“Strategic approaches toward a low carbon economy”

AUTHORS	Fortune Ganda Collins C. Ngwakwe http://orcid.org/0000-0002-6954-8897

ARTICLE INFO	Fortune Ganda and Collins C. Ngwakwe (2013). Strategic approaches toward a low carbon economy. *Environmental Economics*, *4*(4)
RELEASED ON	Thursday, 12 December 2013
JOURNAL	"Environmental Economics"
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

Environmental Economics, Volume 4, Issue 4, 2013

Fortune Ganda (South Africa), Collins C. Ngwakwe (South Africa)

Strategic approaches toward a low carbon economy

Abstract

This paper presents some strategic approaches toward a low-carbon economy. This has become important to improve the awareness of countries, industries and communities towards identifying important practices that may lead to a green economy. The paper adopts a conceptual approach and identifies some approaches towards a low-carbon economy; these include renewable energy, green supply chains as well as effective regulations. The paper suggests that more concentration on these techniques will assist in developing sustainable economies with low carbon. Moreover, it identifies and examines present choices, along with courses of action that are fundamental in generating green societies.

Keywords: low-carbon economy, renewable energy, green supply chain, energy regulation, green policy.
JEL Classification: M14, P28, Q56.

Introduction

As a result of fast, worldwide growth in industrial and economic systems, energy use and carbon emission were growing quickly thereby propelling climate change. It became vital for global nations who aim for sustainable economic emancipation to establish a low-carbon economy that realizes the change towards economic growth. Many academic fronts have idealized a low-carbon economy as an advancement approach characterized by energy efficiency, minimized pollution, less carbon emission as well as high energy performance. Beinhocker and Oppenheim (2013) view a low-carbon economy as a changing economic growth practice from excessive carbon energy to reduced carbon energy levels. Thus, the core implication of low-carbon economy dwells in optimal consumption of energy, effective utilization of energy resources together with efforts to develop green Gross Domestic Product (GDP). Its essence is dependent upon innovation of energy efficient technologies, innovation of industrial systems and organizations as well as central transition plans of human existence and development, in handling a string of environmental matters which arise due to global warming by developing better energy frameworks and minimizing emissions. According to Pappas et al. (2012), transforming climate scenarios marked with extended carbon emissions, along with high pollution result from destructive human activities which employ fossil fuels. Some experts have also identified poor business management practices as a major driver to high greenhouse gas emission. Indeed, Goosen (2012) demonstrates that poor environments have been generated by enterprise operative practices through overutilization of energy resources, blameworthy waste-management activities and increased pollution scales which increase climate change. And also, Omer (2008) informs that buildings consume 40% of global energy. Therefore, there is need to improve establishment, maintenance and use of electrical equipment in human made building facilities so that zero carbon standards are realized. Lastly, Munasinghe (2010) reports that global warming which is caused by climate change through high carbon emission has generated extension of deserts, droughts causing food shortages, undesirable agricultural activities as well as increased loss of natural ecosystems.

Consequently, the questions that warrant this study are: why do we need a low-carbon economy? And, what strategic approaches may lead to a low-carbon economy? Therefore, this paper aims to present thoughts on the need for a low carbon economy, and to present some strategic approaches to a low-carbon economy. The structure of the paper is organized as follows. The next section discusses the need for a low-carbon economy. It is followed by an examination on renewable energy, green supply chains and regulation as relevant emerging approaches towards a low-carbon economy. Finally, a conclusion is presented.

1. Need for a low-carbon economy

A low-carbon economy presents essential paths towards sustainable economic advancement systems that foster energy efficiency, emancipation of circular economic systems, setting up of harmonious communities together with propelling construction of scientific growth issues on associations that involve social, environmental and political fronts (Tongzhou, 2011). Tan and Liu (2012) further explain that low-carbon economies are recognisable by doing away with luxuriant fossil or non-fossil resource use, increased support to organisational policies aimed on carbon offset standards, developing energy saving methods and technology as well as establishing facilities and services with zero carbon agendas. Referring to studies carried out in Inner Mongolia, situated in China, Yang et al. (2012) hint that adoption of renewable sources of energy, developing clean fuel manufacturing systems, establishing carbon sink frameworks such as afforestation and reforestation, as well as increasing awareness on benefits associated with low-carbon environments, are fundamental ways to achieving low-carbon economies. On that note, Nakata et al. (2011) add that increasing carbon emissions have put pressure on governments and associated partners to address climate change issues. In line with this idea, Yongping (2011) argues that green economies are unavoidable outcomes of capitalist systems and are economic growth frameworks, which all stakeholders must accept by minimizing carbon emission through strict enforced statutes, instituting carbon tax, supporting clean manufacturing systems, championing technological advancements along with decreased consumption of carbon emitting resources.

Concerning the agricultural sector, Hui et al. (2012) mention that green agricultural practices help in creating low-carbon economies through energy efficiency, reduced chemical usage, less pollution as well as minimized greenhouse gas emission which results in favorable geographical settings, increased environmental bio-diversity, as well as rich agricultural resources. Thus, sustainable agricultural activities also result in improved health status of people, animal and plant life. Accordingly, Haines (2012) postulates that minimizing greenhouse gas emission in fuel consumption, animal breeding plus upkeep in energy frameworks, results in a low-carbon society that is capable of guaranteeing public health advantages, which include decreased deaths from Ischaemic heart disease, Cerebrovascular disease, Dementia, Breast Cancer and vehicle accidents.

