FORESTRY IDEAS, 2015, vol. 21, No 2 (50): 347–357

SUSTAINABILITY IMPACT ASSESSMENT (SIA) OF RENEWABLE ENERGY SYSTEMS: OVERVIEW OF INDICATORS AND NEEDS FOR FUTURE DEVELOPMENTS

Martina Modotti[1], Isabella De Meo[1], Alessandro Paletto[2*], and Gianluca Grilli[3,4]

[1]Council for Agricultural Research and Economics – Agrobiology and Pedology Research Centre (CREA-ABP), P.za D'Azeglio 30, 50121 Firenze, Italy. E-mail: isabella.demeo@entecra.it
[2]Council for Agricultural Research and Economics – Forest Monitoring and Management Research Unit (CREA-MPF), P.za Nicolini 6, 38100 Villazzano, Trento, Italy.
[*]E-mail: alessandro.paletto@entecra.it
[3]Eurac Research – Institute of Renewable Energy, Drususallee 1, 39100 Bolzano, Italy.
E-mail: gianluca.grilli@eurac.edu
[4]Department of civil, environmental and mechanical engineering, University of Trento, via mesiano 77, 38123 Trento, Italy.

Received: 06 May 2015 Accepted: 15 January 2016

Abstract

In the last decades, the international energy demand has risen greatly due to the world's population growth and the economic development of some big countries (e.g. China, India, Indonesia). The intensive use of fossil fuels is recognized as unsustainable in the long-term period. In this framework, renewable energies represent important sources in order to satisfy the energy demand in a sustainable way. European Union (EU) promotes the use of renewable energy sources (RES) to reduce greenhouse gas (GHG) emissions, to increase energy independence and to promote the renewable industry. Renewable energy policy must take into account the technical aspects of energy production and also the environmental, economic and social aspects, following an integrated approach. Consequently, sustainability assessment has become a fast developing research field and impact assessment tools – based on methods that take in consideration stakeholders' opinions and expectations – are commonly used to support policies or projects implementation. Sustainability Impact Assessment (SIA) is a tool that supports decision-makers in identifying potential impacts of possible policy actions. Environmental, economic and social aspects related to renewable energies are often analyzed with sectorial approaches. To overcome this gap, it is fundamental to develop practical instruments useful for an integrated assessment considering environmental, technical-logistics, financial and social parameters of renewable energy systems. Starting from these considerations, this research investigates the indicators useful to support the SIA of a policy, a plan or a single action related to a renewable energy system. Social and economic dimensions and related indicators are analyzed, also including indicators which straddle between socio-economic and environmental sector. A comprehensive in-depth literature review has been made in order to create a database of criteria and indicators. After creating the database, authors selected 308 suitable indicators: 93 relating to the economic dimension, 152 to the socio-political and cultural one and 63 to the social-environmental dimension. Furthermore, indicators were aggregated into three main impact dimensions (economic, social-political and social-environmental) and six general criteria. Finally, some recommendations are given to contribute at developing new indicators for the assessment of effects of renewable energy systems on sustainability.

Key words: energy-demand, forest biomass, hydropower, socio-economic indicators, solar thermal power, sustainable development, wind power.

Introduction

The world's demand for energy has risen greatly in the last decades, due to population growth and industrialization of some big countries, e.g. China, India, Indonesia (Bronfman et al. 2012, Rotty 1979). In view of the current world energy consumption the extensive use of fossil fuels and non-renewable resources is widely accepted as unsustainable in the long term (Robèrt et al. 2002, Twidell and Weir 2003). In this framework, the search for energy alternatives, involving locally available and renewable resources, is one of the main concerns of scientists, governments, and various stakeholders worldwide. Renewable energies (REs) play a key role for meeting of energy demand in several contexts and RE systems are crucial in sustainable development policies definition (Krajačić et al. 2011, Pistorius et al. 2012, Wilkens and Schmuck 2012).

European Union (EU) promotes the use of energy from RE sources (RES) to reduce greenhouse gas (GHG) emissions, to increase energy independence (Reiche and Bechberger 2004) and to promote the renewable industry, which would encourage technological innovation and employment in Europe (Nishizono et al. 2005, Mathiesen et al. 2011). The Directive 2009/28/EC is one of the main tools to fulfill the EU's Climate and Energy Package "20-20-20" targets for 2020: 20 % rise in energy efficiency, 20 % less GHG emissions and 20 % increase in energy generation from renewable sources.

