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Cherp, Aleh; Jewell, Jessica

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The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration

Aleh Cherp and Jessica Jewell

Scholarly discourses on energy security have developed in response to initially separate policy agendas such as supply of fuels for armies and transportation, uninterrupted provision of electricity, and ensuring market and investment effectiveness. As a result three distinct perspectives on energy security have emerged: the 'sovereignty' perspective with its roots in political science; the 'robustness' perspective with its roots in natural science and engineering; and the 'resilience' perspective with its roots in economics and complex systems analysis. At present, the energy security challenges are increasingly entangled so that they cannot be analyzed within the boundaries of any single perspective. To respond to these challenges, the energy security studies should not only achieve mastery of the disciplinary knowledge underlying all three perspectives but also weave the theories, methods and knowledge from these different mindsets together in a unified interdisciplinary effort. The key challenges for interdisciplinary energy security studies are drawing the credible boundaries of the field, formulating credible research questions and developing a methodological toolkit acceptable for all three perspectives.

Address
Central European University, Nádor utca 9, 1051 Budapest, Hungary

Corresponding author: Cherp, Aleh (Cherpa@ceu.hu)

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Introduction

Energy security has been a practical concern for almost a century and has also emerged as a distinct area of scholarly studies in the last several decades [1,2•]. At the same time the ability of the contemporary energy security studies to inform energy policy has been limited. The historic roots of the energy security ideas can explain this limitation. Such ideas emerged as responses to several separate policy problems. However, the present complexity and the rapid pace of transformation of energy systems mean that these problems can no longer be effectively studied or resolved in isolation from each other. This means that the knowledge developed to address these problems need to be integrated in a field of studies that allows to frame, analyze and conceptualize the seemingly separate energy security issues in an integrated way.

Our review shows that developing a unified field of energy security studies is far from trivial and means much more than compiling lists of various disparate issues related to energy security. This is because historically separate policy challenges shaped at least three distinct perspectives on energy security, rooted in different scientific disciplines such as political science, engineering and economics. Their integration requires overcoming the difference between theories, languages and methods inherent in these disciplines. The last section of the article outlines these differences and proposes the first steps towards overcoming them.

Evolution of energy security challenges

Energy security, oil and geopolitics

In the first half of the 20th century, culminating with World War II, the notion of energy security was closely tied to the supply of fuels for the military. When the British Navy switched from domestic coal to imported oil in the early 20th century, it became vulnerable to an enemy's occupation of oil fields or attacks on transportation lines or refineries. The battles over oil fields in Indonesia, the Middle East, the Caucasus and Romania during World War II vividly highlighted the military importance of oil supplies [3].

The importance of oil for armies did not decrease in the post-war period, but oil also became vital for industrialized societies in many other ways. Developed nations became dependent on motorized vehicles fueled by oil products, not just for passenger transport but also for food production, health care, manufacturing, heating, and electricity generation. At the same time, most industrialized countries did not produce enough oil to satisfy their needs.[1] Moreover, decolonization meant that oil was imported from independent nations rather than from politically dependent territories as before the war. Conversely, many of these developing countries also became dependent on oil export revenues for their economic development and political stability.

[1] With the initial exception of the United States which nevertheless became a net oil importer in 1970.

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The vulnerability of this system became apparent in 1973 when most Arab members of OPEC along with several non-OPEC Arab countries cut oil supplies to the USA, the Netherlands and later to several other countries in protest of the US support to Israel. As a result, the price of oil quadrupled triggering an economic crisis and exposing the fragility of the global oil supply system.

Thus, in the first three-quarters of the 20th century the most politically prominent problem of energy security was protecting oil supplies, vital for the modern armies and economies. The main threat for such supplies was seen as hostile action, within or outside of a formal military conflict. A military metaphor of the 'oil weapon' was quickly coined[2] to describe the 1973 oil embargo [5]. Energy security was conceptualized by political analysts who viewed war and peaceful diplomacy as part of the same 'grand strategy'.

The central part of such strategy for securing oil supplies was establishing international regimes where disruptions of oil flows to industrialized countries would be less likely to occur. The first element was projecting US military and political power to oil producing regions, as articulated in the Carter doctrine, which stated that the United States would use military force in the Persian Gulf region to defend its national interests, specifically 'the free movement of Middle Eastern oil' [6]. The second element was to foster a global market for oil products where a multitude of actors would guarantee that no single player wields too much power. The global oil market approach is a practical expression of a famous Winston Churchill's view that 'safety and certainty of oil lies in variety and variety alone' [7]. The third element was the establishment of the International Energy Agency (IEA) with the mission to co-ordinate emergency response of OECD countries to disruptions of oil supplies. IEA members were required to hold emergency stocks of oil which would be used to counteract any such disruption.

In addition to these responses, oil production was encouraged in regions governed by 'friendlier' countries (Alaska, Canada, and the North Sea). Switching from oil to other energy sources (nuclear, gas) in heating and electricity generation and energy conservation were also promoted. These measures bore fruit in the 1980s and the 1990s when the price of oil dropped and the fears of a physical supply disruption at least temporarily subsided. However, in the last decade, security of oil supplies has recaptured the attention of policy makers — this time not only in the developed world, but also in China [8], India and other rapidly growing economies.

[2] The term 'oil weapon' was used for the first time by the League of Nations considering sanctions against Italy in 1935 [4].

Several factors contribute to this. First, the supplies of conventional oil are widely predicted to peak or plateau in the next 2–3 decades [9]. At the same time, just as in the 1970s, the transport sector is almost entirely dependent on oil. This means that a disruption of oil supply is as likely to paralyze nations now as it was in the 1970s. Secondly, higher and more volatile oil prices, which some argue are affected by an increases in global market speculation [10], are expected to continue [9]. Thirdly, the rise of demand from new consumers in Asia, especially India and China may be exacerbating price volatility and lead to long-term price increases [11,12]. The exclusion of these rapidly growing economies, which will likely account for the bulk of increase in global oil consumption, from the IEA mechanisms is likely to make consumers' response to oil supply disruption less co-ordinated. Finally, oil reserves in OECD countries and other major consuming regions are being depleted so that oil production is once again increasingly concentrated in just a few countries and regions, primarily in the Middle East and former Soviet Union. Some argue that such concentration means increasing vulnerability to both conditions within these regions as well as to the transport routes from these regions which are characterized by a handful of choke points such as the Strait of Hormusz through which a third of all seaborne flows [13]. Taken together, these factors fuel anxiety and fear of tensions which some describe as a 'scramble' between new and old consumers for the remaining and increasingly concentrated resources [14].