All in all, Wei et al. (2011) testify that establishing green economies demand ecological civilization, achievable by putting together orderly environmental recovery and maintenance plans that are empowered with implementable objectives and efficient use of media to communicate zero carbon issues to all stakeholders. On that account, the media must work hand in hand with environmental management divisions so that broader transmission of information is supported in joint gatherings. It must also use different channels to disseminate the important, major demands, basic issues, along with implementation procedures regarding environmental protection. Moreover, the media should transmit current information with respect to ecological civilization on time between concerned partners and hence become a means and stand by which information obtained through various opinions can be expressed. Promoting academic and scientific research on carbon off-sets matters; and erecting government divisions that specialize on these matters, along with championing green finance, in addition to green products, are also critical.

1.1. Emerging strategic approaches for a low-carbon economy. Basic practices that are fundamental to creating low-carbon societies have been identified as renewable energy consumption, erecting green supply chains as well as extensive regulation of energy resources.

2. Renewable energy

These are special resources of energy that, when consumed, are capable of regenerating as well as recycle through natural processes. Thus, the use of these non-exhaustible energy sources has been linked to harmonizing the environment. Essentially, Bergmann et al. (2004) state that renewable energy use results in the following: employment creation; protects and assures expansion of natural environments; reduces carbon emissions; and solves future energy requirements. Below, is a brief discussion on various types of renewable sources of energy.

2.1. Biofuels and biomass (bioenergy). Biofuels are resources such as ethanol, along with biodiesel, which are produced from biomass and are both used as transport fuel. Biomass consists of organic matter from plants and animal waste and these include manure, garbage, wood and crop residue. Evidence reports that bioenergy potential in minimizing carbon emissions total 1220 metric tonnes of carbon dioxide by 2030 (IPCC, 2011). Thus, this resource is renewable and does not emit a lot of greenhouse gas. Consequently, owing to major challenges such as minimized energy security together with high carbon emissions, the US government through its Renewable Fuel Standard (RFS) policy has planned 35 billion gallons of Biofuel and 1 billion of biomass produced diesel to be used by 2022 in the country (NAS, 2011). In addition, the EU has mandated that, for sustainability purposes, 20% of energy should be produced from biogas, bioliquids, as well as biomass; and in each country, 10% of motor car fuel should be obtainable from biofuels and biomass by 2020 (Ernsting, 2009). Specific hindrances in bioenergy adoption have also been identified. For example, biomass cook-stove employment include expanded scientific investigation concerning their applicability with respect to user's needs still outstanding, plus lack of proper certification structures, whilst biogas systems experience high financing costs, absence of suitable technical yardsticks and poor performance pertaining to designs, along with construction (IPCC, 2011). Withal, complex import tariff systems; presence of technical benchmarks that aim to analyze both physical and chemical components of fuels being instituted in many countries; unavailability of appropriate containers that enable transportation of fuel over large distances; and strict sustainability criteria standards for the resource (Junginger et al., 2010), are significant biofuel adoption barriers.

2.2. Geothermal. *Geo* refers to 'earth' whilst *thermal* refers to 'heat', hence geothermal energy plants utiliaze hydro resources that are connected to geothermal reservoirs deep in the earth's crust which then drive turbines that generate clean electricity (RES, 2013). Thus, it is renewable in the sense that heat always moves beneath the earth's crust and so will repeat these cycles over many years in the future, thus assuring beneficiaries of unlimited supply of heat. To boot, vast amount of geothermal energy that can be utilized within the earth's deepest levels estimate up to 12.6 x 10^{12} Ej (Exajoule), whiles 5.4 x 10^{9} Ej is available on and near the earth's crust (Dickson and Fanelli, 2003). Geothermal electricity guarantee assurance to future energy challenges, promote zero combustion hence emit less carbon, is always available and not subject to weather and climate changes and is accessible in many forms which support industries such as tourism, agricultural and power sector (GEA, 2012).

Still, barriers included in geothermal energy usage are the involved distance from geothermal plants to available market which is a matter to consider, large investments required, lack of expertize and awareness on geothermal technologies that prevents its comprehensive adoption, as well as absence of specific legal and regulatory frameworks involving its deployment (Imolauer et al., 2010). Besides, geothermal power generation can result in potentially triggering local earthquake activity, increasing land subsidence, generates high water shortages in dry areas and it affects quality use of natural geysers significant for tourism purposes (IPCC, 2011).

2.3. Solar energy. Solar energy defines power that is generated from sun's radiations which then produce electricity or create energy that heats up water together with air space. Hence, it makes use of photovoltaic (PV) together with concentrating solar power (CSP) in order to generate heat or cooling conditions, to provide lighting demands as well as create fuels that are useable in the transport sector, along with other critical requirements. Solar energy produces no pollution, support preservation of fossil fuels and solar thermal power plants can utilize thermal electricity in stock. Writers, Jordan and Liu (1963), confirm that solar energy is increasingly being popularized by using flat-plate collectors, as well as fast heat absorbing surfaces which assists to provide sufficient generated clean electricity over long periods of time. Solar energy use has expanded from household consumption to solar powered vehicles as a result of advancement in technology. Thus, diversified solar electric motor vehicle forms, range from Hybrid, Full, Plug-in and Vehicle-to-grid cars, and all these models provide solution to energy security and mitigate climate change (Harti, 2009).

Nonetheless, shortage of transmission networks for big schemes situated considerable distances from electric load stations, complicated laws and certifications and lack of benchmarked solar energy measuring frameworks which accounts for all supplied generated power are solar energy identifiable adoption barriers (Denholm et al., 2009). In addition, solar energy technologies are not easy to install, they have high maintenance expense and the consumers are not aware on how to employ such appliances (Sidiras and Koukios, 2004). And also, replacing already built energy networks, high cost of solar energy technologies and inadequate financing involving solar energy projects (Menz, 2005) are potential challenges.