Renewable energies are a strategic issue for the linkage between environmental services and actual policies (Pistorius et al. 2012) and bioenergy from renewable energies can lead to an increase of employment opportunities and new market orientation (Demirbas 2009). In order to implement sustainable development in the energy sector, RE policies must therefore take into account not only the technical aspects of energy production but also social, economic and environmental aspects following an integrated approach by incorporating the links between energy and society, economy and environment in a single framework (Bassi et al. 2010). Moreover, compared to traditional systems, renewable energies systems have a more decentralized structure and their local impacts are more significant (Wilkens and Schmuck 2012): lack of public support can seriously reduce the viability of implementing a given technology (Bronfman et al. 2012).

Sustainability assessment has become a fast developing area also in the renewable energies sector and in the last decades the numbers of tools that can be used for assessing sustainability have grown rapidly (Mascarenhas et al. 2010). In this framework, according to the categorization of sustainability assessment tools by Ness et al. (2005), there is the umbrella of impact assessment tools. This is a small group of tools – based on methods that take in consideration stakeholders opinions and expectations – commonly used to support policy or project implementation (Ness et al. 2005).

Among impact assessment tools Environmental Impact Assessment (EIA) has been developed since sixties to evaluate the impacts on the environment of development projects (Sadler 1999) and after the United Nations Framework Convention on Climate Change (1992) and the third Conference of the Parties (1997) has become a commonplace also in the field of RE systems (Afgan et al. 2003). On the contrary, the assessment of social and cultural aspects of sustainability is still in its infancy in renewable energies sector (Gallego Carrera and Mack 2010).

More recently, in 2002, the European Commission introduced the more comprehensive Sustainability Impact Assessment (SIA) defined as "*a tool to improve the quality and coherence of the policy development process. Impact Assessment identifies the likely positive and negative impacts of proposed policy actions, enabling informed political judgments to be made about the proposal and identify trade-offs in achieving competing objectives*" (European Commission 2002). The importance of SIA as a process more than a simple tool is further emphasized in the revised version of the European Commission's SIA guidelines: "*Impact assessment is a set of logical steps to be followed when you prepare policy proposals. It is a process that prepares evidence for political decision-makers on the advantages and disadvantages of possible policy options by assessing their potential impacts*" (European Commission 2009).

The field of renewable energies often presents a lack in practical tools useful for relating the complexity of interaction among environmental, economic and social aspects that are often considered with sectorial and fragmented approaches. Instead, an accurate planning and setting of both investments, interventions and plants impacts is fundamental to develop an integrated assessment considering environmental, technical-logistics, financial and social parameters of RE systems.

For policies, programs and plans with potential impacts on the environment is usually required the application of SEA (Strategic Environmental Assessment). In this kind of tool, environmental aspects are deeply investigated while in the SIA the analysis of environmental aspects is limited in comparison with social and economic factors (Arbter 2003, Wilkinson et al. 2004).

In the light of these considerations, the objective of the paper is to investigate – through a literature review – the availability of indicators useful to support the SIA of a policy, a program, a plan or a single action related to a RE system. In particular, the authors concentrated their investigation on the social and economic dimensions and related indicators, also including indicators which straddle between socio-economic and environmental sector. Indicators are then aggregated into impact dimensions (economic, social-political and social-environmental) and general criteria, to give to the reader a schematic and synthetic view of the available indicators. Furthermore, the authors select a set of indicators, that are proposed as a contribution for moving forward in implementing and evaluating sustainability indicators for RE systems across different settings and scales. Finally, some recommendations are given with the objective of contributing in the development of new indicators for the assessment of the economic and social effects of RE systems on sustainability.

Material and Methods

Literature review and database creation

A comprehensive in-depth literature review has been made in order to create a database of criteria and indicators of economic and social impacts of RE systems. The literature review was concerned with the impact assessment of four renewable energies: solar thermal power, wind power, hydropower and biomass. Geothermal and marine energies were not included in the present study.

At present biomass is the largest and most important option among renewable energies and the fourth largest energy source after coal, oil and natural gas (Lada-

nai and Vinterbäck 2009). Concerning the three main sources of biomass (agriculture, forest and waste) authors focused their investigation on forest biomass. This choice is due to the fact that forest biomass is one of the renewable and sustainable sources of energy that can be used for producing electricity, heat, and biofuel and the economic and social impacts related to forest biomass energy systems are an important sector of investigation.

