Transition to a Low Carbon Energy System and Energy Security-Synergies and Conflicts

Bengt Johansson[a,b,*], Daniel K Jonsson[a,c], André Månsson[b], Lars J Nilsson[b], Måns Nilsson[c,d].

[a] FOI, Swedish Defence Research Agency, SE-164 90 Stockholm, Sweden

[b] Environmental and Energy Systems Studies, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden

[c] Environmental Strategies Research, School of Architecture and the Built Environment Royal Institute of Technology (KTH), SE-100 44 Stockholm, Sweden.

[d] Stockholm Environment Institute, Linnégatan 87D, SE-104 51 Stockholm, Sweden.

*Corresponding Author: Bengt.H.Johansson@foi.se, Phone +46855503379

Abstract Emissions of greenhouse gases must be significantly reduced in order to limit the risk of severe climatic change. Such reductions will require a long-term transition of the energy system to one in which energy efficiency improvements, electrification, renewable energy, carbon capture and storage and nuclear energy can play important roles. Energy security will be affected by such a transition. This paper summarises the main findings from a research project that investigated the synergies and conflicts between a low carbon energy transition and energy security. Energy security can be interpreted in several different ways. Our approach involves studying energy both as an *object* exposed to security threats, using concepts such as security of supply or security of demand, and the energy system as the *subject* generating or enhancing insecurity and conflict.

Our results indicate that a low carbon energy system can have at least as high level of energy security as the current system, but there will be some new challenges. One is the potential strains and conflicts that can emerge around bioenergy and land use issues. Another is the large scale expansion of variable electricity production, which will require significant investments in new infrastructure. An overlook of institutions and regulations will probably be required to meet the new challenges. The transition period requires special attention; however, since while economic resources and competencies need to be redirected to new, expanding, energy systems, there is a risk that contracting technologies may receive insufficient allocation of resources for maintaining a high level of energy security.

1. INTRODUCTION

To reduce the risks for dangerous climate change the emissions of greenhouse gases have to be significantly reduced (see e.g. IPCC, 2014). This will in turn require a transition of the energy system to a much more efficient one, based largely on non-fossil energy sources. The transition will have an impact on various aspects of energy security. There is no single interpretation of energy security and the concept has been used in various ways in research and policy depending on scientific perspective, national contexts and political agendas. Focus may for example be on security of supply, which can be understood as a reliable and uninterrupted supply of energy at reasonable and stable prices, or on the political pressures or conflicts that may arise as a result of energy's strategic importance.

In this paper we will present a short summary of the learnings from a 3 ½ years research project in which the interrelations between a low carbon transition and energy security were explored. In section 2 we present the approach to energy security that was applied in the project. In section 3, the major energy system changes expected in a low carbon transition are described. In section 4 some of the more important synergies and conflicts between a low carbon transition and energy security are presented. Finally, in section 5, the results are discussed.

2. ENERGY AND SECURITY

The interaction between energy and security can be viewed from many different angles, and in recent years several studies have presented analytical frameworks and indicators in order to capture the essence of the concept (see e.g. Ciută, 2010; Chester; 2011; Sovacool and Mukherjee, 2011; Cherp and Jewell, 2011; Winzer, 2012). As mentioned above, this project used a broad approach to security to describe the various impacts from an energy transition (Johansson, 2013). Such an approach includes both threats to a well-functioning energy system (energy as an object), and situations when the energy system acts as a contributor or enhancer for broader security threats to society (energy as a subject), see Fig. 1.

The "energy as an object" part includes both the concept of *security of supply* and security *of demand.* These concepts have many similarities with regard to potential threats but differ with regard to whose perspective (users or suppliers) is in focus. The threats to a well-functioning energy system, characterised by uninterrupted supply and non-volatile prices, can have technological, natural and human causes, and depend on factors such as limited resource availability in the short or long-time perspective, intentional attacks, accidents, low investments in capital and human resources, and poor governance. Uninterrupted flows and stable prices are common interests for both users and suppliers, whereas they will have different interests as to what is a desirable price level.