In contrast to the 1970s, contemporary energy supply concerns extend to natural gas as well as oil.[3] These concerns primarily apply to the Eurasian gas market where gas is transported through pipelines primarily under long-term contracts. Larsson [15] identified 40 threats and actual cut-offs of Russian gas to the CIS countries in 1991–2008. The Russian-Ukrainian gas crisis in 2009 which followed a dispute concerning the pricing mechanism is the most recent example of a large-scale gas supply disruption with palpable effects in the European Union. Eastern European countries which use natural gas for the bulk of their electricity and heat production and which have historically been importing from Russia through a very limited number of supply routes are among the most vulnerable to such disruptions. The ongoing attempts to diversify gas import routes to Western Europe for example through the Nord Stream pipeline rise additional energy security concerns. Although liquieified natural gas (LNG) accounted for some 30% of the global gas trade in 2010 it requires significant initial investment and is still not a solution for many landlocked Eurasian countries. Additionally, analysts are now discussing the

[3] Even imports of coals by such major consumers as India and China have increased recently but no energy security issues have been explicitly articulated in relation to this increase so far [9].

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implications of the recent advances in horizontal drilling and a dramatic cost decrease in formerly unaffordable gas reserves on energy security issues connected to natural gas supply. So far, the conclusion of these discussions is that the 'shale gas revolution' is not likely to have tangible effects in Europe in the near term [16•].

Consuming nations are not the only ones who have experienced increasing worries; in recent decades, anxieties of exporters of energy resources have also risen. The collapse of the Soviet Union shortly following the 1980 'oil glut' highlighted the fact that economies of many oil exporting nations are vulnerable to price fluctuations disrupting their energy export revenue.[4] This increased attention to 'demand security', or ensuring stable energy demand and prices. At the same time, the phrase 'resource curse' has been coined to designate the negative effects of excessive dependency on oil exports for political regimes and economic growth [18]. However, efforts to diversify away from relying almost exclusively on oil (and gas) export revenues have met varying degrees of success [19].

The landscape of global security has changed as well. It is no longer a bipolar world of the 1970s and the 1980s or the optimism of the 1990s, which followed the end of the Cold War and the reduced risk of a global armed conflict. Instead, it is shaped by the threat of international terrorism, instability in the oil-rich Arab countries as well as parts of Asia, Africa, and the former Soviet Union, the acquisition of nuclear weapons by India and Pakistan and the changing role of China. These international security developments are reflected in an increasingly complex web of energy/security alliances where the old players of OPEC and the IEA now function in parallel with the host of other organizations, treaties and regimes [20•].

Thus the traditional challenge of securing sufficient supplies of oil or other internationally traded fuels for nationally vital energy services, especially for defense and the transport sector has remained at the center of the energy security agenda for almost a century. Not surprisingly, much of the energy security literature, both contemporary and historic has been devoted to this challenge. Although in recent decades, the analysis of this fundamental aspect of energy security has become more sophisticated, it is still firmly rooted in political science and related disciplines such as public policy, security theories, international relations and global governance studies. The central question asked by this literature is who controls energy resources and through which mechanisms.

There are currently two notable schools of such studies. One is the older 'geopolitical' school initially stimulated by the world war experiences, the oil crises of the 1970s and dependence of the US on Middle Eastern oil. The current geopolitical literature takes into account the new realities of the 'peak oil', the rise of Asian oil consumption, and the new political situation in Europe and the former Soviet Union. It applies discourses initially developed for oil to natural gas, coal, rare metals and energy technologies. The main focus of the geopolitical school is on power balances and control over energy assets and resources mapped onto military, political or 'civilizational' alliances [14,21].

The other school focuses on institutions and regimes of global governance (including international markets) as well as on non-state actors and arrangements rather than on the balance of power of various national actors [22–25]. This school is increasingly informed by modern social science theories and the realities of global interdependence reflected in the globalization and global governance theories.

In summary, the central energy security discourse for most of the 20th century has been guided by strategic security studies and political theories. Natural science, engineering and economic knowledge has been incorporated in the (geo)political discourse often resulting in great simplifications of complex concepts (e.g. 'peak oil') but has not contributed to framing and conceptualizing energy security problems within this discourse. In order to attract policy makers' attention to non-geopolitical threats, alternative discourses on energy security rooted in these other disciplines emerged.

Energy security, natural resources and technical systems

While energy security challenges have been discussed in terms of military and geopolitical strategies since the early 20th century, another line of thinking on energy security has shaped in the last several decades. Its emergence was connected with the rise of systems analysis and attempts to understand the behavior of complex systems with the help of computer modeling and insights from natural and technical sciences. There were two important ideas from this thinking which have penetrated political and public discourse on energy security.

The first idea was that of globally limited resources. The first global model of resource consumption was presented as the 'Limits to Growth' report by the Club of Rome [26]. Although it did not specifically deal with oil consumption, its main finding — that expansive economic and population growth cannot be sustained beyond several decades because of natural resource constraints — was ominous against the backdrop of the oil crises of the 1970s. These crises had nothing to do with the scarcity of

[4] The exact effect of the oil price slump of the 1980s on the Soviet Union is a matter of debate, however, few would argue that the drop in oil prices weakened the country's economic reforms by depressing their earnings [17].

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oil but were often portrayed as such, thus drawing the attention to the 'limits' theory. The idea of limited resources has reemerged in the early 21st century when in the words of Daniel Yergin 'in the background of [energy security] concerns — but not too far back — is the anxiety over whether there will be sufficient resources to meet the world's energy requirements in the decades ahead' [7]. These concerns are most vividly reflected in the so called 'peak oil' theory which provokes a lively scientific and policy debate, central to contemporary energy security discourses [27–29]. Many of those scientists who do not adhere to the 'peak oil' theory use the idea of global limits to point to other constraints on using energy resources, most significantly — climate change.