The literature review has been made with special regards to the developed countries, since the same energy policy recommendations could hardly be adapted to such different social and economic contexts like the ones of developing countries. Considering the gap between developed and developing countries on the use of renewable energies producing technologies (El Fadel et al. 2013), to take into consideration developing countries own specificities would require an additional and specific research.

In consideration of the recent development of these issues and of the rapid change of the legislative and political framework only documents published after 2000 have been selected.

For the literature review a set of keywords has been defined and used to browse publications in major online scientific databases and search engines. The keywords employed were: “renewable energies” (i.e. “hydropower”, “solar”, “wind”, “forest biomass”), “sustainability impact assessment”, “social impact assessment”, “indicator/index” (and “socio-economic indicator”), “socio-economic/cultural dimension”, “socio-economic/cultural impacts”. Other papers were identified from reference lists of retrieved papers. Through this cascading research 85 documents have been selected (Fig. 1).

As the next step, a database was developed characterizing the documents and their results in a common framework. The database was created in order to manage the collected bibliographic information and to identify and systematically collect indicators related to effects of RE systems on sustainability. All studies were thoroughly reviewed and the relevant information and characteristics were extracted and inserted into the database. The database was filled following nine key information: year of publication, authors’ nationality, type of document (research article, review, book, report, web site, mixed typology), analysis of case studies in the document (yes or no, and if yes: scale and

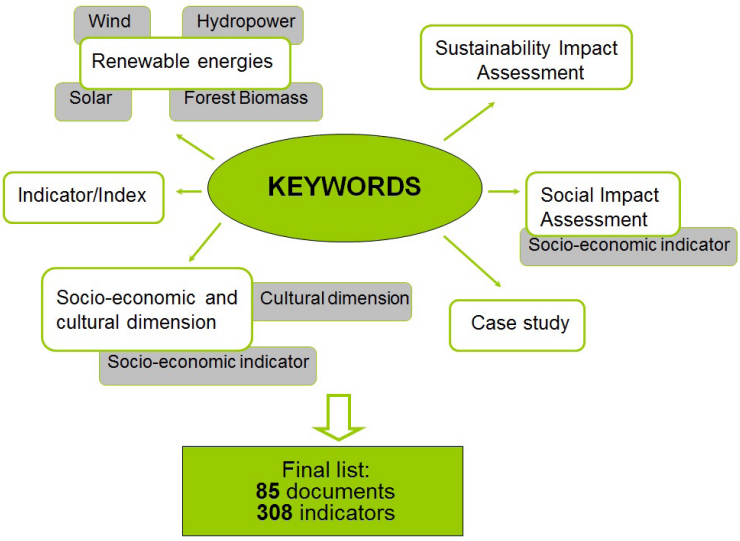

Fig. 1. Review methodology.

geographical area of the case study), used methodology (macro-category of the methodology or specific methodology), existence of a detailed list/review of indicators (yes or no), construction of a general/aggregate index (yes or no).

Since sometimes the methodologies and the assumptions used in the studies differ considerably, results were presented using different formats, and other documents had shortfalls, authors decided to exclude from the analysis some documents which could not be placed in a common framework.

Selection of indicators

After database establishment, indicators fields were analyzed to selected suitable indicators assessing economic and social effects of RE systems on sustainability. As a result, 308 indicators were found: 93 relating to the economic dimension, 152 to the socio-political and cultural dimension and 63 to the social-environmental dimension.

A detailed table has been drawn in order to put together all the available information about the selected indicators. The table is structured to include "description of the indicator", "recommendations for the use", "unit of measure", "methodology" for the definition of the indicator and "bibliographic references".

As next step indicators were evaluated and selected with respect to their suitability to assess energy systems effects on sustainability. In literature it is possible to find several criteria to assess valid indicators, and the appropriateness of the criteria depends on the purpose for which indicators are selected. The selection was guided by the quality criteria. Authors selected indicators modifying the criteria defined by Meadows (1998) and successively expanded by Gallego Carrera and Mack (2010). The selection of "good" indicators was guided by the following relevant aspects:

i) Indicators with a clear value;

ii) Indicator coherent and consistent (logical);

iii) Indicators sufficient in information;

iv) Indicators that can be applied throughout Europe;

v) Indicators that can be disaggregated at small scale level.

