12

THE ENERGY SERVICES DIMENSION OF ENERGY SECURITY

Jaap C. Jansen and Adriaan J. Van der Welle

Introduction

The world energy supply–demand system has all the ingredients in the making for a lasting security of supply problem for humankind. This is poised to bring about a key policy challenge, in the medium and long term if not in the short term.

Worrisome global trends are unfolding with regard to factors determining the long-term cost of energy use. These suggest that the broader issue of supply security deserves urgent and persistent attention by policymakers. Virtually all energy supply chains—for both fossil fuels and non-fossil fuels—are facing huge supply limitations. Supply limitations do not only apply to fossil fuels but also to minerals, resulting in adverse impacts for a range of renewable and energy storage technologies (HCSS, 2009; USGS, 2010). Official projection providers such as the International Energy Agency (IEA) and US Energy Information Administration (EIA), tend to project roughly a 45 percent higher world primary energy use by 2030 than current use (approximately 500 exajoules, i.e. 5×10^{20} joules) and a near doubling by year 2050. Several energy policy analysts (e.g., Turner, 2008; Moriarty and Honnery, 2009; Nel and Cooper, 2009; Rutledge, 2009) question the feasibility of these mainly demand-driven energy supply projections.

The seriousness of limitations to global primary energy use, if true, may provide some comfort to climate change concerns. For instance, the potential for strongly increasing GHG emission from coal combustion seems, typically, to be strongly overrated as seems to be the case with global coal reserves (Rutledge, 2009; Kavalov and Peteves, 2007; EWG, 2007; Tao and Li, 2007). Yet in the absence of strong and enduring effective policy responses, these limitations are poised to be reflected by a steeply upward long-term trend in fossil fuel and electricity prices, along with rising price volatility and more frequent physical supply disruptions.

In low- and medium-income countries, security of supply (SoS) tends to be assigned quite a high priority on the national energy policy agenda. To date, the energy policy issue topping the agenda of policymakers in most OECD countries is "climate change," while in emerging economies the issue is also contemplated closely, although so far allusions to hard commitments are prudently avoided. In OECD countries "energy security" is currently also ranking high on the priority list, whilst certainly in the developing countries, particularly those poorly endowed with fossil fuels, "energy security" is considered important. The latter policy issue tends to go in cycles—typically short-lasting—given prime attention by policymakers in the wake of sudden price spikes in the world oil market or (threats of) market intervention and physical supply disruption of oil or natural gas by major exporting countries. Cases in point are the US$147 per barrel oil price spike in the summer of 2008 and the disruption in Russian gas supplies to the EU through the Drushba gas pipeline in January 2009.

This chapter is structured as follows. Section 2 introduces the concepts of energy security and energy services security. A theoretical framework for analysis of energy services security (ESS) is presented in Section 3. A simple application of this framework, focusing on the delivery of electric energy end-use service, is explained in Section 4, and some major policy-oriented conclusions are drawn in Section 5.

Energy security versus energy services security

An oft-adopted definition of "energy insecurity" is "the loss of welfare that may occur as a result of a change in price or availability of energy" (Bohi and Toman, 1996).[1] This definition considers the economic impacts of energy insecurity. According to this definition, a situation of extreme energy security would be characterized by uninterrupted supply of "energy"—that is, fuel (derivatives) and electricity—at competitive prices.

Another approach considers the policy perspectives of energy security. It aims at a secure energy supply system meeting some key requirements. For example, APERC proposes an energy supply system should achieve (APERC, 2007):

1. *Availability* (depletion, inadequate upstream and midstream investments, etc.).
2. *Accessibility* (restrictions imposed by governments of fuel-exporting countries, exercise of market power, exposure of fuel supply chain components to disruptive events including weather-related ones, technical failures, human errors, or acts of terrorism or war, etc.).
3. *Affordability* (cost per unit of energy to end-users—broken down by the main components of fuel supply chains—might compromise societal security).
4. *Acceptability* (environmental concerns and social/cultural barriers hampering supply because of negative perceptions among the population).