The second idea penetrating the mainstream energy security discourse from scientific and technical disciplines was that of vulnerability of complex technical systems. In 1982, Lovins and Lovins brought this idea to the fore with their book Brittle Power which argued that the U.S. electricity system is vulnerable to major failures since it relies on large-scale power generation technologies which are primarily fueled by depletable, and often imported energy sources [30].

Such vulnerability was most visibly manifested by accidents at the Three Mile Island (1979) and Chernobyl (1986) nuclear power plants and more recently by Fukushima (2011). In these nuclear accidents, complex technical systems, failed either because of human mistakes or because of unforeseen events. The Chernobyl disaster impacted national security in the most direct sense by contributing to a demise of a modern nation state, the Soviet Union. A long-term ramification of these major nuclear accidents has been the virtual halting of nuclear power expansion in Western countries. As a result, nuclear energy, once considered almost a panacea for energy insecurity, was suddenly viewed as a much less viable option. Moreover, by the early 21st century, nuclear facilities in the developed world together with the industry's workforce, have started to age [31], stimulating a search for new options to generate electricity.

Along with the increasing complexity of energy systems in the second half of the 20th century was the growing sensitivity of industrialized societies to even short-term disruptions be it because of sabotage, terrorist attacks, extreme natural events or technical failures. A set of critical infrastructure vulnerability studies addressed these problems in the last decades (see [32] for a summary). No part of modern energy systems is as vulnerable to even short-term disruptions as electricity generation and transmissions. Systematic research about security of electricity supply has been advanced in a number of studies [33–35]. This scientific and engineering thinking has shaped the policy response formulated in terms of technical standards regulating backup generation capacities, early warning and load distribution systems (see for example [36,37]).

In summary, the second stream of energy security thinking which emerged in the later decades of the 20th century was concerned with vulnerabilities of energy systems to factors other than politically motivated disruptions of access to oil and gas. These studies expanded the energy security discourse from the geopolitical question of 'Who controls energy systems?' to the technical problem of 'How vulnerable are energy systems?'. While this perspective has not eliminated the need for political and institutional analysis, it requires a different type of expertise, especially in societies relying on technically complex and rapidly changing energy systems.

Energy security, markets and uncertainty

The next important stream of thinking on energy security developed in the context of de-regulation of energy supply which took place in many countries in the 1980s and 90s. The proponents of deregulation believed that markets can deliver energy more efficiently and ensure necessary investment in energy infrastructure while the diversity of market actors would guarantee security of supply. In some sense, energy markets were meant to depoliticize energy supply and thus make it less vulnerable to the types of politically motivated disruptions that shaped the earlier thinking on energy security. The thinking rooted in economic analysis at times explicitly challenged the notions of energy independence as 'not only obsolete but [potentially] dangerous' [38].

Viewing energy as a market commodity rather than a public good has increased the relevance of economic rather than political analysis. Market theories shift the focus from physical availability to the price of commodity so it is not surprising that the notions of 'economic welfare', 'price' and 'affordability' became common in recent definitions of energy security: for example, the 'availability of sufficient supplies at affordable prices' ([7], p. 70–71), 'the loss of economic welfare that may occur as a result of a change in the price or availability of energy' [1] or '[ensuring] the uninterrupted physical availability of energy products and services on the market, at a price which is affordable for all consumers' [39].

Energy deregulation, however, has not been entirely beneficial for energy security due to various flaws in market and regulation design. The most notable case of such insecurity was the Californian energy crisis in the late 1990s when Enron traders manipulated the electricity market in such a way that both prices and the rate of blackouts significantly increased [40].

For one, purely profit-driven investments go into the cheapest, but not necessarily the most secure options [38]. The debate about the trade-offs between security

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Table 1

Three perspectives on energy security.

Perspective	Sovereignty	Robustness	Resilience
Historic roots	War-time oil supplies and the 1970s oil crises	Large accidents, electricity blackouts, concerns about resource scarcity	Liberalization of energy systems
Key risks for energy systems	Intentional actions by malevolent agents	Predictable natural and technical factors	Diverse and partially unpredictable factors
Primary protection mechanisms	Control over energy systems. Institutional arrangements preventing disruptive actions	Upgrading infrastructure and switching to more abundant resources	Increasing the ability to withstand and recover from various disruptions
Parent discipline	Security studies, international relations, political science	Engineering, natural science	Economics, complex system analysis

and efficiency borrowed from the analysis of spreading risks in investment portfolios. Developed initially in the 1970s [41] and independently in the 1990s [42], it advanced the concept that risks of failures of energy systems can be minimized by applying the mean-variance portfolio theory (MVP) in order to diversify among energy options with different risk profiles (as reflected in their price history). This thinking, inspired by economic and portfolio management theories, was notably different from both the idea that energy security can be ensured by establishing political (or military) control over energy systems and the idea that a secure energy system can be engineered according to a deliberate plan. The difference lay in recognizing the uncertaining of different threats and the need to distribute the risk between various energy options.

The concepts of systemic uncertainty and diversity were taken to another level by Stirling [43] who extensively relied on complex systems theories, particularly with roots in evolutionary biology. Stirling argued that because of the inherent uncertainty in energy systems and technologies, there is no way to effectively hedge risks (even by such methods as MPV) other than by diversifying energy options as much as possible. This view was echoed by other scholars such as Keppler [38] who argued that markets are excellent at managing quantifiable risk but must rely on governments to provide insurance for non-quantifiable uncertain risk.

The most notable contribution of this school was the introduction of systematic analysis of diversity of energy portfolios. Further development of these theories in the last decade introduced more insights from technology learning and further elaborated the concepts of resilience and flexibility in energy security analysis [44•–47]. Diversity indexes are now routinely used to evaluate energy security of various jurisdictions and other elements of economic and market analysis are penetrating energy security policies. In relation to energy security Stirling [47] speaks of diversity of 'fuels, technologies, producer regions, industrial interests, supply and trade, infrastructures, workforces and regions'.

The three perspectives

As we have seen, energy security challenges began first and foremost as separate policy problems. Policy making on these problems was informed and advised by thinking in separate fields of expertise. As a result, three distinct perspectives on energy security emerged, each guided by its own mindset rooted in a different academic discipline and each with a predominant focus on a specific set of threats, responses and resilience strategies (Figure 1 and Table 1).