After the selection process, indicators which passed the filter process were aggregated into three main impact dimensions (economic, social-political and social-environmental) and six criteria. Criteria define the essential components of socio-economic context against which the impacts of RE development may be assessed. In particular, criteria encompass impacts on local economy, on societal values and visions and on cultural sphere and specifically concern: (1) the impact and the efficiency of the system in the ambit of the local economy; (2) the impact on the quality of life and on the social stability,

Table 1. Indicators: impact dimensions and criteria.

Impact dimension	Criteria
Economic	Changes in local economy
	Efficiency and reliability of the energy system
Social/political	Political stability, participation, human capacity and system legitimacy
	Quality of life
	Local traditions, cultural values and property rights
Social/ environmental	Social component of risk

involvement and legitimacy; (3) the impact tied to the social risk; (4) the impact on local traditions and cultural values (Table 1).

Results and Discussion

Literature review and database creation

The results of the in-depth literature review showed that almost 50 % of the selected documents have been published between 2006 and 2011. This period can be rightly considered the period of highest scientific development of the SIA issue. From the geographical point of view (Fig. 2), the largest amount of studies has been made in Greece (11 peer-review articles), followed by Germany (9), Switzerland (8), Portugal (6), United Kingdom and China (5), United States, Jordan and Italy (4). For 18 other countries were selected from three to one documents.

It was not possible to find any detailed information for about 17 % of the selected documents, due to the impossibility to access the full text of the document or because they were written in original language (not English, French or Italian). For this reason, authors decided to keep them as references since they had been cited as important sources from other authors included in the list.

When considering the scale of analysis, 31 out of the 85 documents (37 % of the total) present one or more case studies analysis (Fig. 3), most of which are case studies at national scale (45 %) or at regional scale (29 %).

The scale of analysis is an important element because studies related to renewable energies plants impacts – like other analyses in different sectors – have different resolutions and range of applicability that depend largely on the focus and scale of analysis. Furthermore, a large number of indicators are used to assess different kinds of impacts on sustainability and the choice of appropriate indicators usually depends on the context and scale of analysis. In addition, when considering social/political impact, according to the scale of analysis there are different social groups and social interests involved in the decision-making process (Mohammadi et al. 2013).

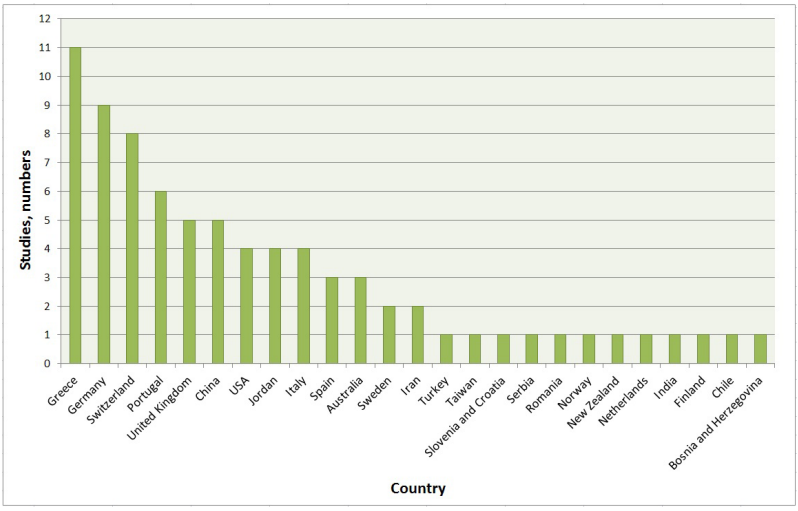

Fig. 2. Distribution of the analyzed documents by country.

Finally, 24 of the selected documents (29 %) showed an aggregate sustainability index.

Aggregate indices are formed by the combina-

tion of several indicators in order to provide a more complete and synthetic picture, compared with the individual indices. We conducted a careful analysis of documents containing aggregate sustainability index, because they can incorporate several key sustainability indicators in a single framework, allowing the consideration of the multi-dimensionality of sustainability. Moreover, an aggregate sustainability index can be easily interpreted and communicated to the stakeholders and citizens; for this reason these indices are useful in analyzing the effect of a policy or plan implementation (Böhringer and Löschel 2006).