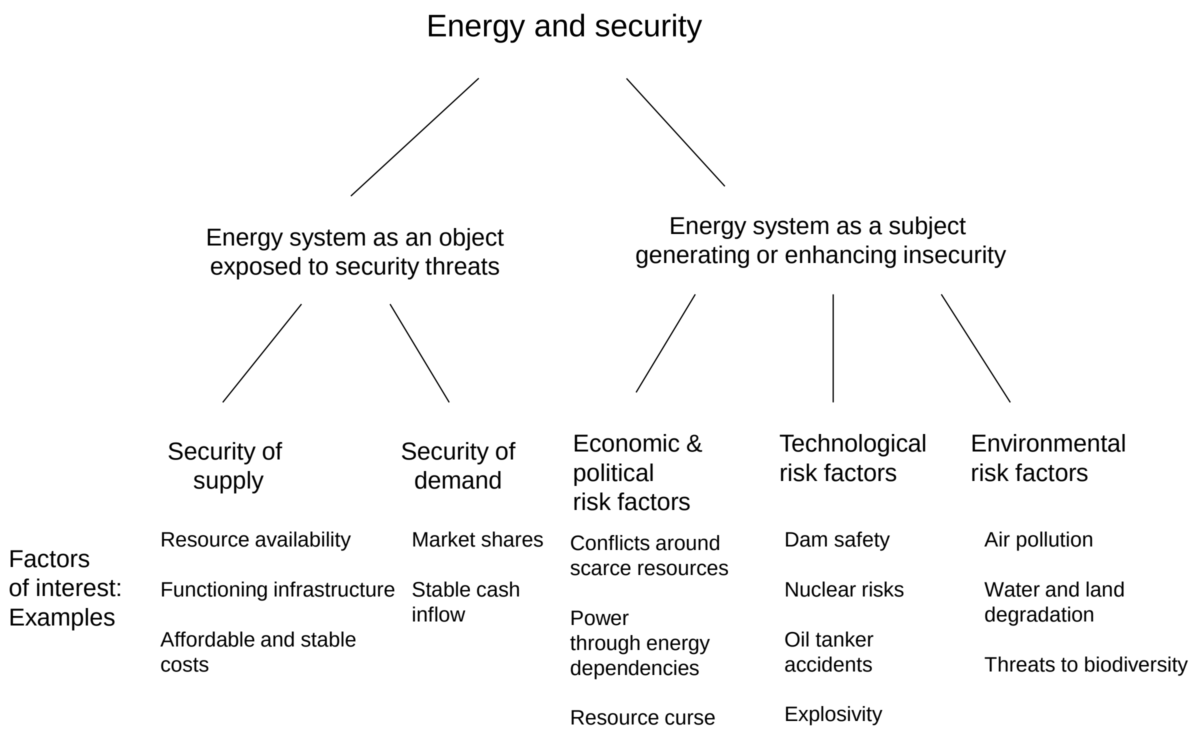

Figure 1. The analytical structure used in this paper to study the relations between energy and security Developed from Johansson (2013a).

The "energy as a subject" field includes energy as contributor to, or enhancer of, insecurity or conflicts. Conflicts and stresses may be a result of an aspiration to gain access to valuable energy resources, or to use the energy systems to harm other actors for example through forms of political pressure or terror attacks. They can also be unintended by-effects that act as a threat multiplier. Four different categories of destabilisers, that are combinations of economic, political and/or physical factors, can be distinguished: i) local abundance of resources, also known as the "resource curse", ii) environmental degradation that causes scarcity of renewable resources, iii) reduced security of supply that causes knock-on effects (e.g. economic instability), and iv) interactions with food prices that have adverse effects on food security. The scale of these conflicts has historically been mainly local and has affected human security, but some could potentially expand to a national or even a regional domain. (Månsson, 2014).

Fuels and energy technologies can contribute to risks to human security due to their physical and chemical properties (e.g. radiation risks, toxicity, or fire and explosion risks) and through the environmental risks created by the emissions of greenhouse gases and other air pollutants, water pollution and intensive land use (Johansson, 2013a).