Problems related to oil security, initially for military use, and later for the transport sector have historically shaped the 'sovereignty', perspective on energy security rooted in strategic security studies, international relations theories and political science. It focuses on energy security threats posed by external actors, be they hostile states or terrorists, 'unreliable' exporters, or overly powerful 'foreign' energy companies. The main threats originate from intentional actions such as embargoes, malevolent exercise of market power, or acts of sabotage or terrorism. Analysis of energy security related to this school of thought focuses on the configuration of interest, power, alliances and space for maneuver (for example, the ability to switch suppliers or energy options) of different actors.[5] Risk-minimization strategies within the sovereignty perspective include switching to more trusted suppliers or weakening a single agent's role through diversification, substituting imported resources with domestic ones, and casting military, political and/or economic control over energy systems.

The increasing importance of energy in general and electricity in particular leads to the policy challenge of ensuring smooth functioning of increasingly sophisticated

[5] It is interesting that from the sovereignty perspective the asymmetry of energy power relations is interpreted as a threat per se, even when it does not empirically manifest itself in actual disruptions of energy systems. This is because the potential 'energy weapon' can be used even without 'firing it'. For example, powerful energy actors may extract various concessions from other actors as in case of Russia securing the extended lease of its military base in Crimea from Ukraine, in an apparent trade-off for favorable natural gas contract terms.

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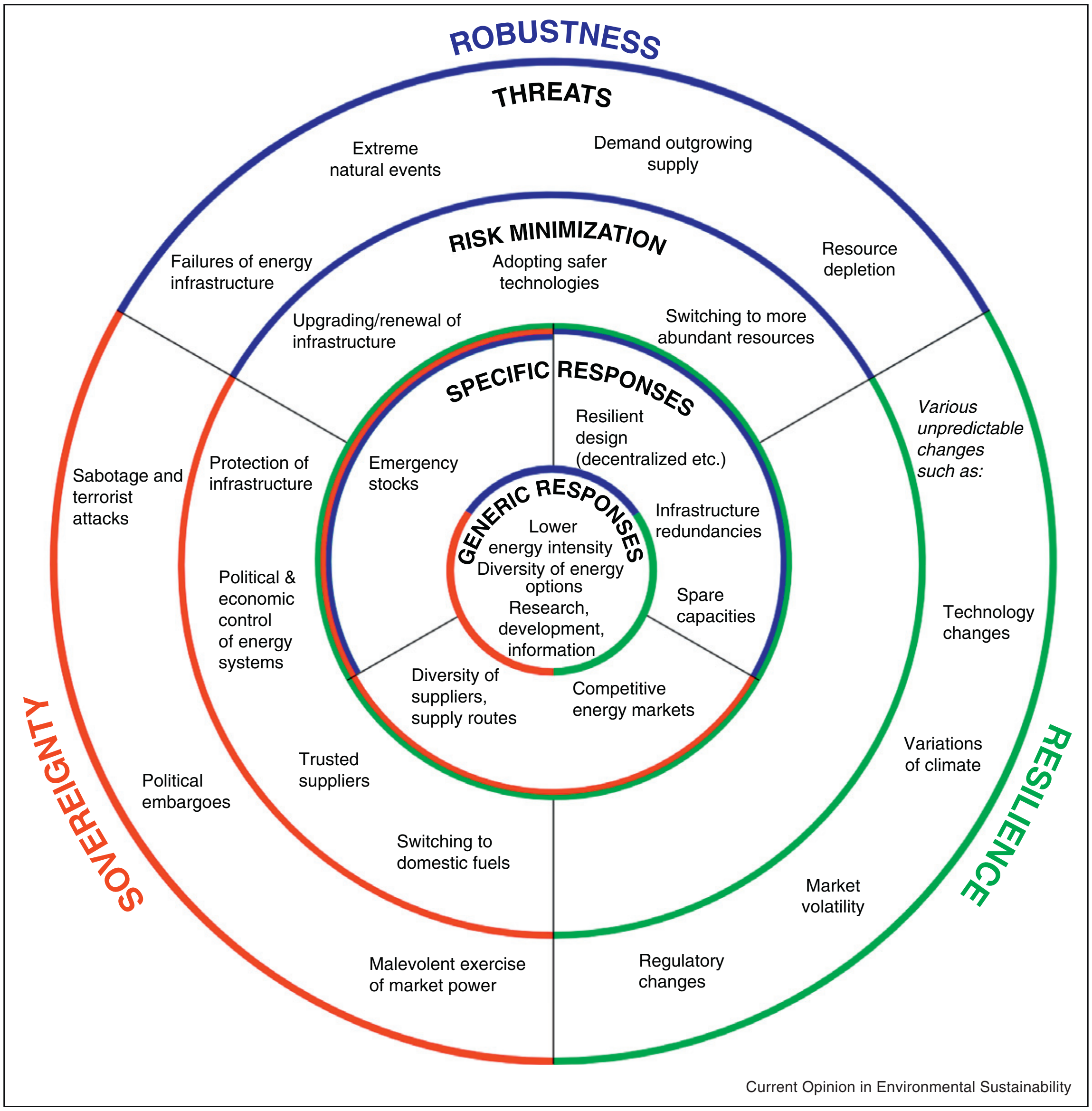
Figure 1



Three perspectives on energy security: the three perspectives on energy security have their roots in separate academic disciplines: political science (the sovereignty perspective), natural science and engineering (the robustness perspective) and economics (the resilience perspectives). They differ with respect to their focus on different energy security threats and response strategies. The 'no-regrets' responses situated in the center of the diagram address the concerns of all three perspectives. Graphic design: V. Vinichenko.

systems, especially under the 'global limits' (be it 'peak oil' or climate) resulted in the emergence of the second, '**robustness**' perspective with its roots in engineering and natural science. From this perspective, energy security threats are seen as 'objective', largely quantifiable factors such as growth in demand, scarcity of resources, aging of infrastructure, technical failures, or extreme natural events. Minimizing risks of such disruptions within this framework involves upgrading infrastructure, switching to more abundant energy sources, adopting safer technologies, and managing demand growth.