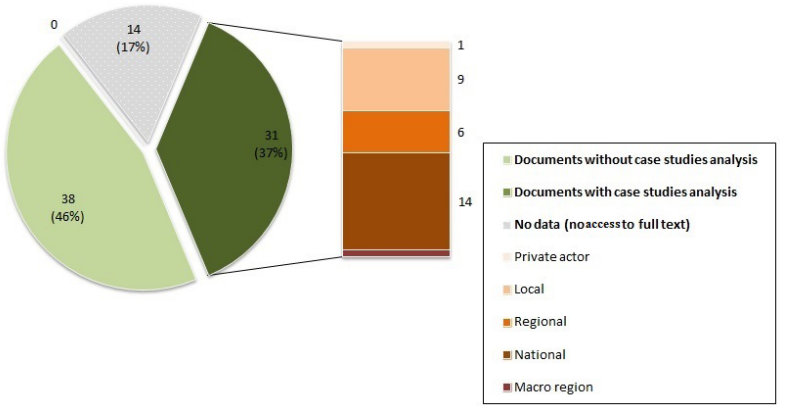

Fig. 3. Documents with a case-study approach and scale of the analysis.

With regard to the methodology used, all studies applied a Multi-Criteria Analysis (MCA). Such results confirm, in line with other studies (Omann 2004), that sustainability is more and more intended as a multi-dimensional issue and that MCA can give good results, when sustainable development is concerned and social context of the process is considered.

Selection of indicators

As discussed above, 308 indicators and sub-indicators have been selected, which evidenced that social and political impacts turned out to be the most investigated ones, while the cultural aspects seem to have been significantly less developed by existing literature. It would thus be interesting to conduct further research on them, also because public policies aiming at promoting environmental awareness and a more sustainable consumer behaviour among citizens are crucial in order to integrate renewable energies into local systems.

Without claiming to be complete, having a list including such a large number of indicators could be useful for practitioners or researchers interested in the field, for example in order to create a synthetic index to be used for the assessment of the social sustainability of renewable energies projects.

According to the quality criteria described, 28 of the 308 indicators were selected in order to reach a comprehensive assessment of the impacts of RE development at the local or regional scale. The indicators were allocated to six overarching criteria as illustrated in Tables 2, 3 and 4. This set of indicators allow a balanced analysis of the three impact dimensions.

Table 2. Criteria and indicators used to quantify the economic impacts of renewable energy development.

Criteria	Indicators	Unit of measure
Changes in local economy	Local system flexibility to market changes	Sensitivity to fuel price fluctuations
	Effects on business opportunities and productive diversification of the area	Number of new jobs/year
	Regional/local value added	Euro/year and MWh exergy
	Heat price package (total cost of heat for the village)	Euro/year and MWh exergy
Efficiency and reliability of the energy system	Continuity of energy service	Interruption of the energy supply
	Independence from non-renewable energy sources	MWh/year and MWh exergy
	Resources efficiency	Percentage of consumption
	System efficiency	Percentage of energy losses
	Costs efficiency	€/MW
	Reliability of the system	Ordinal Scale

It is important to remember that the multiplicity of indicators developed in the RE field evidences the importance of a methodological and conceptual work in this area (Voinov 1998). When applying SIA to a specific RE system, the set of indi-

Table 3. Criteria and indicators used to quantify the social-political impacts of renewable energy development.

Criteria	Indicators	Unit of measure
Political stability, participation, human capacity and system legitimacy	Compatibility with the national energy policy objectives	Ordinal scale
	Local people empowerment, stakeholders participation,	Percent of documented responses addressing stakeholders and local people suggestions
	Improvement in energy-related education and research	Ordinal scale
	Social and political acceptance of the system and potential of conflicts	Percent favourable opinion
	Effects on social cohesion	Relative scale (number of households)
Quality of life	Job creation	Number of full time equivalent jobs
	New jobs related benefits for local people and workers	Euros per day
	Traffic contribution	Ordinal scale
	Impacts on the quality of landscape	m^2 of landscape/KWh
	Impacts on people's habitat and quality of life	Percentage of the population that perceives the impact
	Economic benefits for local community	Euros per day
	Noise exposure	Ordinal scale (number or resident feeling affected by noise)

Table 4. Criteria and indicators used to quantify the social-environmental impacts of renewable energy development.