3. THE LOW CARBON TRANSITION

During recent years a significant number of scenarios describing low carbon transitions have been presented both by researchers and by policy actors (see e.g. Söderholm et al., 2011 and Johansson, 2013b for reviews). Although the scenario studies differ in approaches, there are a number of mitigation measures that occur in most of them. Energy efficiency improvements, renewable energy, carbon capture and storage (CCS) and nuclear power are building stones in most scenarios. However, their respective importance differs depending on assumptions regarding cost developments, success in RD&D activities, and implementation barriers including acceptance issues (the latter are especially important for nuclear power). Indirectly, electrification is often an important part of the transition, as the electricity system, in comparison to the supply low carbon liquid or gaseous fuels, is assumed to be relatively easier to decarbonise. In the project we have especially looked into the energy security consequences of energy efficiency improvements and renewable energy (see e.g. Johansson, 2013c; Jonsson and Johansson, 2013; and Månsson et al., 2014). In some scenarios for industrialised countries the energy efficiency improvements are resulting in absolute reductions in energy use. In other scenarios energy efficiency improvements lead to significant reductions in energy use levels compared to business-as-usual scenarios, but nevertheless the absolute levels may remain on current levels or increase due to economic growth.

4. CONFLICTS AND SYNERGIES BETWEEN MITIGATION MEASURES AND ENERGY SECURITY

Energy efficiency

Energy efficiency improvements reduce the demand for scarce energy resources (fossil and renewable) and the strain on several infrastructure systems such as refineries and electricity transmission. High energy efficiency makes a specific amount of stored energy last a longer period during a shortage situation. Reduced heat losses in well-insulated buildings will also reduce the negative consequences of a loss in energy supply. Energy efficiency will, however, in most cases be of little help in case of a total supply cut in the electricity system. In the short and medium term perspective, energy efficiency will provide more redundancy in the supply system and thus lower risk for disturbances. However, in the longer run, it is probable that the system will adapt to the new energy demand levels and that these advantages will reduce over time. Energy efficiency improvements will also reduce the energy intensity of the economy (and single actors), and thus make it less vulnerable to changes in energy prices (Jonsson and Johansson, 2013).

For energy suppliers, energy efficiency in importing countries can lead to reduced incomes as long as they are not compensated for by increased demand of energy services. However, as many exporting countries subsidize energy for domestic consumers, energy efficiency improvements domestically, could increase the amounts available for export at higher international market prices (Jonsson and Johansson, 2013).

Energy efficiency reduces imports but whether this leads to increased security is a matter of discussion between various theoretical schools. Although reduced imports leads to decreased dependence of other actors' behaviour, some security policy scholars highlight the advantages interdependence may have on the general security level (e.g. Keohane and Nye 1997).

Energy efficiency should reduce the risks for negative impact on food security as falling energy prices expected from energy efficiency improvements would lead to cheaper inputs in agriculture and reduced bioenergy demand would lead to less competition for land resources.

Renewable energy

An increased use of renewable energy will reduce the demand for finite fossil resources and enable a long-term energy supply, if the renewable energy sources are not utilized at levels above their long-term productivity (Johansson, 2013c). As there are still significant fossil fuel resources, the importance of this aspect will increase over time. During a transition period, with deteriorating economic conditions for contracting fossil fuels, there is a risk that these fossil fuels will receive insufficient allocation of resources for maintaining a high level of energy security.

Fossil fuels are dominating the energy mix in most countries and an increased use of renewable energy would increase diversity, and thus reduce the vulnerability for disturbances in energy supply. As the renewable sources are less concentrated than oil and gas, increased use of renewable energy could reduce the dependence of specific countries and transit routes.

However, as renewable and fossil energy are often substitutes and fossil fuel can be used as input in production of renewable energy, an increased use of renewable energy will not insulate local markets from events on the fossil fuel markets.

A security of supply aspect, often highlighted for renewable energy, is the challenges increased variable electricity production can pose for balancing supply and demand. To handle this, several studies highlight the need to invest in transmission lines, energy storage and smart electricity system (see e.g. Kempton et al., 2005; Purvins et al., 2011; and Bove et al., 2012), and to adapt the pricing methods to handle that prices under long periods could be lower than what would be necessary to cover investment needs. An advantage is that distributed production, characterizing renewable energy, reduces the consequences of a failure on a single production plant or transmission link.

The risks that exporters of renewable energy should be in the position to exploit dependencies, will probably be lower than for current fossil fuels although there are studies indicating that such risks will remain in certain situations (Lilliestam and Ellenbeck, 2011, Tynkkynen, 2014). The potential conflicts between bioenergy and food security is, however, raised in several studies (see e.g. Faij 2008; Nonhebel, 2012). An increased competition for productive land could generate conflicts regarding the possession of land and water resources; increase the price on agriculture land and food which could increase the risk for local and regional conflicts. The interaction between bioenergy and biodiversity is also an important aspect to manage.