Finally, the practical challenges of establishing functioning energy markets and ensuring effective long-term investment in energy systems and technologies stimulated thinking borrowed from economics and complexity science. This resulted in the emergence of the third, '**resilience**' perspective. It sees the future as inherently unpredictable and uncontrollable because of high complexity, uncertainty and non-linearity of energy systems, markets, technologies and societies. In such an uncertain future, the threats are also highly unpredictable and may include regulatory changes, unforeseeable economic

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crises (or booms), change of political regimes, disruptive technologies, and climate fluctuations. The resilience perspective does not focus on analyzing, quantifying or minimizing such inherently uncertain risks. Instead it searches for more generic characteristics of energy systems (flexibility, adaptability, diversity) that ensure protection against any threats by spreading risks (both known and unknown) and preparing for surprises.

The difference between the three perspectives can be illustrated by the 'peak oil' debate. From the robustness perspective, the key questions are 'how much (conventional) oil is left?' and 'how difficult is it to get it?' [29,48]. From the sovereignty perspective the important questions are: 'who will control the remaining barrels of oil?' and 'will nations go to war to secure access to these resources?' [14]. From the resilience perspective the central question is 'will the global economy and energy system be able to adjust to the declining oil production?' [28]. Each of the three ways to formulate the problem implies different ways of looking for and formulating answers.

The core energy security concerns associated with each perspective are shown in Figure 1. At present, not only many of these concerns are overlapping, but also the solutions have to be increasingly integrated, even more so under energy transitions. This increasing interaction between energy security challenges defines the contemporary energy security agenda and requires a new level of interaction between the three perspectives.

Energy security: the contemporary challenge

By the end of the 20th century, energy security was no longer a purely geopolitical problem, though securing access to internationally traded fuels, especially oil, and was still at its center. The need to take into account vulnerabilities of complex technical systems, the global limits, and the role of markets and investments brought natural science, engineering, and economics in the orbit of energy security discourses. At the same time, the most notable idea in the energy security community in the last decade has been that these diverse challenges to energy security, which had historically been tackled separately, have recently become increasingly entangled. For example, replacing imported natural gas in electricity generation with renewable energy requires redesigning of electric grids to ensure secure supply from decentralized and intermittent sources as well as market incentives for adequate investments and affordable prices of electricity. Substituting oil in the transport sector may require massive electrification of vehicles and therefore finding the way to increase the generation capacity or developing effective and secure biofuel systems which may intertwine with food production, trade and landuse. This means that energy security policies and studies should focus on the entire energy system, not just one of its components be it a single fuel (such as oil or natural gas), carriers (such as electricity), or an end-use sector (such as transport). The recognition of the need for such an integrated approach can even be seen from the IEA, an organization historically focused on oil security, which is now adopting a more 'comprehensive' view of energy security, according to its Executive Director [49]. In practical terms this means that energy security challenges have to be resolved simultaneously rather than one by one.

Furthermore, the global energy challenges clearly articulated in the last decade: most notably the need to decarbonize energy systems while ensuring universal access to modern forms of energy for some 2–3 billion people who currently lack it [50•], have serious implications for energy security. There is a growing recognition by policy makers that all key energy challenges should be resolved both urgently and simultaneously. For example, [39] defines the common objective of EU energy policy as '[ensuring] the uninterrupted physical availability of energy products and services on the market, at a price which is affordable for all consumers (private and industrial), while contributing to the EU's wider social and climate goals'.

Thus, many countries aim to address all energy security challenges in an integrated manner and in conjunction with other energy issues such as climate and universal access. This policy intent has not yet been translated in any workable mechanism for global or, for most countries, national energy governance [20•]. It also presents a serious challenge for energy security studies. Isolated analysis from political scientists, engineers, or economists is no longer sufficient for public policy advising; rather, policy makers require an integrated view of energy security. The progress of contemporary energy security studies in developing such as view is reviewed in the next section.

Contemporary energy security literature: the challenge of integration

The current policy focus requires expanding the focus of energy security studies from specific questions such as 'how to reduce dependency on foreign oil?' or 'how to ensure reliable electricity' to the more overarching one: 'how do we make our energy systems more secure without merely trading one vulnerability for another one?'. This implies finding integrated solutions to multiple energy security challenges. Much of the contemporary energy security literature is therefore devoted to developing an integrated understanding of energy security.

A notable group of studies seek to elaborate such an understanding by drawing lists of old and new energy security concerns and grouping these concerns into 'aspects' or 'dimensions' of energy security. Such publications almost invariably start with the assertion that the

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'old' concept of energy security focusing primarily on oil supplies is outdated. Subsequently, additional issues are proposed to be included in the definition of energy security. These often include availability of fuels other than oil, price and economic issues, reliability as well as sometimes social, environmental, and economic issues [51]. Unfortunately, the method of including or excluding issues into the scope of energy security studies is rarely transparent or rigorous. Sovacool and Brown [2•] use a meta-survey of existing literature to identify contemporary energy security concerns. This is a relatively systematic method, but its value is diminished by the fact that many of the underlying studies use arbitrarily drawn lists of concerns. A serious problem is that an integrated analysis cannot be achieved by simply placing disparate concerns on the same list. Another problem is that energy security concerns vary from one country to another [7,52,21,53•] and therefore universal definitions or checklists of issues have limited value.

Many studies seek to integrate the long and seemingly disconnected lists of energy security concerns by classifying them into 'dimensions' or 'aspects' of energy security with generally understandable names appealing to common sense. For example, Alhajii [54] refers to 'economic, environmental, social, foreign policy, technical and security' dimensions of energy security. Von Hippel *et al.* [51] list 'energy supply, economic, technological, environmental, social/cultural and military/security' dimensions of energy security. Sovacool and Brown [2•] group the concerns into availability, affordability, efficiency, and environmental stewardship. Another widely referred taxonomy is the 4 A's or: 'availability' (i.e. physical availability of resources), 'accessibility' (geopolitical aspects associated with accessing resources), 'affordability' (economic costs of energy) and 'acceptability' (social and often environmental stewardship aspects of energy) [53•]. While such classifications help in attracting attention of policy makers and the public to different aspects of energy security, they are only the first step on the way to develop a systematic scientific understanding of energy security challenges. This is because the basis for these classifications is rarely systematically justified: they often seem almost as arbitrary as the lists of energy security concerns which they seek to structure. Moreover, classification is not integration. Placing several concerns in one group does not necessarily help us to understand them better or to develop integrated solutions.