The issue label "energy security" misses a fundamental point: energy is typically not in short supply. Rather, it is *useful energy*, not *energy per se*, that is in short supply.[2] Walt Patterson refers to the First Law of Thermodynamics which implies that no single joule of energy gets lost (Patterson, 2007). By implication, nobody produces or consumes energy. Given these observations, energy security strictly speaking is a non-issue.

This seems trivial but it is not. Patterson observes that ambient energy is, by and large, plentiful across the earth: almost everywhere existing in orders of magnitude above current needs for useful energy. Ambient energy includes sources such as wind power, solar energy, river flow, and marine energy. In principle, ambient energy can be used directly, converted into electricity or into a stored form of energy. The abundance of energy around the world is further enhanced, if rather poorly dispersed globally, by natural resources that embody stored energy such as uranium, coal, natural gas, oil, biomass, and geothermal. At the same time, worldwide expanding conurbations of mega-cities pose local challenges for adequate access to ambient energy sources.

This brings in the direct connection of supply security issues with *energy services*. Energy services can be defined as economic goods produced by the deployment of useful energy.[3] In turn, useful energy is obtained directly from ambient energy flows, for example solar heating, or from energy contained in energy carriers including electricity. A major focal point of this conversion is the part of the energy transferred by energy carriers to deliver useful energy that does not meet this purpose (i.e., "energy losses"). Note furthermore that energy services include outputs from non-energy industrial feedstocks.[4]

The demand for end-use energy services generates final energy demand. This, in turn, impacts activity levels all along the electricity and fuel supply chains up to primary energy supplies. Table 12.1 provides, for the main energy uses, that is, electricity generation, transport, heating, and cooling, some broad avenues for reducing demand for fossil fuels in meeting end-use energy services.

We propose to use the term *energy services security* (ESS) instead of energy security as the notion that covers the central topic of this chapter.[5] Hereafter, ESS refers to *the extent to which the population in a defined area (country or region) can have access to affordably and competitively priced, environmentally acceptable energy services of adequate quality*. This definition implies an end-use orientation to enable a genuinely integrated approach to the multifaceted ESS issue.

Table 12.1 Broad framework of major options for reducing societal dependency on fossil fuels on longer timescales

Main application	*Fossil fuel*	*Major options*	
		Demand reduction	*Switch away from fossil fuels*
Power generation	Oil & Natural gas & Coal	Efficiency standards for generation and power using equipment Reduction T&D losses Demand-side saving behavioral changes	Renewables-based generation Nuclear power (?)
Road vehicles	Oil & Gas (CNG, GTL) & Coal (CTL)	Fuel/CO_2 efficiency standards	(Hybrid) electric-battery vehicles Biofuels
		Demand-side saving behavioral changes Sustainability-oriented spatial planning	Hydrogen fuel cell vehicles Modal shift away from FF, e.g. towards bikes for short-distance trips
Train	Oil & Coal	Fuel/CO_2 efficiency standards	Electrification Biomass
		Demand-side saving behavioral changes	Modal shift away from FF
Ships, Aircraft	Oil	Fuel/CO_2 efficiency standards Demand-side saving behavioral changes	Biofuels Modal shift away from FF
Residential & commercial heating	Oil & Natural gas & Coal	Efficiency standards for buildings/heating equipment	Biomass Electric heating District heating/μCHP on green gas
		Demand-side saving behavioral changes	Solar water heaters Heat pumps (ambient/ aquifers)
Industrial process heat	Oil & Natural gas & Coal	Efficiency standards Good housekeeping Process changes	Biomass CHP Substitutes and structural demand shifts away from FF-intensive materials/ products

Table 12.1 (continued)

Main application	*Fossil fuel*	*Major options*	
		Demand reduction	*Switch away from fossil fuels*
Industrial feedstock	Oil & Natural gas & Coal	(Efficiency standards)	Degradable biomass substitutes (e.g. plastics) Biochemicals substitutes (e.g. biomass-based fertilizer)
		Demand-side savings	DRI based on biogas and electricity Charcoal

Legend:
FF: fossil fuels
CNG: compressed natural gas
GTL: gas-to-liquids
CTL: coal-to-liquids
T&D: transmission and distribution
DRI: direct reduced iron