CCS and nuclear energy

A successful expansion of CCS would make it possible to continue to use a certain amount of fossil fuels also in a carbon restricted world. This opens for a broader variety of low-carbon alternatives and thus a greater diversity of supply. On the other hand, the technology could risk strengthening lock-ins in fossil-fuel intensive systems, with well-known energy security problems especially for natural gas. CCS differs from the other mitigation alternatives since it does not seem to have any specific advantages in addition to emission mitigation, the use of carbon dioxide for enhanced oil and gas recovery excluded. For the only accepted storage alternative, geological storage, environmental risks seem to be low. The major problems for CCS seem to be public acceptances and, because of that, low political support, and that an expansion would require strong public governance and planning (IEA, 2013).

The risks highlighted in relation to nuclear power are mainly emanating from dealing with radioactive materials, the risk for nuclear accidents with widespread damages to society and the environment, and the risk that fissile materials would lead to the proliferation of nuclear weapon. These risks are valued differently among nations where some plan a significant expansion of nuclear, whereas countries such as Germany have decided to close nuclear. With a large scale expansion of nuclear globally, new or worsened risks could emerge as limited U-235 resources could increase the efforts to reprocess nuclear waste and develop breed reactors (MIT, 2003). This could probably increase the risk for accidents, attacks and weapon proliferation. Today, the nuclear fuels comes from a small amount of countries which could be a risk factor, but disturbances on the market leading to increased prices should have less impact on production costs as the fuel costs are only a small fraction of total production costs for nuclear electricity.

Electrification

Electrification of transportation and certain industrial processes (Åhman et al., 2012) could facilitate developing an energy system with low greenhouse gas emissions. Simultaneously, it improves the conditions for high diversity in the choices of energy sources as the electricity system can consist of a mix of renewable energy sources, nuclear and fossil fuels with CCS and the prices would be less dependent of a single fuel market. If vehicles in addition to using electricity could utilize several energy carriers (electricity, liquid fuels) the vulnerability would be reduced even more. The importance of a robust and well-functioning electricity system will on the other hand be even more important than today.

There is a great uncertainty around how the electricity system will develop in the future with expected large fractions of variable electricity production from solar and wind. The effects on energy security, is thus also uncertain. Balancing future electricity systems will be conducted through a mix of flexible demand, integrated power systems with increased transmission capacities, and several energy storage solutions (see e.g. Huber, et al., 2014). How high the level of security of supply will be is an economic issue that depends on amongst others the level of investments in redundancy (extra transmission lines, storage, reserve power etc.). One rather certain effect is more fluctuating electricity prices, but the importance of these fluctuations will differ among various customers.

The importance of external factors –an EU perspective

External factors determine the outcome of many of the energy security aspects. From an EU perspective, perhaps the most prominent external factor when considering security of supply will be if there is a global climate action or not. This factor may also play a part when analyzing if the energy system might generate or enhance insecurity, but in that case, specific local, national, regional and contextual factors with indirect implications are more important (Jonsson et al., 2014).

For example, the occurrence of conflicts may involve energy issues, but often just as a subset of other causes (Koubi et al. 2013), and will probably not be a direct effect of for example EU energy policy. The geopolitical risk factor, i.e. the potential risk associated with a certain dependency, is always a product of political intentions, on the one hand, and subjective perceptions of security, on the other hand. In the geopolitical context it should be noted that more prominent importers have greater possibilities to affect supplier behavior than small consumers (Smith Stegen 2011). So a coherent European energy policy based on unity and solidarity among member states, regardless if EU is following the EU Energy Roadmap or not, will be a robust strategy to handle geopolitical risks (Jonsson et al., 2014).

Increased securitization of energy, bringing more military involvement can function as a unilateral strategy, but in that case only to protect specific flows. Anyhow, it will not be a direct effect of the realization of low-carbon scenarios. When it comes to increased securitization in order to maintain international flow security, with the higher aim to promote continued globalization, the EU can hardly act unilaterally but is dependent on the political intensions of, and cooperation with, other countries. As of today, both the EU and the US are dependent on functioning global markets, which to various degrees are protected with military power (Stokes and Raphael 2010).

