not clear-cut and some threats could be classified as belonging to more than one of the defined groups.

The typology can be used for broad interdisciplinary academic analyses of the nexus between energy and security and as a support in policy development processes. Although many of the building blocks of the typology are included in existing policy analyses they are too seldom integrated in broad comprehensive analyses.

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