2.4. Ocean energy. Ocean energy utilizes all the energy forms contained in sea water so as to produce electricity that does not emit carbon. The non-exhaustible energy resource within the ocean is derived from ocean waves, tidal flows, salinity gradients, ocean thermal energy conversion (OTEC), tidal range, along with ocean currents and has ability to mitigate carbon emissions by generating 1 943 TWh (Terawatt-hour) of energy annually by 2050 (IPCC, 2011). At present, more than 30 countries have started to adopt ocean energy technology systems (Khan and Bhuyan, 2009). In spite of that, more research and development is of great importance pertaining to this renewable energy as only tidal barrages ocean technology has been comprehensively tested (IPCC, 2011). For instance, current research proves that up to 50 and even more wave energy equipment is still being investigated and analyzed (US DOE, 2010). Moreover, Ocean Thermal Energy Conversion (OTEC) employment can result in release of harmful substances (ammonia and chlorine) and increased thermal impacts which kill marine environments, it is also difficult to build OTEC plants owing to unfriendly oceanic environments and there is high lack of expertise in OTEC systems (Etemadi et al., 2011).

2.5. Hydro power energy. Hydropower is the most commonly used renewable energy globally and is generated using established hydro frameworks and water resources such as dams and lakes. It does not pollute environments, does not produce waste material hence is environmentally compatible (Kling and Self, 2008). It has been selected to be the most fully developed, dependable and economically efficient non-fossil fuel electricity production technology at hand (Brown et al., 2011). The water systems also bury carbon elements within their channel beds and they can also take in more carbon emissions when compared to amounts they give off (Cole et al., 2007). Nonetheless, prevalence of environmental disasters such as floods along with droughts, seasonality changes in river flow, along with differences in precipitation and evaporation affecting volume of the water reservoir also results in low amounts of hydro-electricity that can been generated (IPCC, 2011). In the same line, the world's 45000 biggest dams are not built to compatibly exploit hydropower projects and it also results in resettlement of people away from their original homelands (WCD, 2000). As well, poor environmental water management systems, inadequate hydrological information, unforeseen and unfavourable geological forms, lack of sufficient capital and poor planning of the river basins (IPCC, 2011) are noted hindrances in hydropower advancement.

2.6. Wind energy. Wind energy is a result of solar energy conversion processes and is also clean along with being non-exhaustible. Wind power is created when the wind cause the blades of mounted turbines to rotate which ultimately cause the generator to turn producing electricity (Office of the Ohio, 2010). If wind speed doubles, electricity production from the turbine increases eight times more (EWEA, 2009). Reliably, 160GW (Gigawatt) of employed wind energy generation systems can capably produce power amounting to 1.2 Ej on a yearly basis, which then propel reduction in carbon emissions that is estimated to be 0.2Gt (Gigaton) annually (GWEC, 2010). Nevertheless, wind energy generation usually rely on plant efficiency, nature of landscape, least possible quantity of wind that can be utilized and advancement of the energy density involving the wind (Hoogwijk et al., 2004). And also, wind energy performance is dependent upon prevalent weather conditions at particular time scales (Apt, 2007). Hence electricity generation will be disrupted at particular times; something which has economic costs, especially for production industries. Moreover, wind turbines produce electromagnetic field (Krug and Lenke, 2009) which affects aviation, communication and shipping industries, and also generates noise to local communities (WHO, 2009). Evidence also suggests that widened employment involving wind energy require better and up to date systems which enhances planners to develop electric equipment that can optimize wind energy deployment (NERC, 2009). Plus, it also require large financial investment with initial establishment expenses varying from 75% to 80% of total costs whilst operating and maintenance costs add to the remaining total (EWEA, 2009). An additional low carbon energy producing source that is not considered renewable includes nuclear power.

2.7. Nuclear power. Nuclear power applies continuously supplied nuclear fission of uranium in order to produce heat together with electricity. Thus, nuclear energy benefits include generation of heat, along with electricity without being accompanied by emission of carbon (NEA, 2012). Its utilization has the potential to grow more than oil and gas since the uranium resource reserves are abundant and they are also found in almost every part of the world (NEA, 2008). At present, 60 nations have consulted the International Atomic Energy Agency (IAEA) on ways and processes that enhance them to fully integrate nuclear power projects within their economic and industrial sectors (WEC, 2010). However, hindrances connected with full exploitation of nuclear power in generating a low-carbon economy include long-run uranium resource shortages; inadequate and insufficient present technological nuclear advancements; problems in establishing nuclear electricity plants globally; as well as its inability to supply direct replacement for non-renewable fuels (Golay, 1995). In the same vein, nuclear power research and development has been very slow, involved with high degree of secrecy, plus its sustainability rests on minimizing its inventory costs, as well as designing facilities that effectively manage its radioactive waste (Abu-Khader, 2009). Noticeably, nuclear power plants are very expensive to construct and maintain, as its establishments costs are estimated USD 4000 per kilowatt of electrical energy (Harding, 2007).

3. Green supply chain

Green supply chains involves diversified, supervised and monitored green practice of related business enterprises that are associated with providing essential commodities to the final consumer. Thus, owing to climate change and the rise in greenhouse gases, green supply chain frameworks increase organizations' strategic competitiveness if enterprises form mutual relationships that allow information sharing and exchange on low-carbon capacity advancement; recycle products and systems; build and upgrade low-carbon value chain assessment frameworks; as well as integrate low-carbon firm culture (Hongjuan and Jing, 2011). In line with this idea, Park et al. (2010) illustrate that favorable balances (i.e., good reputation, joint co-operative green business ventures) are developed when economic development, together with environmental accountability of enterprises, establish value within the supply chain by introducing green management practices. Consequently, crucial information and steps required of organisations to improve their supply chains so that they embrace green policies have been raised.