Bad governance in terms of e.g. ‘resource curse’ or human security issues in exporting countries are also products of a number of local circumstances, rather than a simple cause-effect chain of what the energy system looks like. More decisive characteristics associated with the exporting country seem to be the presence of a democratic system (e.g. Canada) or the absence of such (e.g. Turkmenistan), if revenue is distributed among the population (e.g. Norway), if the general corruption level is high (e.g. Venezuela), or if there is a lack of diversity in the economic base (e.g. Saudi Arabia) (Jonsson et al., 2014).

5. DISCUSSION AND CONCLUSION

When studying the transition of a specific region, for example the EU, the impact on energy security depends on the strategies pursued in other regions. As EU: s demand is only a small fraction of global demand; its impact on the strain on global resources will only be minor. If other regions continue using fossil fuels this would have impact on the availability of fossil fuels in scenarios where there are still significant amounts of fossil fuels used. On the other hand if all regions have ambitious strategies for GHG mitigation, the strain on global biomass resources will be much greater than if EU goes by itself. Geopolitical strategies of various governments might in turn have great importance on energy security.

Which energy security aspects that turn out to be problematic vary depending on what strategy is chosen. No energy system is without problem and although many parts of energy security strategies such as diversification, and investments in infrastructures and human resources seem to be robust regardless of system, other security aspects are clearly affected by the choice of energy system.

Although new low carbon systems seem to be able to provide a high level of energy security, specific problems might arise during the transition period. During this period insufficient resources might be directed to stagnating sectors, which might get problems to recruit important competences. At the same time investments might be too low to catch up with fast expanding new technologies which might give problems for example in the electricity system. An opposite aspect is the positive effect energy efficiency improvements could have during a transition period, an effect that might diminish as the energy system is adapted to the new conditions.

What is included in the concept of energy security depends amongst others on whose security the focus is directed to. Much focus in energy security studies is directed to the regional or national level. We believe that there is a need to complement this view with a stakeholder perspective looking on energy security in various sectors or individual households and companies. Low import dependency is often used as a proxy for high energy security but this is a blunt measure and could be misleading for at least two reasons. First, interdependency and economic integration can contribute to security. Second, a narrow focus on import dependency could hide important aspects of energy security such as a well-functioning and robust infrastructure, stable prices and the capacity to handle unexpected disturbances.

Also in the future energy security will depend on efficient governance. Much of the necessary regulation will be unaffected by exactly how the energy system is designed, whereas other dealing with for example land use aspects will be more important with a large fraction of renewable energy.

There is always a need to strike a balance between security and economy. Even if, for example, it would be positive to reduce import dependency (as for example the EU argues), it has to be weighed against the potential cost advantages of producing for example renewable electricity or biomass outside the region.

Energy security has, historically, to a great deal been about oil and gas. In a transition to a low carbon society more focus has to be directed to the energy security of renewable systems, new technologies such as CCS and electric vehicles and the electricity system. Furthermore, focus should be on securing energy services rather than the flow of specific energy carriers.

It is extremely difficult to rank future energy systems according to their energy security level. It is important to note that prioritising among various energy security factors is mainly a political issue rather than a question for researchers. The role of the researchers might, however, be to critically scrutinize the reasoning for the political priorities and the consistency between targets and policies.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the economic support provided by the Swedish Energy Agency.

7. REFERENCES

Åhman M., Nikoleris A., Nilsson L.J. 2012. *Decarbonising industry in Sweden, an assessment of possibilities and policy needs*. Report No 77, Environmental and Energy Systems Studies, Lund University.

Bove R., Bucher M., Ferretti F. 2012. Integrating large shares of wind power in macro-economical cost-effective way. *Energy*, **43**, 438-447.

Cherp A., Jewell J. 2011. The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration., *Current Opinion in Environmental Sustainability*.**3**, 202-212.

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

Ciută F., 2010. Conceptual notes on energy security: total or banal security. *Security Dialogue*. **41**, 123-144.

Faij A. 2008. *Bioenergy and global food security.* Externe Expertise für das WBGU-Hauptgutachten Welt im Wandel: Zukunftsfähige Bioenergie und nachhaltige Landnutzung. Berlin: Wissenschaflitches Beirat der Bundesregierung Globale Umweltsverändrungen.