The other large group of studies seeks to achieve an integrated understanding of energy security by quantification rather than by classification. It is focused on developing indicators which would signal significance of energy security risks and resilience capacity. Kruyt *et al.* [53•] provide a comprehensive overview of the most commonly used indicators. Cherp and Jewell [55•] discuss the process of constructing indicators and their limitations. In some cases, such studies propose compound indices of energy security combining several indicators [56,57•] or the Supply-Demand Index (SDI). Indicator systems can support integrated policy making in several ways. First, a transparent process of developing indicators forces systematic thinking about risk and resilience factors. For example, the SDI explicitly includes vulnerabilities arising at the demand-side of energy chain not systematically considered in the prior studies. Secondly, well designed indicator frameworks make energy security challenges more manageable because they allow tracking progress over time as well as comparison between countries and policy options. Thirdly, aggregated indices such as SDI may help in comparing and prioritizing diverse energy security concerns and finding policy trade-offs.

The widely pointed limitations of quantitative thinking and especially compound indices are their undercounting non-quantifiable concerns, uncertainties and non-linearities as well as obscuring policy choices in assumptions especially related to weighting and aggregating indicators. This may be the reason that the policy usage of one-concern indicators such as import dependency is still far greater than the usage of more sophisticated indicators or compound indices reflecting several concerns.

Finally, there are several promising attempts to construct a theory of energy security based on general systems principles rather than on analysis of empirically observable threats. For example, Keppler [38] offers a risk management framework for analyzing energy security which is 'built around notions of flexibility, diversification, responsiveness, impact reduction, rather than an excessive focus on any single measure of risk'. His three dimensions of energy security: geopolitical, technical and economic are close to the three perspectives on energy security identified in the previous section. Within this framework Keppler especially closely focuses on security of electricity supply in Europe and the role of nuclear energy. Stirling [47] proposes a framework which incorporates energy security into broader concepts of technological vulnerability, sustainability and transformations. He classifies the risks into short-term 'shocks' and long-term 'stresses' and the style of action as 'control' and 'response'. The 2×2 matrix of shocks–stresses and control–response gives four strategies: stability, durability, resilience and robustness. Stirling also identifies 'no-regret strategies' such as 'foster diversity, enhance equity, engage stakeholders, promote learning, catalyze reflexivity'.

The way ahead

Our brief overview shows that energy security studies have historically evolved within several distinct disciplines responding to separate policy challenges. This evolution has resulted in the emergence of at least three specific epistemological and policy communities which

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explored energy security problems from different perspectives. Each of these communities has focused on a specific set of problems and presented a distinct repertoire of policy responses. While such responses have been relatively effective in the past, the complexity of contemporary energy security problems is such that they can no longer be dealt with in isolation from each other. This defines the fundamental challenge of modern energy security studies: achieving the scholarly and policy integration of the previously isolated perspectives. The goal of such integration is far from trivial, since each perspective is rooted in its own distinct language, methods, discourses, and conceptual frameworks, not to mention the associated communities of practice.

The previous section showed that such integration has not been achieved in contemporary energy security studies. The bulk of the modern energy security literature addresses the integration in an insufficiently deep and rigorous level. In particular, 'integration by classification' or 'quantification' of disparate concerns, reviewed in the previous section, is not able to bridge the gap between different disciplinary mindsets. Scholarship truly contributing to integration should fully respect and incorporate knowledge from each of the constituent disciplines and focus on those areas where insights from one perspective can help resolve the challenges faced by another.

Elements of such interdisciplinary analysis are already emerging in some of the literature. For example, insights from the economic theory are systematically brought in to enhance the sovereignty perspective in the study of US dependency on imported oil [58] and fossil fuel imports to the European Union [59]. Likewise there are interesting attempts to link economic and technical analysis as well complexity theories in explaining the connection between liberalization, investment and reliability of electricity networks [34,60]. However, at present these attempts are far too fragmented to ensure a steady progress in understanding of interconnections between energy security challenges when problems are entangled, open-ended and rapidly evolving.

Systematically approaching the colossal task of developing an interdisciplinary field of energy security studies might start in establishing at least three starting conditions: firstly, drawing the boundaries of the field; secondly, establishing central research questions; and thirdly, identifying a set of credible methods and theoretical frameworks.

Concerning the first point, we have already noted that the existing studies rarely use a systematic approach to including or excluding various issues in their analysis of energy security. It is partly because this seemingly simple task is fundamentally interdisciplinary. On the one hand, the starting point for defining energy security should be empirically observed policy concerns. Studies which dismiss such concerns as 'subjective' and come up with artificial abstract definitions of energy security cannot claim to be policy relevant. On the other hand, political rhetoric should be carefully reflected upon before being used as a basis for defining energy security.

For example, the Global Energy Assessment (GEA, [61]) argues that at the core of energy security concerns is the vulnerability of nationally vital energy services without which modern states cannot function. This argument, based on a critical analysis of national energy security strategies, focuses the GEA inquiry on identifying such vital services: transport fuels, heat and electricity for residential and commercial sector, energy for industry, and energy export revenues. While the GEA approach needs to be further refined and contextualized, it is an example of a process of transparent and systematic boundary-setting for integrated energy security studies informed by several disciplines.

Another example of systematically framing energy security problems is the study of the 'polysemic nature' of energy security by Chester [52]. The idea that energy security has different meaning in different context (also mentioned by Yergin [7] and Kruyt *et al.* [53•]) is a step beyond the universal definitions or generic checklists of energy security concerns proposed by the bulk of modern literature. If such concerns differ from country to country then they can be identified by combining historic policy and energy systems analysis at the national level. For example, Leung [8] shows how the historic experience of China shapes the energy security perspective of this country.