Criteria	Indicators	Unit of measure
Social and social-environmental component of risk	Perceived risks and benefits related to the energy system	Ordinal scale for psychometric variables (personal control, catastrophic potential…)
	Mortality due to accidents	Fatalities/GWh
	Risk prevention and management	Ordinal scale
	Exceptional risk	Maximal number of fatalities
	Trust in risk management agencies	Ordinal scale
	Impacts on atmospheric emissions	Kg/MWh energy

cators must allow the assessment of the relationships between RE system and environment, showing how well the system is working and measuring its impact on various dimensions of sustainability (Afgan et al. 2003).

The selected indicators range from the economic to ecologic and social aspects because, respect to traditional energy systems, renewable energies systems are characterized by less environmental pollution but more local impacts (Polatidis et al. 2006).

The objective of the authors was to select a set of indicators that are feasible to measure. In fact, while efforts have been made to build consensus about the necessity of addressing renewable energies production impact on sustainability, practical and measurable indicators that cover social, economical and cultural aspects of sustainability are still scarcely developed. Moreover, many proposed indicators lack precision in definitions and protocols for measurement.

Conclusions

Shifting from traditional energy systems to RE systems is one of the most important challenge in the context of sustainable development policies aiming at facing climate change. At the same time, RE promotes sustainable energy production, a more developed environmental awareness and more sustainable consumer behaviour. RE development is one of the fundamental objectives of our society in order to satisfy the increasing demand for new energy resources.

If renewable energies are considered to be an effective way to reduce negative environmental impacts, their sustainability needs to be assessed not only from an environmental or technical point of view, but also regarding the socio-economic aspects.

Newer tools such as the EU Sustainability Impact Assessment (SIA) represent an area where guideline set-up is still in early developmental stages and results of the present research showed that further research on the link between SIA and RE systems is desirable as it turned out to be the less investigated dimension of sustainability.

After completing the review, we can confirm that there is a great variety of valuable socio-economic indicators for RE systems management. In this respect, tree groups of indicators were presented in this research, which reflect the econom-

ic, social-political and social-environmental criteria.

It is necessary to remind that when adopting and implementing a set of indicators, an in depth evaluation of the feasibility of the indicators to the specific context is needed. Frequently managers of renewable energies systems have a limited social science background, and they need to improve their skills and expertise in the sector to objectively ponder their choices. Otherwise, the database structured with the present work can be useful to various stakeholders including policy-makers, planners, managers and other actors of the renewable energies sector. Moreover, it seems a valid starting point for the developing of sustainable strategies in the field of renewable energies.

The literature review highlighted that SIA covers fields within social sciences, economy, engineering, human health and other disciplines. As a major conclusion, interdisciplinarity is seen as a tendency in sustainability issues and an interdisciplinary approach is required when approaching to developing synthetic and composite indexes, to be used for the assessment of the social sustainability of renewable energies projects.

The present contribution hopes to provide a first and limited step also for future researches aimed at assessing the impacts of energy systems via multidimensional indicators.

Acknowledgments

This study was conducted in the frame of the recharge.green project “Balancing Alpine Energy and Nature” (http://www.recharge-green.eu), which is carried out within the Alpine Space Programme, and is co-financed by the European Regional Development Fund. The recharge.green project is focused on the analysis of how to reconcile biodiversity conservation of ecosystems and production. The research was realized in the ambit of an agreement between AgroParisTech-centre Massy and Agrobiology and Pedology Research Centre of Council for Agricultural Research and Economics (CRA-ABP) for a stage niveau Master 1 Master STVE Mention “Espaces Ressources Milieux”.

References

Afgan N.H., Carvalho M.G., Hovanov N.V. 2003. Sustainability assessment of renewable energy systems. In: New and Renewable Technologies for Sustainable Development, Springer US: 11–33.

Bassi A.M., Powers R., Schoenberg W. 2010. An integrated approach to energy prospects for North America and the rest of the world. Energy Economics 32(1): 30–42.

Arbter K. 2003. SEA and SIA – two participative assessment tools for sustainability. In: EASY-ECO 2 Conference, Vienna: 15–17.

Böhringer C., Löschel A. 2006. Promoting renewable energy in Europe: A hybrid computable general equilibrium approach. The Energy Journal special issue 2: 135–150.

Bronfman N.C., Jiménez R.B., Arévalo P.C., Cifuentes L.A. 2012. Understanding social acceptance of electricity generation sources. Energy policy 46: 246–252.