Huber, M., Dimkova, D., Hamacher, T. 2014. Integration of wind and solar power in Europe: Assessment of flexibility requirements. *Energy*, **69**, 236-246.

IEA 2013. *Technology Roadmap, Carbon capture and storage*. International Energy Agency, Paris.

IPCC, 2014. Summary for Policymakers, In Edenhofer,O., Pichs-Madruga R., Sokona Y., Farahani E., Kadner S., Seyboth K., Adler A., Baum I., Brunner S., Eickemeier P., Kriemann B., Savolainen J., Schlomer S., von Stechow C., Zwickel T., and Minx J.C. (Eds.).: *Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Johansson B. 2013a. A broadened typology on energy and security. *Energy,* **53**, 199-205.

Johansson B. 2013b. Energy efficiency in low-carbon and energy roadmaps. *Eceee 2013 Summer study, France 3-8 June.*

Johansson B. 2013c. Security Aspects of Future Renewable Energy Systems –A Short Overview. *Energy,* **61**, 598-605.

Jonsson D. K. Johansson B. 2013. How can improved energy efficiency affect energy security? *Eceee 2013 Summer study, France 3-8 June.*

Jonsson, Daniel K.; Månsson, André; and Johansson, Bengt. 2013. Energy Security and Climate Change Mitigation as Combined Areas of Analysis in Contemporary Research.*Energy Studies Review*: Vol. **20**: Iss. 2, Article 5.

Jonsson D. K. Johansson B., Månsson A., Nilsson L. J., Nilsson M., Sonnsjö H. 2014. Energy Security Matters in low-carbon energy systems. *Submitted manuscript.*

Keohane, R., Nye, J.S., 1997. Realism and Complex Interdependence, in: Crane, G.T., Amawi A. (Eds.), *The Theoretical Evolution of International Political Economy* . Oxford University Press, New York, pp. 133-140.

Kempton W, Tomic J. 2005 Vehicle-to-grid power implementation: From stabilizing the grid to supporting large scale renewable energy. *Journal of Power Sources*, **144,** 280-294.

Koubi V., Spilker G., Bohmelt T., Bernauer T., 2013. Do natural resources matter for interstate and intrastate armed conflict? *Journal of Peace Research*, August 21: 1-17.

Lilliestam, J., Ellenbeck, S. 2011. Energy security and renewable electricity trade—Will Desertec make Europe vulnerable to the "energy weapon"? *Energy Policy*, **39**, 3380-3391.

MIT. 2003. *The Future of Nuclear Power, an Interdisciplinary MIT Study*, Massachusetts Institute of Technology, Boston.

Månsson A. 2014. Interactions between energy and conflicts: Overview and conceptual framework. *Submitted to Energy Research & Social Science*

Månsson, A., Sanches-Pereira, A., Hermann, S., 2014. Biofuels for road transport: Analysing evolving supply chains in Sweden from an energy security perspective. *Applied Energy*, **123**, 349-357.

Nonhebel S. 2012. Global food supply and the impacts of increased use of biofuels. *Energy*, **37**, 115-121.

Purvins A., Zubaryeva A., Llorente M., Tzimas E., Mercier A. 2011. Challenges and options for a large wind power uptake by the European electricity system. *Applied Energy*, **88**, 1461-1469.

Smith Stegen, K., 2011. Deconstructing the "energy weapon": Russia's threat to Europe as case study. *Energy Policy*, **39**, 6505-6513

Söderholm P., Hildingsson R., Johansson B., Khan J., Wilhelmsson F. 2011. Governing the transition to low-carbon futures: A critical survey of energy scenarios for 2050. *Futures*, **43**, 10, 1105-1116.

Sovacool BK, Mukherjee I., 2011. Conceptualising and measuring energy security: A synthesis approach. *Energy*, **36**, 5846-5853.

Stokes, D., Raphael, S., 2010. *Global Energy Security and American Hegemony*. The John Hopkins University Press.

Tynkkynen V-P. 2014. Russian bioenergy and the EU’s renewable energy goals. Perspectives of security. In Oxenstierna S., V-p Tynkkynen (Eds.*) Russian Energy and Security up to 2030*, Routledge, London och New York.

Winzer, C., 2012. Conceptualizing energy security. *Energy Policy*, **46**, 36-48.

8. KEYWORDS

Climate change, energy security, energy policy