The next crucial step is formulating research questions capable of deepening our understanding of the interaction between energy security challenges and identifying integrated solutions. For example, there is virtually no research on the interaction between the scientific analysis of vulnerabilities of energy systems and policy narratives about risks and response capacities. At the same time, such narratives are often used in both setting the agenda of energy security research and interpreting its results. To use the GEA example once again, its detailed study of energy security conditions in some 130 countries [62] is presented as five global 'stories': 'oil and transport', 'natural gas in Eurasia', 'adequacy of electricity supply', 'multiple energy vulnerabilities of low-income countries', and excessive reliance on energy export revenues in some economies. Stirling [47] explains why only a narrow range of possible technology transformation (and energy security) strategies is followed in real-life policies. Cherp and Jewell [55•] discuss how energy security indicators are selected to reflect the predominant narratives. Further research is needed to see whether some important global messages are missing and whether national energy security narratives are compatible with these stories.

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The next critical element is that of methodology and theoretical frameworks. Once again, the issue here is bridging different disciplinary methods from political science, engineering and economics. This is of course easier said than done, but examples from other fields can provide models and inspirations for energy security studies. For example, Ostrom's [63] success in studying co-evolution of resource systems, their users and governance mechanisms shows the feasibility of co-analyzing scientific, economic, and policy variables in specific contexts and then using the results of such analyses to enrich more general theories. In case of energy security, such approach would involve systematic co-analysis of energy systems (including resources, infrastructure and uses), markets and technologies as well as perceptions, power balances, and political interests. An important point is that such analysis should be strongly focused on specific national contexts rather than abstract and generic considerations. The complexity of energy security challenges should be first learned by deeply studying the national-level interactions between the Physical, the Political and the Economic. It is possible that many of such interactions are unique to their specific contexts, but it is also likely that universal principles of such interactions can be derived to eventually shape more general theories of energy security that would embrace and bridge the three perspectives outlined in this article.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest

1. Bohi DR, Toman MA: *The Economics of Energy Security*. Kluwer Academic Publishers: Norwell, Massachusetts; 1996.

2. • Sovacool BK, Brown MA: **Competing dimensions of energy security: an international perspective**. *Annu Rev Environ Resour* 2010, **35**:77-108.

This paper provides a meta-analysis of energy security studies to identify dimensions of energy security.

3. Yergin D: *The Prize: The Epic Quest for Oil, Money, and Power*. New York: Simon & Schuster; 1991.

4. Stern: **Oil Market Power and United States National Security**. *Proc Natl Acad Sci U S A* 2006, **103**:1650.

5. Paust JJ, Blaustein AP: **Arab oil weapon — a threat to international peace**. *Am J Int Law* 1974, **68**:410.

6. Carter. The American presidency project; 23 January 1980. Available from: http://www.presidency.ucsb.edu/ws/index.php?pid=33079#axzz1KTFpFIXZ [accessed 28.03.11].

7. Yergin D: **Ensuring energy security**. *Foreign Affairs* 2006, **85**:69-82.

8. Leung GCK: **China's energy security: perception and reality**. *Energy Policy* 2011.

9. IEA: *World Energy Outlook 2010*. Paris: OECD; 2010.

10. Tang K, Xiong W: **Index investment and financialization of commodities**. *Vox* 2010.

11. Hamilton JD: **Causes and consequences of the oil shock of 2007–2008**. *Brookings Pap Econ Act* 2009.

12. Kilian L: **Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market**. *Am Econ Rev* 2009, **99**:.

13. Lehman Brothers: *Energy and Power*. New York: Lehman Brothers; 2008.

14. Klare MT: *Rising Powers, Shrinking Planet: the New Geopolitics of Energy*. illustrated ed.. New York: Metropolitan Books; 2008.

15. Larsson RL: *Energikontroll: Kreml, Gazprom och rysk energipolitik (Energy control. Kremlin, Gazprom and Russian Energy Policy)*. Stockholm: Swedish Defence research agency (FOI); 2008.

16. • Stevens P: *Chatham House Report*. London: The Royal Institute of International Affairs; 2010.

This paper discusses both the opportunities and uncertainties inherent in the 'shale gas revolution' including its likely impacts on gas prices and investment in both traditional and new energy sources.

17. Strayer: *Why did the Soviet Union collapse? Understanding historical change*. Armonk, NY: M.E. Sharpe; 1998.

18. Karl TL: **Understanding the resource curse**. *Covering Oil: A reporter's Guide to Energy and Development*. New York: Revenue Watch, Open Society Institute; 200521-27.

19. Humphreys M, Sachs J, Stiglitz JE: *Escaping the Resource Curse*. New York: Columbia University Press; 2007.

20. • Cherp A, Jewell J, Goldthau A: **Governing global energy: systems, transitions, complexity**. *Global Policy* 2011, **2**:75-88.

This paper discusses the emergence and the interaction of the three global energy governance arenas focused on energy security, climate change and access to modern energy. The authors argue that the complexity and uncertainty inherent in sustainable energy transitions requires an equally complex polycentric global governance institutions.

21. Müller-Kraenner S: *Energy Security: Re-measuring the World*. London and Sterling, VA: Earthscan/James & James; 2008.

22. Goldthau A, Witte JM: **Global energy governance: the new rules of the game**. *Brookings Inst Pr* 2010.

23. Florini A, Sovacool BK: **Who governs energy? The challenges facing global energy governance**. *Energy Policy* 2009, **52**:9-48.

24. Victor DG, Yueh L: **The new energy order**. *Foreign Affairs* 2010, **89**:61-73.

25. Lesage D, Van De Graaf T, Westphal K: *Global Energy Governance in a Multipolar World*. Ashgate Pub Co.; 2010.

26. Meadows DH, Meadows DL, Randers J, Behrens WW, of RC: *The Limits to Growth*. New York: Universe Books; 1972.

27. Gallagher B: **Peak oil analyzed with a logistic function and idealized Hubbert curve**. *Energy Policy* 2011, **39**:790-802.

28. Korowicz: *Tipping Point*. Dublin: The Foundation for the Economics of Sustainability; 2010.

29. Aleklett K, Höök M, Jakobsson K, Lardelli M, Snowden S, Söderbergh B: **The peak of the oil age-analyzing the world oil production reference scenario in world energy outlook 2008**. *Energy Policy* 2009.