For that reason, Plambeck (2012) interprets that monitoring and control of firms' operations assist in lessening climate change in its supply chains through taking up renewable sources of energy, increased support of zero-carbon commodities, integrating expense of carbon emissions in supply chains and achieving energy efficiency. For instance, Gopalakrishnan et al. (2012) state that British Aerospace (BAe) supply chains can be made sustainable by selecting suppliers who adhere to environmental yardsticks; conducting carbon emission tests in acquiring raw materials; instituting carbon footprint management models; promoting government laws that address carbon and environmental issues; as well as increasing employee engagement in green practices. In addition, Koh et al. (2011) witness that in Taiwan IT enterprises, the deployment of Waste Electrical and Electronic Equipment (WEEE) plus the Restriction of the use of certain Hazardous Substances (RoHS) systems result in creation of green supply chains as they avoid using dangerous materials in product designs, support replacement of old harmful equipment components, champion quality assurance standards, achieve carbon offset yardsticks, advocates for optimal use of resources as well as support product recycling. Moreover, retail outlets have also gone through increasing demand from environmentalists, fighting for the introduction of low carbon compatible frameworks in their supply chains.

On that account, Styles et al. (2012) validate that retailers have experienced rising global pressures that seek incorporation of environmental matters in their supply chains. therefore, associated processes involve, erecting better supply chain activities, procurement procedures should be green certified, innovation should create better environmental benchmarks and eco products should get first preference in marketing matters (Styles et al., 2012). Adding value to this assertion, examinations done in the UK supermarkets proves that accounting carbon on food products is being done voluntarily and so empower suppliers to select products they want to record carbon footprint which eventually deceive customers, hence food policies that specifically address carbon labelling matters must be enforced as this improves consumer awareness and force supply chains to maintain zero carbon standards (Gadema and Oglethorpe, 2011).

And also, studies conducted in UK indicates public view dissatisfaction over carbon labelling of products as printed carbon emission values on their products cannot do much in raising customer awareness as they only seek customer response and acceptance (Upham et al., 2011). Evidently, Cohen and Vandenbergh (2012) also document that increased leakage is encountered as only home country customers benefit from minimized product carbon footprint whiles worldwide carbon scenarios maybe affected as a result of false documented product carbon labelling. And also, rebound effects by customer choice in green product buying, lessen their environmentally friendly attitude involving other aspects concerning their lives. Thus, retailers stimulate environmental betterment of supply chains by deploying supplier advancement schemes, imposing environmental standards expected from suppliers as well as practising product traceability and product certification (Schoenberger et al., 2012) which minimizes fake product labelling. Despite the fact that managing supply chains results in green economies, considerable linked hindrances have been identified.

Briefly, Liu (2012) conveys that the major barriers firms encounter in authorizing carbon management include, short-term managerial contracts whiles carbon matters are long term, lack of inducements which motivate carbon offset priorities, along with bureaucratic organization structures that hinder flexibility plus innovativeness. Furthermore, there is high shortage of low-carbon equipment as well as notable uncertainty pertaining to carbon markets. In a nutshell, results obtained from Chinese production firms that are using Energy Saving and Emission Reduction (ESER) system in its supply chain evidenced the main barriers as absence of short-term rewards, large costs involved in refuse handling and making ESER commodities, insufficient information on energy trends, top managers reluctant behavior and shortage of workforce who understand environmental matters (Zhu and Geng, 2013).

4. Regulation

Carbon accounting has seen development of related but different energy supervision activities in economic, scientific and political fronts. At organizational capacity, the tool assists firms to make better energy choices, manage energy flow trends, stimulate improvement in eco-efficiency and initiate commodity innovation, in the pursuit to mitigate climate change (Schaltegger and Csutora, 2012). Hughes (2013) also contributes that low-carbon environments are realized when efficient systems focusing on evaluating energy patterns, judging relationships constructed by different actors in the energy network and assessments on how existing energy frameworks can overall inform long-term energy policy making, are established. For these reasons, below are brief descriptions on various types of energy regulation practices that create low-carbon societies.

4.1. Green buildings. Green buildings are sustainable structures that are environmentally compatible (i.e., reduce pollution, carbon emission, waste and improve occupant health) and use less resources (e.g., energy, water) in their entire life cycle. Surely, studies conducted in the UK highlight that the country aims for carbon emission reduction realization of 80% by 2050, and 30% component of that share is emanating from households. Therefore, the country has assumed low-carbon housing refurbishment (LCHR) projects that will empower architects to design and build carbon regulated housing (Davies and Osmani, 2011). And also, Personal Carbon Trading (PCT) in the UK has also been linked with households. Fawcett (2010) confirms that Personal Carbon Trading (PCT) was considered by the British government as a capable carbon emission reduction proposition that makes sure that adults are offered carbon allowance that consider emissions within their residential properties and when they undertake individual travelling, though it was predicted to go down with time depending on national energy policy restructuring processes. Moreover, UK industries have also assumed energy regulation schemes through introducing competent domestic equipment, incorporating statute laws that consider building project qualification, as well as improved energy regulation frameworks on established plants (Clarke et al., 2008).

4.2. Smart grids. Owing to high global energy deficiencies, climate change, as well as high pollution, smart-grid appliances have been supported to generate clean energy (Peng and Yan, 2011). As such, they are electricity systems that intelligently incorporate all activities that generators and users exercise whiles linked to such a framework by fostering long-term, safe and efficient power delivery (ETPSG, 2010). Giving high importance to Smart Grids, Verbong et al. (2013) disclose that investigations undertaken in Netherlands witnesses that the introduction of smart grids improve electrical energy facilities since computerized technology creates better physical plus economic electricity structures, considerably reduce carbon and provide economic benefits to all partners. Fundamentally, smart grids make use of current Information and Communication technology (ICT) to enhance supply of energy from non-exhaustible sources of energy; builds smart-energy assessment models; meets and regulates customer energy needs, as well as foster efficient power transmission (Young, 1964). Smart grid acceptance has also been connected with particular limitations.