Theoretical framing

Much recent work on "energy security" focuses on vulnerability to supply disruptions of internationally traded fuels, notably oil and natural gas, affecting fuel prices and even the outright physical availability of fuels (e.g., Bohi and Toman, 1996; Lefèvre, 2007).[6] The main theme in this approach is on (mitigating) supply-side market power and its adverse impact on economic welfare in fuel-importing countries. Other analysts also consider the vulnerability to international trade in fuels for fuel-exporting countries, zooming in on the economic aspects of "demand security" (e.g., Alhajji, 2008) as well as the social and political impacts, investigating the validity of the "resource curse" hypothesis (e.g. Karl, 1997 Bannon and Collier, 2003; Collier, 2008). Analysts considering the politics of (preventing) disruptions in international fuel supply chains examine the destabilizing impacts on international political relationships (e.g., Müller-Kraenner, 2007; Klare, 2008).

Disruptions and vulnerabilities

Recently a useful overarching framework has been proposed by Nicolas Lefèvre (2010) and a consortium of consultants led by Ecofys to map supply disruptions and vulnerabilities, and analyze their effects.Ecofys *et al.* (2009) define three broad categories of root causes of energy insecurity: (1) extreme events, (2) inadequate market structures, and (3) resource concentration. Resource depletion is subsumed by the third category. Table 12.1 illustrates this categorization.

Historic or potential energy security disruptions and vulnerabilities can trigger a chain of knock-on effects in distinct stages, each with (potential) net loss of economic welfare. This is depicted in Figure 12.1. This approach enables a structured identification and analysis of the impacts of vulnerabilities as well as alternative policies and measures on energy insecurity, or rather, as we would phrase it, energy services insecurity.

Table 12.2 Classification of root causes of energy insecurity

Category	*Type*	*Brief description*
Extreme events	Extreme weather	Extreme weather events can temporarily disable energy infrastructures and the supply of energy. A recent example is the impact of Hurricane Katrina, which hit the Gulf of Mexico in 2005, disabling a significant portion of the US oil and gas production and processing capacity. There are however many other possible extreme weather events with potential energy security consequences including those which impact on the demand side (e.g. exceptionally cold or hot days) or on the supply side (e.g. reduced cooling water availability).
	Large scale accidents	Much like extreme weather events, accidents can lead to unplanned outages of key energy infrastructures.
	Acts of terrorism	Acts of terrorism against key infrastructures (e.g. refineries or pipelines) or bottlenecks along specific energy trade routes (e.g. the straight of Hormuz) can cause disruptions to energy systems.
	Strikes	Due to the strategic nature of energy, strikes or other forms of social unrest may specifically target the operation of key energy system components.
Inadequate market structure	Insufficient investments in new capacity	Market structures which fail to generate timely investments in key energy system infrastructures can contribute to making the system more vulnerable and ultimately generate energy insecurity.
	Load balancing failure in electricity markets	Because electricity is not storable in any meaningful volumes system operators must effectively balance supply and demand in real time to ensure system reliability. The task is challenging and requires that certain technical characteristics be met. When this is not the case systems sometime fail or do not operate in an efficient manner causing a loss of welfare for users.
Supply shortfall associated with resource concentration		Due to the concentration of resources in certain regions of the world, exploration and production as well as transport of fuels are also concentrated. This generates a certain degree of market power which can adversely affect energy systems.

Source: Adapted from Ecofys *et al.* (2009), p. 12.

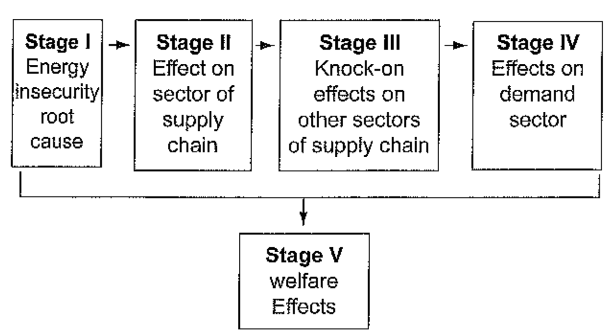

Figure 12.1 Generic causal mechanisms of energy insecurity: an impact in stages approach proposed by Ecofys *et al.* (2009), p. 13.