Demirbas A. 2009. Political, economic and environmental impacts of biofuels: A review. Applied Energy 86: 108–117.

El Fadel M., Rachid G., El-Samra, R., Boutros G.B., Hashisho J. 2013. Knowledge management mapping and gap analysis in renewable energy: Towards a sustainable framework in developing countries. Renewable and sustainable energy reviews 20: 576–584.

European Commission 2002. Communication from the Commission on Impact Assessment. COM (2002) 276 final.

European Commission 2009. Impact Assessment Guidelines. SEC (2009) 92. 50 p.

Gallego Carrera D., Mack A. 2010. Sustainability assessment of energy technologies via social indicators: result of a survey among European energy experts. Energy Policy 38: 1030–1039.

Krajačić G., Duić N., da Graça Carvalho M. 2011. How to achieve a 100 % RES electricity supply for Portugal? Applied Energy 88: 508–517.

Ladanai S., Vinterbäck J. 2009. Global potential of sustainable biomass for energy. Report 013 Swedish University of Agricultural Sciences, Department of Energy and Technology, Uppsala. 29 p.

Mascarenhas A., Coelho P., Subtil E., Ramos T.B. 2010. The role of common local indicators in regional sustainability assessment. Ecological Indicators 10: 646-656.

Mathiesen B., Lund H., Karlsson K. 2011. 100 % renewable energy systems, climate mitigation and economic growth. Applied Energy 88: 488–501.

Meadows D. 1998. Indicators and Information systems for sustainable development. A report to the Balaton Group. The Sustainability Institute. P.O. Box 174 Hartland, Four Corners, USA. 78 p.

Mohammadi S., de Vries B., Schaefer W. 2013. A Comprehensive Review of Existing Urban Energy Models in the Built Environment. In: Planning Support Systems for Sustainable Urban Development. Springer Berlin Heidelberg: 249–265.

Ness B., Urbel-Piirsalu E., Anderberg S., Olsson L. 2005. Categorising tools for sustainability assessment. Ecological Economics 60: 498–508.

Nishizono T., Iehara T., Kuboyama H., Fukuda M. 2005. A forest biomass yield table based on an empirical model. Journal of Forest Research 10: 211–220.

Omann I. 2004. Multi-criteria decision aid as an approach for sustainable development analysis and implementation. PhD thesis. University of Graz (Austria). 272 p.

Pistorius T., Schaich H., Winkel G., Plieninger T., Bieling C., Konold W., Volz K.R. 2012. Lessons for REDDplus: A comparative analysis of the German discourse on forest functions and the global ecosystem services debate. Forest Policy and Economics 18: 4–12.

Polatidis H., Haralambopoulos D. A., Munda G., Vreeker R. 2006. Selecting an appropriate multi-criteria decision analysis technique for renewable energy planning. Energy Sources 1(2): 181–193.

Reiche D., Bechberger M. 2004. Policy differences in the promotion of renewable energies in the EU member states. Energy Policy 32: 843–849.

Robèrt K.H., Schmidt-Blee B., Aloisi de Larderel J., Basile G., Jansen J.L., Kuehr R., P. Price T., Suzukig M., Hawkenj P., Wackernagel M. 2002. Strategic sustainable development - selection, design and synergies of applied tools. Journal of Cleaner production 10: 197–214.

Rotty R.M. 1979. Energy demand and global climate change. Elsevier Scientific Publishing Co., Amsterdam: 269–283.

Sadler B. 1999. Framework for environmental sustainability assessment and assurance. In: Petts J. (Ed.). Handbook of Environmental Impact Assessment: Process, Methods and Potential. Blackwell Science, Oxford: 12–32.

Twidell J., Weir T. 2003. Renewable Energy Resources. 2nd edition. Taylor & Francis, London (2006). 624 p.

Voinov A.A. 1998. Paradoxes of sustainability. Journal of General Biology 59: 209–218

Wilkens I., Schmuck P. 2012. Transdisciplinary Evaluation of Energy Scenarios for a German Village Using Multi-Criteria Decision Analysis. Sustainability 4: 604–629.

Wilkinson D., Fergusson M., Bowyer C., Brown J., Ladefoged A., Monkhouse C. Zdanowicz A. 2004. Sustainable Development in the European Commission's Integrated Impact Assessments for 2003. Institute for European Environmental Policy, London. 47 p.