In light of this view, smart grids have been deployed from their characteristic features as essential models that replace the old designs (uni-directional energy transmission arrangement) to new (bi-directional) frameworks, but they are inadequate in the sense that intelligent supervision and monitoring of all energy sources, along with their energy vectors is significant, hence intelligent energy networks (IEN) should be supported (Orecchini and Santiangeli, 2011). Necessarily, user products that include washing machines, stoves, televisions and refrigerators, must be developed in a way that enables them to manage market signals coming from the Advanced Metering Infrastructure (AMI) system, which negatively results in far-flung distribution of data as well as personal equipment, thereby causing identifiable legal, confidentiality and safety risks that may require particular attention (Pernick and Wilder, 2007). Furthermore, the old energy framework designs will present significant challenges on whether the systems will be capable enough to manage smart-grid appliances and the established network facility (Abel, 2007). Additionally, one limiting aspect that involves energy smart-grid adoption is perception since only a few number of persons and organisations participate in the energy smart-grid understanding (Brass, 2010) hence extended public policies should be integrated.

4.3. Carbon capture and storage. Necessarily, Markusson et al. (2012) mention that Carbon Capture and Storage (CCS) has been identified as a major technological framework that lessens climate change since it is capable of removing carbon in burning energy sources, manufacturing systems and electricity production, then stock this carbon in the earth's crust, which keeps it from reaching the earth's surface. In Europe, CCS practices with regard to the provision of electricity, as well as in firms that utilize large amounts of energy, could enhance attainment of zero carbon targets (Scott, 2013). With regard to Canada, CCS activities have been highly associated with being deployed in trades that include coal-fired electricity projects; natural gas treatment industries; iron and steel production firms; and chemical manufacturing enterprises (Mitrović and Malone, 2011).

Hence, coal-fired electricity generation which utilize Carbon Capture and Storage (CCS) technology potentially generates low-carbon emissions. However, coal-fired projects that use CCS technology were identified to be propelling health risks, especially from ground water; increase environmental dangers through extraction of coal, there are no formally established laws on CCS liability and control; and it requires to be analyzed on whether it should be incorporated as a suitable approach at utility level (Lilliestam et al., 2012). Research conducted on Spain's publics regarding CCS practice indicates various associated risks and benefits. The benefits include minimized carbon emission, lower pollution realized and the carbon dioxide can be reutilized for other purposes. The risks are carbon dioxide leakage, explosions can take place in storage systems, marine environments can be destroyed, increased investment expenses and there is limited capacity for carbon storage (Oltra et al., 2010). And also, CCS challenges include reducing running costs, establishing suitable infrastructure, minimizing subsurface unreliability, as well as dealing with law and monitoring matters (Herzog, 2011).

Conclusion

The paper has outlined the necessity and benefits associated with creating a low carbon economy. Thus, low-carbon societies boost energy efficiency, support sustainable growth of economic systems, build cordial global societies and champion scientific development on interactions that involve diverse aspects of life. Using current written work, fundamental practices that develop low-carbon economies were determined and explored. These approaches included renewable energy adoption, establishing green supply chains and energy regulation exercises. Primarily, renewable energy sources evaluated are solar, geothermal, ocean, wind, biofuels and biomass, hydro-power sources and an additional low-carbon energy producing source, which is nuclear energy. Their strengths include reduced carbon emission, are non-exhaustible, support less pollution and are environmentally compatible, though most are capital intensive. Green supply chains result in minimized carbon emission, incorporated zero-carbon culture in firms, improved organisations strategic competitiveness and allow enterprises to interact on issues involving low-carbon capacity growth. Lastly, energy regulation was examined under green buildings, smart grids, along with carbon capture and storage. Hence, they critically reduce carbon emission; propel energy efficient technological innovativeness; and realize energy efficiency by removing energy gaps and malfunctioning appliances in the energy structure.