Resilience as a key concept

Most recent work on energy security fails to consider the resilience of a defined country (or region) to cope with the impacts of adverse ESS ("energy security") trends and events. At best, supply-side security-enhancing measures, such as diversification of the fuel mix, foreign suppliers, and international fuel transport routes and modes, are analyzed. Typically, recent '"energy security" policy research documents may mention some demand-side policies and measures such as energy intensities but with little further elaboration. A notable exception is Scheepers *et al.* (2007) who explicitly consider *inter alia* energy intensity on the demand side.

The magnitude of risks to ESS security is not only determined by exposure to vulnerabilities on the supply side of energy inputs driving the delivery of energy services. The resilience of a recipient society to adverse supply-side vulnerability events/trends works as a cushion that dampens the impacts of supply-side vulnerability.

Energy services security (ESS) is a more inclusive concept than energy security. The timely performance and affordability of desired energy services at quality levels considered adequate by the end-users for the end-use applications concerned is not only affected (in a negative way) by all sorts of supply-side vulnerabilities. The key point is that a broad range of resilience factors that exercise a stabilizing influence on the robustness of the energy services delivery system is identified and thoroughly analyzed as well.

ESS components

Myriad one-event impulses and gradually strengthening or declining forces exercise a negative or positive impact on the level of energy services security. In order to bring structure to the analysis of these ESS aspects, we categorize these ESS-change-initiating phenomena into main ESS-content perspectives, namely *ESS dimensions*.

Each dimension consists of main components and, where appropriate, subcomponents, sub-subcomponents, etc., down to the most elementary dimension attribute level. Components (subcomponents) are also referred to as main (sub-) themes or aspects. Hence, the dimensions have a branch structure, each branch being shaped by the distinct dimension components. Where feasible, we allocate indicators of ESS content attributes to dimension (sub-) components. Many ESS indicators are of a quantitative nature, while others are of an ordinal ranking nature with at least two scoring options. We wish to restate that, for each relevant dimension next to major ESS-reducing vulnerabilities, major ESS-raising system resilience attributes need to be identified to partly/fully/more than offset these vulnerabilities.

On the one hand, each distinct ESS dimension has to bundle a broad range of related ESS content aspects. On the other hand, ESS content aspects encompassed by different dimensions should have no, or at most a fairly remote, logical relationship with each other. Furthermore, a clear differentiation among countries (regions) should be possible in principle with respect to their characteristics regarding each of these ESS dimensions. Based on these criteria we propose the following ESS dimensions:

1. Reliability
2. Energy costs
3. Policy framework
4. Public acceptance.

We have refrained from introducing environmental impact as an additional dimension. In the Trias Energetica (competitiveness, security of supply, environmental impact), this dimension is covered by another principal energy policy domain. Moreover, to the extent that environmental impact is relevant for public acceptance of technologies used in major supply chains enabling the delivery of energy services, it is encompassed under the public acceptance dimension.

ESS contextual attributes

Two principal contextual attributes cross-cut among components of each ESS dimension, that is, *timescale* and *location*. They do not contribute content attributes as such to the ESS concept. Yet they provide essential contextual information needed for interpreting an indicator of an ESS content attribute. The value of certain content attributes of the ESS issue can change substantially, depending on the timescale and the location boundaries that we consider. Key questions in this respect are:

- For which timescale does the metric provide relevant information on the content attribute concerned? Short-term ESS issues as against long-term ESS issues may require rather different policies and measures.
- For which jurisdiction does the metric provide relevant information on the content attribute concerned? This, in turn, is relevant for the level at which possible public interventions should be considered.

The timescale for which energy services security is contemplated is quite relevant. Typically, for very short-term time horizons, disruptions in physical availability of energy services and sudden price spikes attract key attention by private stakeholders and the public sector alike. For long-term time frames the risks of structurally rising fuel and electricity prices and increasing price volatility are key ESS concerns.[7] The reliability or physical availability of energy sources to drive energy services is the prime concern in near-term time frames. This is exemplified by the need for second-to-second balancing of supply and demand by power systems and the need for reliable gas supply in cold winter days in, for example, many European countries where space heating is predominantly gas-based.