30. Lovins AB, Lovins LH. Brittle Power. Andover, MA: Brick house Publishing Company; 1982.

31. UK Conservative Party: Rebuilding security. Conservative energy policy for an uncertain world; 2010.

32. Farrell AE, Zerriffi H, Dowlatabadi H: **Energy infrastructure and security**. *Annu Rev Environ Resour* 2004, **29**:421-469.

33. Hines P, Apt J, Talukdar S: **Trends in the history of large blackouts in the United States**. *2008 IEEE Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century*. 2008:1-8.

34. Yu W, Pollitt M: **Does liberalisation cause more electricity blackouts? Evidence from a global study of newspaper reports**. *Electricity Policy Research Group, EPRG Working Paper*. 2009:830.

35. Lukszo Z, Deconinck G, Weijnen MPC: *Securing Electricity Supply in the Cyber Age: Exploring the Risks of Information and Communication Technology in Tomorrow's Electricity Infrastructure*. Dordrecht, New York: Springer; 2010.

Please cite this article in press as: Cherp A, Jewell J. The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration, Curr Opin Environ Sustain (2011), doi:10.1016/j.cosust.2011.07.001

36. European Parliament: **Directive 2005/89/EC of the European Parliament and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure investment**. *Off J Eur Union* 2006.

37. North American Electric Reliability Corporation: *Reliability Standards for the Bulk Electric Systems of North America*. Princeton, NJ: North American Electric Reliability Corporation; 2010.

38. Keppler: *International Relations and Security of Energy Supply: Risks to Continuity and Geopolitical Risks*. Brussels: Directorate General External Policies of the Union, European Parliament; 2007.

39. European Commission: Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. Brussles; 2010.

40. Weaver Can Energy Markets Be Trusted? The Effect of the Rise and Fall of Enron on Energy Markets. Houston Bus Tax Law J; 2004, 4.

41. Bar-Lev D, Katz S: **A portfolio approach to fossil fuel procurement in the electric utility industry**. *J Finance* 1976, **31**:933-947.

42. Awerbuch S: **Market-based IRP: it's easy!!!**. *Electricity J* 1995, **8**:50-67.

43. Stirling A: **Diversity and ignorance in electricity supply investment: addressing the solution rather than the problem**. *Energy Policy* 1994, **22**:195-216.

44. • Stirling A: **Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios**. *Energy Policy* 2010, **38**:1622-1634.
This paper discusses the rational and a systematic approach to measuring diversity in energy systems.

45. Skea J: **Valuing diversity in energy supply**. *Energy Policy* 2010.

46. Yoshizawa G, Stirling A, Tatsujiro S: **Electricity system diversity in the UK and Japan: a multicriteria diversity analysis**; 2009.

47. Stirling A: **From sustainability, through diversity to transformation: towards more reflexive governance of technological vulnerability**. In *Vulnerability in Technological Cultures: New Directions in Research and Governance.* Edited by Hommels, Mesman, Bijker. Cambridge, MA: MIT Press; 2011. . m.

48. Aguilera RF, Eggert RG, Gustavo Lagos CC, Tilton JE: **Depletion and the future availability of petroleum resources**. *Energy J* 2009, **30**:141-174.

49. Comprehensive energy security for global green growth: East Asia climate forum 2010. Seoul; 2010.

50. • AGECC: *Energy for a Sustainable Future. Summary Report and Recommendations*. New York: The UN's Secretary-General's Advisory Group on Energy and Climate Change; 2010.
This paper summarizes the global energy challenges including those related to energy security and argue why their simultaneous and urgent resolution is necessary to achieve social and economic goals.

51. von Hippel D, Suzuki T, Williams JH, Savage T, Hayes P: **Energy security and sustainability in Northeast Asia**. *Energy Policy* 2009:1-12.

52. Chester L: **Conceptualising energy security and making explicit its polysemic nature**. *Energy Policy* 2010, **38**:887-895.

53. • Kruyt B, van Vuuren DP, de Vries HJM, Groenenberg H: **Indicators for energy security**. *Energy Policy* 2009, **37**:2166-2181.
This paper provides a summary classification of contemporary energy security concerns and indicators.

54. Alhajii AF: **What is energy security? (4/5)**. *Middle East Econ Surv* 2007:L(52).

55. • Cherp A, Jewell J: **Measuring energy security: from universal indicators to contextualized frameworks**. In *The Routledge Handbook to Energy Security.* Edited by Sovacool B. Routledge; 2010.
This paper addresses conceptual issues in quantitative evaluation of energy security.

56. Jansen JC, van Arkel WG, Boots MG: *Designing Indicators of Long-term Energy Supply Security*. Petten, Netherlands: ECN; 2004.

57. • Jansen JC, Seebregts AJ: **Long-term energy services security: what is it and how can it be measured and valued?** *Energy Policy* 2010, **38**:1654-1664.
This paper describes a novel approach to measuring long-term energy security with special attention to energy services.

58. Greene DL: **Measuring energy security: can the United States achieve oil independence?** *Energy Policy* 2010, **38**:1614-1621.

59. Le Coq C, Paltseva E: **Measuring the security of external energy supply in the European Union**. *Energy Policy* 2009, **37**:4474-4481.

60. Dobson I, Carreras BA, Lynch VE, Newman DE: **Complex systems analysis of series of blackouts: cascading failure, critical points, and self-organization**. *Chaos* 2007, **17**:026103.

61. GEA: *The Global Energy Assessment: Toward a More Sustainable Future*. Laxenburg, Austria/Cambridge, United Kingdom/New York, USA: IIASA and Cambridge University Press; 2011.

62. Cherp A, Adenikinju A, Goldthau A, Hughes L, Jansen J, Jewell J *et al.*: **Energy and security**. *Global Energy Assessment: Toward a More Sustainable Future*. Laxenburg, Austria/Cambridge, United Kingdom/New York, USA: IIASA and Cambridge University Press; 2011.

63. Ostrom E: **A diagnostic approach for going beyond panaceas**. *Proc Natl Acad Sci U S A* 2007, **104**:15181.

Please cite this article in press as: Cherp A, Jewell J. The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration, Curr Opin Environ Sustain (2011), doi:10.1016/j.cosust.2011.07.001