References

1. Abel, A. (2007). Smart grid provisions in H.R. 6, 110th Congress (Order Code RL34288). Washington, DC: Congressional Research Office. http://www.fas.org/sgp/crs/misc/ RL34288.pdf. Accessed 15 March 2013.
2. Abu-Khader, M.M. (2009). Recent advances in nuclear power: A review, *Progress in Nuclear Energy*, 51(2), pp. 225-235.
3. Altenburg, T. (2011). Interest groups, power relations, and the configuration of value chains: The case of biodiesel in India, *Food Policy*, 36 (6), pp. 742-748.
4. Andrew, J., Kaidonis, M.A. & Andrew, B. (2010). Carbon tax: Challenging neoliberal solutions to climate change, *Critical Perspectives on Accounting*, 21 (7), pp. 611-618.
5. Apak, S., Atay, E. & Tuncer, G. (2012). Renewable hydrogen energy regulations, codes and standards: Challenges faced by an EU candidate country, *International Journal of Hydrogen Energy*, 37 (7), pp. 5481-5497.
6. Apt, J. (2007). The spectrum of power from wind turbines, *Journal of Power Sources*, 169, pp. 369-374.
7. Beinhocker, E. & Oppenheim, J. (2013). Economic opportunities in a low-carbon world. Available at http://unfccc.int/press/news_room/newsletter/guest_column/items/4608.php, Accessed 14 March 2013.
8. Bergmann, A., Hanley, N. & Wright, R. (2006). Valuing the attributes of renewable energy investments, *Energy Policy*, 34 (9), pp. 1004-1014.
9. Binbin, W. & Yifang, S. (2011). Evaluation System and Empirical Research on the Development of Low Carbon Economy-Taking Daqing as an Example, *Energy Procedia*, 5, pp. 435-439.
10. Brass, K. (2010). GE: The Greatest Barrier to the Smart Grid Is Perception. Available at http://gigaom.com/2010/04/09/ge-the-greatest-barrier-to-the-smart-grid-is-perception/. Accessed 14 March 2013.
11. Brown, A., Müller, S. & Dobrotková, Z. (2011). Renewable energy markets and prospects by Region, International Energy Agency (IEA)/OECD, Paris. Available at http://www.iea.org/publications/freepublications/publication/Renew_Regions.pdf, Accessed 25 December 2012.
12. Budzianowski, W.M. (2012). Negative carbon intensity of renewable energy technologies involving biomass or carbon dioxide as inputs, *Renewable and Sustainable Energy Reviews*, 16 (9), pp. 6507-6521.
13. Chiu, C. & Chang, T. (2009). What proportion of renewable energy supplies is needed to initially mitigate CO2 emissions in OECD member countries? *Renewable and Sustainable Energy Reviews*, 13, pp. 1669-1674.
14. Clarke, J.A., Johnstone, C.M., Kelly, N.J., Strachan, P.A. & Tuohy, P. (2008). The role of built environment energy efficiency in a sustainable UK energy economy, *Energy Policy*, 36, pp. 4605-4609.
15. Cohen, M.A. & Vandenbergh, M.P. (2012). The potential role of carbon labelling in a green economy, *Energy Economics*, 34 (1), pp. S53-S63.
16. Cole, J.J., Prairie, Y.T., Caraco N.F., McDowell, W.H., Tranvik L.J., Striegl R.R., Duarte C.M., Kortelainen, P., Downing, J.A., Middleburg, J. & Melack, J.M. (2007). Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget, *Ecosystems*, 10, pp. 171-184.
17. Davies, P. & Osmani, M. (2011). Low carbon housing refurbishment challenges and incentives: Architects' perspectives, *Building and Environment*, 46 (8), pp. 1691-1698.
18. Denholm, P., Drury, E., Margolis, R. & Mehos, M. (2009). *Solar Energy: The Largest Energy Resource, Generating Electricity in a Carbon Constrained World*, Elsevier, Paris, France.
19. Dickson, M.H. & Fanelli, M. (2003). *Geothermal energy: Utilization and technology*, Renewable Energy Series, United Nations Educational, Scientific and Cultural Organization, Paris, France, 205 p.
20. Ernsting, A. (2009). Biomass and Biofuels in the Renewable Energy Directive. Available at http://www.biofuelwatch.org.uk/docs/RenewableEnergyDirective.pdf, Accessed 03 December 2012.

21. Etemadi, A., Emdadi, A., AsefAfshar, O. & Emami, Y. (2011). Electricity Generation by the Ocean Thermal Energy, *Energy Procedia*, 12, pp. 936-943.
22. ETPSG (2010). Strategic Deployment Document for Europe's Electricity Networks of the future. Draft for 3rd General Assembly. European Technology Platform Smart Grids (ETPSG). Available at http://www.smartgrids.eu/documents/SmartGrids_SDD_FINAL_ APRIL2010.pdf Accessed 23 November 2012.
23. EWEA (2009). *Wind Energy, the Facts*. European Wind Energy Association (EWEA), pp. 488, Brussels, Belgium.
24. Fawcett, T. (2010). Personal carbon trading: A policy ahead of its time? *Energy Policy*, 38 (11), pp. 6868-6876.
25. Gadema, Z. & Oglethorpe, D. (2011). The use and usefulness of carbon labelling food: A policy perspective from a survey of UK supermarket shoppers, *Food Policy*, 36 (6), pp. 815-822.
26. Garnett, T. (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy*, 36 (1), pp. S23-S32.
27. GEA (2012). Why support Geothermal Energy? Geothermal Energy Association(GEA). Available at geo-energy.org/pdf/FINALforWEB_WhySupportGeothermal.pdf, Accessed 03 November 2012.
28. Gomi, K., Shimada, K. & Matsuoka, Y. (2010). A low-carbon scenario creation method for a local-scale economy and its application in Kyoto city, *Energy Policy*, 38 (9), pp. 4783-4796.
29. Golay, M.W. (1995). Barriers to using nuclear power for mitigation of global warming, *Progress in Nuclear Energy*, 29 (Supplement), pp. 19-22.
30. Goosen, M.F.A. (2012). Environmental management and sustainable development, *Procedia Engineering*, 33, pp. 6-13.
31. Gopalakrishnan, K., Yusuf, Y.Y., Musa, A. & Ambursa, H.M. (2012). Sustainable Supply Chain management: A case study of British Aerospace (BAe) Systems. *Int. J. Production Economics*, 140 (1), pp. 193-203.
32. GWEC (2010). *Global wind power boom continues despite economic woes*, Global Wind Energy Council (GWEC), Brussels, Belgium.
33. Haines, A. (2012). Health benefits of a low carbon economy, *Public Health*, 126 (Supplement 1), pp. S33-S39.
34. Harding, J. (2007). Economics of nuclear power and proliferation risks in a carbon- constrained world, *The Electricity Journal*, 20 (10), pp. 65-76.
35. Harti, J. (2009). Electric Vehicles and Renewable Energy Potential, State of the world 2009, Climate Connections.Available at http://www.worldwatch.org/files/pdf/SOW09_CC_electric%20cars.pdf, Accessed 13 December 2012.
36. Herzog, H.J. (2011). Scaling up carbon dioxide capture and storage: From megatons to gigatons, *Energy Economics*, 33 (4), pp. 597-604.
37. Hongjuan, Y. & Jing, Z. (2011). The Strategies of Advancing the cooperation Satisfaction among Enterprises Based on Low Carbon Supply Chain Management, *Energy Procedia*, 5, pp. 1225-1229.
38. Hoogwijk, M., de Vries, B. & Turkenburg, W. (2004). Assessment of the global and regional geographical, technical and economic potential of onshore wind energy, *Energy Economics*, 26 (5), pp. 889-919.
39. Hughes, N. (2013). Towards improving the relevance of scenarios for public policy questions: A proposed methodological framework for policy relevant low, *Technol. Forecast. Soc. Change*, 80 (4), pp. 687-698.
40. Hui, Y., Cui-xia, L., Yao, C. & Rao, F. (2012). Developing Potential of Low-carbon Agriculture in Heilongjiang Province, *Journal of Northeast Agricultural University (English Edition)*, 19 (1), pp. 91-96.
41. Imolauer, K., Richter, B. & Berger, A. (2010). Non-technical barriers of geothermal projects. In: *Proceedings World Geothermal Congress*, Bali, Indonesia, 25-30 April 2010. Available at www.geothermal-energy.org/pdf/IGAstandard/ WGC/2010/0314.pdf, Accessed 10 March 2013.
42. IPCC (2011). Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (IPCC). Available at http://www.ipcc.ch/pdf/special-reports/srren/SRREN_Full_Report.pdf, Accessed 10 March 2013.
43. Jordan, R.C. & Liu, B.Y.H. (1963). A rational procedure for predicting long term average performance of Flat plate energy collectors, 7 (2), pp. 53-74.
44. Junginger, M., Faaij, A., van Dam, J., Zarrilli, S., Mohammed, A. & Marchal, D. (2010). Opportunities and Barriers for International Bioenergy Trade and Strategies to Overcome Them. IEA Bioenergy Task 40, pp 17. Available at www. bioenergytrade.org/downloads/t40opportunitiesandbarriersforbioenergytradefi.pdf, Accessed 10 March 2013.
45. Kai, Q. (2011). Research of university science and technology innovation system based on low-carbon economy, *Energy Procedia*, 5, pp. 1032-1036.
46. Karplus, V.J., Paltsev, S., Babiker, M., Reilly, J.M. (2012). Should a vehicle fuel economy standard be combined with an economy-wide greenhouse gas emissions constraint? Implications for energy and climate policy in the United States, *Energy Economics*, 36, pp. 322-333.
47. Khan, J. & Bhuyan, G.M. (2009). Ocean Energy: Global Technology Development Status. Report prepared by Powertech Labs for the IEA-OES, Document T0104, Implementing Agreement for a Co-operative Programme on Ocean Energy Systems (OES-IA), Lisboa, Portugal. Available at: www.iea-oceans.org/_fi ch/6/ANNEX_1_ Doc_T0104.pdf, Accessed 10 March 2013.
48. Kling, E. & Self, D. (2008). Maximum power Alabama 4-H, Renewable energy, www.aces.edu/.../Renewable_ Sources_of_Energy_1.pdf - United States, Accessed 07 December 2012.
49. Koh, S.C.L., Gunasekaran, A. & Tseng, C.S. (2011). Cross-tier ripple and indirect effects of directives WEEE and RoHS on greening a Supply Chain, *Int. J. Production Economics*, 140 (1), pp. 305-317.
50. Krug, F. & Lewke, B. (2009). Electromagnetic interference on large wind turbines, *Energies*, 2 (4), pp. 1118-1129.