Most economics actors are driven by myopic time-bounded behavior. To counteract this serious externality of myopic time-bounded rationality, guidance by policymakers to foster long-term ESS would seem to be of key importance.

Three localization aspects of ESS problems can be discerned relative to the location where the energy services concerned are (to be) provided. First, the "control area," within which jurisdiction the energy services concerned are to be delivered, is of relevance. Second, the location of impacts of an ESS-disruptive phenomenon along the relevant supply chains of energy services is important. We note that the relevant (market) area for certain ESS aspects, for example the price of oil, is the whole world. Alternatively, within power systems proper, the areas in which knock-on impacts of supply disruptions and vulnerabilities can propagate are more regionalized, that is, the synchronized power areas that can cover several countries and the control areas of distinct system operators are of relevance to that effect.

The third aspect regards the localization of the impacts of an ESS-change-initiating factor. A good understanding of the local conditions at each successive impact area contributes importantly to the analysis of ESS. Detailed analysis of each key component/node of the main supply chains that enable the performance of a certain category of end-use service is essential for a good understanding of the risk and resilience factors affecting ESS for the category of energy services considered. Supply chain components/nodes are not necessarily cross-cutting across all ESS dimensions. Hence, consideration should be given to including important supply chain nodes in the composition of those ESS dimensions for which they assume relevance. This might be the case, notably, for some components of reliability (dimension 1) and energy costs (dimension 2).

Applying the framework: a fuel price disturbance

A simple example might help to demonstrate how the theoretical framework can be applied. We analyze in a generic way just one effect of a fuel price disturbance, that is, the knock-on price effect upon the cost of an end-use energy service along the supply chain of a (secondary) final energy carrier.

The fuel supply chain destined for end-use energy services delivered by the electricity supply sector can be structured in a generic fashion as follows (in backward supply chain direction):

- demand for an electricity end-use energy service;
- electricity demand by end-use appliances;
- demand for distribution network and ancillary system services;
- demand for transmission network and ancillary system services;
- demand for electricity generation services;
- electricity generation;
- transport chain of input energy carriers to electricity generation plants;
- (applicable for secondary energy carriers only) PES-SEC conversion plants; transformation of primary energy source (PES; primary fuel) into the secondary energy carrier (SEC) considered used as an input fuel by the power supply sector;
- transport chains of PES (embarkation, haulage, disembarkation), with elaboration of routes and modes (e.g. LNG, piped natural gas);
- production or import of the primary energy source (PES).

The second ESS dimension distinguished in the theoretical framework introduced in the preceding section is energy cost. Several ESS aspects can be categorized as components shaping this dimension. One of these aspects is price escalation. The cost/price change of a primary fuel, for example natural gas, is transmitted to the cost of an electrical energy service, as shown in Table 12.3.

Table 12.3 Generic analysis scheme for determining the impact of (changes in) the unit value (unit cost; price) of a primary energy source on the cost of an end-use energy service, allowing for the various supply chain components

Energy service (ES)	Description	(1)
Unit:	Dimension A	(2)
Unit value:	€2009	(3)
End-use appliance	Description	(4)
Final energy carrier (FEC)	Description	(5)
Unit:	Dimension B	(6)
Unit value:	€2009	(7)
Units required/unit of energy services	Dim B / Dim A	(8)
Cost of FEC input	€2009	(9) = (8) * (7)
Cost share of FEC in ES	%	(10) = (9) / (3) * 100%
Energy conversion plant	Description	(11)
Input fuel for final energy carrier	Description	(12)
Primary energy source (PES)	Description	(13)
Unit (primary energy source):	Dimension C	(14)
Unit value:	€2009	(15)
Units required / unit of final energy carrier	Dim C / Dim B	(16)
Cost of PES in cost FEC input	€2009	(17) = (16) * (15)
Cost share PES in cost FEC input	%	(18) = (17) / (9) * 100
Cost share of PES in ES	%	(19) = (18) * (10) / 100%

Note that, in principle, the main supply chains can include supply chains for non-energy inputs, for example steel or metallic minerals, and even non-material inputs. Non-energy constraints may also create huge challenges to ESS. Just some examples are: skilled manpower limitations to operate the electricity transmission and distribution networks or to operate nuclear energy cycle facilities; shortages of dry-bulk carriers to transport hard coal; shortages on the steel market to produce various types of power plants, including nuclear power plants and wind turbines; shortages of copper affecting notably T&D networks, wind turbines, and solar photovoltaic equipment; shortage of platinum to produce fuel cells; shortages of lithium to produce lithium-ion batteries, etc.