51. Lilliestam, J., Bielicki, J.M. & Patt, A.G. (2012). Comparing carbon capture and storage (CCS) with concentrating solar power (CSP): Potentials, costs, risks, and barriers, *Energy Policy*, 47, pp. 447-455.
52. Liu, Y. (2012). An empirical research of awareness, behaviour and barriers to enact carbon management of industrial firms in China, *Science of the Total Environment*, 425, pp. 1-8.
53. Markusson, N., Kern, F., Watson, J., Arapostathis, S., Chalmers, H., Ghaleigh, N., Heptonstall, P., Pearson, P., Rossati, D. & Russell, S. (2012). A socio-technical framework for assessing the viability of carbon capture and storage technology, *Technological Forecasting & Social Change*, 79 (5), pp. 903-918.
54. Menz, F.C. (2005). Green electricity policies in the United States: case study, *Energy Policy*, 33 (18), pp. 2398-2410.
55. Mitrović, M. & Malone, A. (2011). Carbon capture and storage (CCS) demonstration projects in Canada, *Energy Procedia*, 4, pp. 5685-5691.
56. Munasinghe, M. (2010). Selected Papers of Beijing Forum 2008, Addressing the Sustainable Development and Climate Change Challenges Together: Applying the Sustainomics Framework, *Procedia Social and Behavioural Sciences*, 41, pp. 6634-6640.
57. NAS (2011). Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy, National Academy of Sciences (NAS). Available at dels.nas.edu/resources/static.../Renewable-Fuel-Standard-Final.pdf, Accessed 08 December 2012.
58. NEA (2008). Nuclear Energy Outlook (No. 6348). Nuclear Energy Agency (NEA), http://ny.whlib.ac.cn/pdf/Nuclear_Energy_Outlook_2008.pdf, Accessed 08 March 2013.
59. NEA (2012). The Role of Nuclear Energy in a Low-carbon Energy Future, Nuclear Energy Agency (NEA), http://www.oecd-nea.org/nsd/reports/2012/nea6887-role-nuclear-low-carbon.pdf, Accessed 08 December 2012.
60. NERC (2009). *Accommodating High Levels of Variable Generation*, North American Electric Reliability Corporation (NERC), Princeton, NJ, USA.
61. Office of the Ohio (2010). Renewable Energy Sources: Wind power. Available at pickocc.org/.../renewable energy/Solar_Power.pdf, United States, Accessed 10 December 2012.
62. Oltra, C., Sala, R., Sola, R., Masso, M.D. & Rowe, G. (2010). Lay perceptions of carbon capture and storage technology, *International Journal of Greenhouse Gas Control*, 4 (4), pp. 698-706.
63. Omer, A.M. (2008). Energy, environment and sustainable development, *Renewable and Sustainable Energy Reviews*, 12 (9), pp. 2265-2300.
64. Orecchini, F. & Santiangeli, A. (2011). Beyond smart grids – The need of intelligent energy networks for a higher global efficiency through energy vectors integration, *International journal of hydrogen energy*, 36 (13), pp. 8126-8133.
65. Pappas, C., Karakosta, C., Marinakis, V. & Psarras, J. (2012). A comparison of electricity production technologies in terms of sustainable development, *Energy Conversion and Management*, 64, pp. 626-632.
66. Park, J., Sarkis, J. & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization, *Journal of Cleaner Production*, 18 (15), pp. 1494-1501.
67. Peace, J. & Juliani, T. (2009). The coming carbon market and its impact on the American economy, *Policy and Society*, 27 (4), pp. 305-316.
68. Peng, L. & Yan, G. (2011). Clean Energy Grid-Connected Technology Based on Smart Grid, *Energy Procedia*, 12, pp. 213-218.
69. Pernick, R. & Wilder, C. (2007). *The clean tech revolution: The next big growth and investment opportunity*, New York, NY: HarperCollins.
70. Plambeck, E.L. (2012). Reducing greenhouse gas emissions through operations and Supply Chain management, *Energy Economics*, 34 (1), pp. S64-S74.
71. RES (2013). Geothermal. Renewable Energy Source (RES). Available at www.renewableenergyworld.com/.../2013/.../2013-geothermal-last-m..., Accessed 11 March 2013.
72. Schaltegger, S. & Csutora, M. (2012). Carbon accounting for sustainability and management. Status quo and challenges, *Journal of Cleaner Production*, 36, pp. 1-16.
73. Schoenberger H. Styles, D. & Galvez-Martos, J. (2012). Environmental improvement of product Supply Chains: A review of European retailers' performance, *Resources, Conservation and Recycling*, 65, pp. 57-78.
74. Scott, V. (2013). What can we expect from Europe's carbon capture and storage demonstrations? *Energy Policy*, 54, pp. 66-71.
75. Sidiras, D.K. & Koukios, E.G. (2004), Solar systems diffusion in Local markets, *Energy Policy*, 32 (18), pp. 2007-2018.
76. Styles, D., Schoenberger, H. & Galvez-Martos, J. (2012). Environmental improvement of product Supply Chains: Proposed best practice techniques, quantitative indicators and benchmarks of excellence for retailers, *Journal of Environmental Management*, 110, pp. 135-150.
77. Tan, L. & Liu, C. (2012). Decision-making model of Low-carbon Economy, *Procedia Engineering*, 37, pp. 96-100.
78. Tongzhou, Q. (2011). The Analysis of Ecological Ethics in the Low-carbon Economy, *Energy Procedia*, 5, 2481-2485.
79. Upham, P., Dendler, L. & Bleda, M. (2011). Carbon labelling of grocery products: public perceptions and potential emissions reductions, *Journal of Cleaner Production*, 19 (4), pp. 348-355.
80. US DOE (2010). Energy Efficiency and Renewable Energy Marine and Hydrokinetic Database, Energy Efficiency and Renewable Energy, US Department of Energy (USDOE), Washington, DC, USA. Available at www.eere.energy.gov/windandhydro/hydrokinetic/ default.aspx. Accessed 13 March 2013.