The above scheme enables the analysis, in a structured way and in a backward chain direction, of how the demand for a unit of end-use energy service ultimately depends on the delivery of a certain volume of primary fuel. Analyzing the upstream dimension of the supply chain, for each of the services needed it can be considered if efficiency, diversification, and/or substitution improvements can be realized. Ultimately, the relationship between the incremental demand for the end-use energy service and the standard requirement for the primary fuel considered can be established. In turn, this paves the way to establish the impact of a change in the price of the fuel on the delivery cost of one unit of the end-use service considered. But it also permits the gauging of the impact of efficiency improvements regarding intermediary supply chain services on, for example, the import dependence for the fuel concerned.

Why should energy services be taken as a point of departure?

This chapter has introduced a theoretical framework for energy-related supply security issues that takes energy services as a point of departure. This diverges from the conventional approach which departs from pre-set demand-driven scenarios. Key parameter values of such scenarios, such as given (high) rates of economic growth, are fed into complex but highly stylized economy-energy-environmental models, which are specified on the basis of observed relationships, including technological progress captured by observed technology learning rates. Next the model provides the required supply of fuels and secondary energy carriers, including, importantly, power and, in turn, the investment needs for the distinct energy subsectors to ensure adequacy of supply, including certain minimum redundancy standards.

To ensure "energy security," most policymakers tend to content themselves by and large with two major activities. These are: (1) standard energy infrastructure planning and plan realization, and (2) diversification of fuel sourcing and fuel transport routing to hedge against resource concentration as their main supply security concerns. In other words, they tend to aim to enable citizens and other private actors within their jurisdictions to enjoy pre-set growth in material prosperity without having to assume any responsibility that the energy requirements will be matched by adequate supply. Where required, the invisible hand of the price mechanism guides private actors towards making their part of the infrastructural investments required.

We posit that the passive, demand-driven, top-down energy systems planning and operational management paradigm is in urgent need of replacement. Energy systems planning and operation is to become a shared responsibility of all actors using energy supply systems, including notably the beneficiaries of end-use energy services. This is to be enabled by regulatory and contractual frameworks making the true time- and location-differentiated cost of all major elements of the energy supply system transparent. This applies to energy end-use services, energy system services all along the supply chain, and, last but not least, energy resources transparent to the maximum extent possible. Flexibility and responsiveness on the demand side are key to raising the resilience of a country to actual and potential vulnerabilities to energy services security. Improved market functioning with transparent price discovery signals and improved and timely public disclosure of relevant market information are key strategy components to raising a demand response. Raising awareness among end-users of the resource intensity and environmental footprint of the choices they make to use their discretional purchasing power is relevant as well. This will help to articulate social preferences in the way of appreciably less resource-intensive portfolios of energy services.

It is evident that raising the level of prosperity and productive employment is receiving top priority by governments throughout the world, including in particular the emerging Asian economies. Doing so proactively over a long-term time horizon, warrants integration of long-term energy services security and environmental sustainability concerns into all other policy domains. This holds true all the more so, as choices regarding investments in buildings, public infrastructure, and spatial planning tend to be characterized by very long capital turnover periods with strong lock-in effects regarding patterns of energy and material use over long periods ahead. High resilience to vulnerabilities regarding energy services security and environmental integrity cannot be achieved without the active engagement of the general public. An energy services security approach, rather than a predominantly supply-side-oriented energy security approach, will help to make this happen.