81. Verbong, G.P.J. Beemsterboer, S. & Sengers, F. (2013). Smart grids or smart users? Involving users in developing a low carbon electricity economy, *Energy Policy*, 52, pp. 117-125.
82. Wan, N., Ji, X., Jiang, J., Qiao, H. & Huang, K. (2013). A methodological approach to assess the combined reduction of chemical pesticides and chemical fertilizers for low-carbon agriculture, *Ecological Indicators*, 24, pp. 344-352.
83. WCD (2000). *Dams and Development – A New Framework for Decision-Making*, World Commission on Dams (WCD), Earthscan, London, UK.
84. WEC (2010). 2010 Survey of Energy Resources, World Energy Council (WEC). Available at: http://www.worldenergy.org/documents/ser_2010_report.pdf, Accessed 13 March 2013.
85. Wei, Z., Hulin, L. & Xuebing, A. (2011). Ecological Civilization Construction is the Fundamental Way to Develop Low-carbon Economy, *Energy Procedia*, 5, pp. 839-843.
86. WHO. (2009). *Night Noise Guidelines for Europe*, World Health Organization (WHO), Geneva, Switzerland.
87. Yang, X., Xu, M. & Han, W. (2012). Pathways to a Low-carbon Economy for Inner Mongolia, China, *Procedia Environmental Sciences*, 12, Part A, pp. 212-217.
88. Yusuf, Y.Y., Gunasekaran, A., Musa, A., El-Berishy, N.M., Abubakar, T. & Ambursa H.M. (2012). The UK oil and gas Supply Chains: An empirical analysis of adoption of sustainable measures and performance outcomes, *International Journal of Production Economics.* Available at http://dx.doi.org/10.1016/j.ijpe.2012.09.021.
89. Yongping, N. (2011). The Economic Thinking on Low Carbon Economy. *Energy Procedia* 5, pp. 2368-2372.
90. Young, G.O. (1964). Synthetic structure of industrial plastics (Book style with paper title and editor), in *Plastics*, 2nd ed., Vol. 3, J. Peters (Ed.), New York: McGraw-Hill, pp. 15-64.
91. Zeng, S. & Zhang, H. (2011). Promoting low-carbon development of electric power industry in China: A circular economy efficiency perspective, *Energy Procedia*, 5, pp. 2540-2548.
92. Zhu, Q. & Geng, Y. (2013). Drivers and barriers of extended Supply Chain practices for energy saving and emission reduction among Chinese manufacturers, *Journal of Cleaner Production*, 40, pp. 6-12.