Notes

1 This section is based on Jansen and Seebregts (2010).
2 A major point in case is that technology for the conversion of many kinds of ambient energy is still lacking commercial, and in certain instances even technical, maturity.
3 Gary Kendall defines an energy service as a useful output of an energy input (Kendall, 2008: 153).
4 The energy resources to meet this category of energy services are also part of the supply security equation. Hence, energy policy legislation neglecting this category—e.g. the newly adopted EU directive on renewable energy sources—weakens the coherence between different domains of energy policy.
5 See also Jansen and Seebregts, 2010.
6 This section is based on Jansen 2009.
7 This also holds for the contract-based segment of the natural gas markets. Such contracts are usually indexed on oil product price benchmarks or on benchmark prices of spot markets for natural gas. In north-west Europe a trend appears to be emerging towards a shift away from oil-based pricing ("gas-to-gas" competition: see e.g. Stern, 2009).

References

Alhajji, A.F. 2008. "What is Energy Security?" *Energy Politics* 4 (Spring).

Bannon, I. and P. Collier (eds.). 2003. *Natural Resources and Violent Conflict: Options and Actions* (Washington, DC: World Bank).

Bohi, D.R. and M.A. Toman. 1996 *The Economics of Energy Supply Security* (Norwell, MA: Kluwer).

Collier, P. 2008. *The Bottom Billion: Why the Poorest Countries are Failing and What can be Done About It* (New York: Oxford University Press).

ECOFYS, ERAS, REDPOINT. 2009. *Analysis of Impacts of Climate Policies on Energy Security: Final Report.* Report prepared for DG Environment of the European Commission (London and Utrecht: European Commission).

The Hague Centre for Strategic Studies (HCSS). 2009. *Scarcity of Minerals: A Strategic Security Issue* (The Hague: HCSS).

Jansen, J.C. 2009. "Energy Services Security: Some Metrics and Policy Issues," paper presented at the fourth ENERDAY conference, Dresden, April 4.

Jansen, J.C. and A.J. Seebregts. 2010. "Long-Term Energy Services Security: What is it and how can it be Measured and Valued?" *Energy Policy* 38: 1654–1664.

Karl, T.K. 1997. *The Paradox of the Plenty: Oil Booms and the Petro-States* (Berkeley, Los Angeles, and London: University of California Press).

Kavalov, B. and S.D. Peteves. 2007. *The Future of Coal.* Report EUR 22744 EN (Petten, the Netherlands: DG JRC and Institute for Energy, February).

Kendall, G. 2008. *Plugged In: The End of the Oil Age* (Brussels: World Wide Fund for Nature).

Klare, M.T. 2008. *Rising Powers Shrinking Planet: The New Geopolitics of Energy* (New York: Metropolitan Books).

Lefèvre, N. 2007. *Security and Climate Policy: Assessing Interactions* (Paris: OECD and International Energy Agency).

Lefèvre, N. 2010. "Measuring the Energy Security Implications of Fossil Fuel Resource Concentration," *Energy Policy* 38: 1635–1644.

Moriarty P. and D. Honnery. 2009. "What Energy Levels can the Earth Sustain?" *Energy Policy* 37: 2469–2474.

Müller-Kraenner, S. 2007. *Energy Security: Re-Measuring the World* (London and Sterling, VA: Earthscan).

Nel, W.P. and C.J. Cooper. 2009. "Implications of Fossil Fuel Constraints on Economic Growth and Global Warming," *Energy Policy* 37: 166–180.

Patterson, W. 2007. *Keeping the Lights On: Towards Sustainable Electricity* (London: Earthscan).

Rutledge, D. 2009. *Hubbert's Peak, The Coal Question, and Climate Change.* PPT presentation. Available at: http://Rutledge.caltech.edu.

Stern, J. 2009. *Continental European Long-Term Gas Contracts: Is a Transition Away from Oil Product-Linked Pricing Inevitable and Imminent?* Report no. NG 34 (Oxford: Institute for Energy Studies, September).

Tao, Z. and M. Li. 2007. "What is the Limit of Chinese Coal Supplies: A STELLA model of Hubbert Peak," *Energy Policy* 35: 3145–3154.

Turner, G.M. 2008. "A Comparison of the Limits to Growth with 30 Years of Reality," *Global Environmental Change* 18: 397–411.

US Geological Survey (USGS). 2010. *Mineral Commodity Summaries 2010* (Washington, DC: United States Government Printing Office).