Energy Policy39 (2011) 2193–2196

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Macro-level integrated renewable energy production schemes for sustainable development

Bobban G. Subhadra*

Department of Internal Medicine, School of Medicine, University of New Mexico, Albuquerque, NM 87131, USA

ARTICLE INFO

Article history:
Received 3 November 2010
Accepted 4 February 2011

Keywords:
Energy technology and innovation
IREP
Renewable energy

ABSTRACT

The production of renewable clean energy is a prime necessity for the sustainable future existence of our planet. However, because of the resource-intensive nature, and other challenges associated with these new generation renewable energy sources, novel industrial frameworks need to be co-developed. Integrated renewable energy production schemes with foundations on resource sharing, carbon neutrality, energy-efficient design, source reduction, green processing plan, anthropogenic use of waste resources for the production green energy along with the production of raw material for allied food and chemical industries is imperative for the sustainable development of this sector especially in an emission-constrained future industrial scenario. To attain these objectives, the scope of hybrid renewable production systems and integrated renewable energy industrial ecology is briefly described. Further, the principles of Integrated Renewable Energy Park (IREP) approach, an example for macro-level energy production, and its benefits and global applications are also explored.

1. Introduction

The production of renewable clean energy is a prime necessity for the sustainable future existence of our planet (IPCC, 2007; Lund, 2007). Renewable energies represent a cornerstone to steer our energy system in the direction of sustainability and generating electricity, heat or biofuels from renewable energy sources has become a high priority in the energy policy strategies at national level as well as at a global scale (Resch et al., 2008). However, there are many practical challenges associated with large scale deployment of renewable energy production. Renewable energy technologies are often recognized as less competitive than traditional electric energy conversion systems. Obstacles with renewable electric energy conversion systems are often referred to the intermittency of the energy sources and the relatively high initial capital cost (Skoglund et al., 2010). Moreover, renewable energy production systems can be highly resource-intensive because of the less-dense energy content nature of new generation energy systems compared to energy-dense fossil fuels. Wind and solar energies are infinite from a resource standpoint; however, the available land from which to harvest them is finite. Similarly, the land required to grow any biomass feedstock for biofuel to meet a large demand is also finite (Subhadra, 2010a). Similarly, water – another finite natural resource – consumption represents a major challenge for future energy production (Subhadra and Edwards, in press; Subhadra, 2010b, in press; Gerbens-Leenes et al., 2009). Thus, the primary constraint in future energy scenarios is not energy sources as such but rather the land and water required to harvest or grow or process them. This constraint on natural resources becomes particularly important in the wake of another global challenge. There is greater need for more agricultural land for providing 'dietary energy' for the planet's growing population (Sachs et al., 2010; Godfray et al., 2010). However, the productive agricultural land on our planet is decreasing due to extreme climate and unpredicted weather attributed mainly to increasing greenhouse gas (GHG)-emissions (IFPRI, 2009). Moreover, the agricultural lands which are already in use might need more natural resources such as irrigation water for the same level of production which brings additional constraints on available water resources.

2. Need for macro-level renewable energy production schemes

Due to an intensified discourse on climate change and its effects, it has from a societal point of view, become more desirable to adopt and install CO_2 neutral power plants (Skoglund et al., 2010). Realizing the need for clean-energy production, legislative mandates for renewable energy research and production are underway in many countries (Verbruggen et al., 2010; Taylor, 2008). The effort to meet these needs for new energy sources should take care not to sacrifice other critical natural resources. Unsustainable production schemes for new

* Tel.: +15052204145; fax: +15052565753.
E-mail address: BSubhadra@salud.unm.edu

0301-4215/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2011.02.019

energy production could also lead to irreversible consequences in natural resources; therefore, intensive research and modeling must be conducted to investigate and predict the effect of new generation energy systems on global natural resources.

There is no doubt that the ongoing research investments to develop different sectors of renewable energy sources such as solar, wind and geothermal might lead to giant leaps in basic research, micro-level innovations and broaden the existing knowledge base. However, it is difficult to glean the best out of all these efforts and transform them into meaningful deliverables to society in the absence of macro-level energy production structures. Studies have shown that large scale renewable energy implementation plans must include strategies for integrating renewable sources in coherent energy systems influenced by energy savings and efficiency measures (Lund, 2005).To obtain a meaningful reduction in GHG-emissions and to produce optimum sustainable renewable energy needs higher level planning and a carefully thought out macro-level energy production model. The paradigm shift towards larger commercial renewable energy production needs innovative design and deployment strategies because of the larger natural resources footprint of these entities.

3. Hybrid renewable energy production systems

As mentioned earlier, one common disadvantage of renewable resources such as wind and solar energy, is their unpredictable behavior, in addition, the variation of these sources may not match with the time distribution demand (Yang et al., 2008). Furthermore, the wind energy systems may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy. As to solve these drawbacks, the complementary combination of each component characteristic may lead to enhancement of system efficiency and reliability. In addition, combined utilization of these renewable energy sources, a concept called hybrid system, are therefore becoming increasingly attractive and are being widely used as alternative of oil-produced energy (Nema et al., 2010). Hybrid system incorporates a combination of one or several renewable energy sources such as solar photovoltaic, wind energy, micro-hydro and may be conventional generators for backup (Deshmukh and Deshmukh, 2008; Bernal-Agustín and Dufo-López, 2009; Paska et al., 2009). Hybrid energy system is an excellent solution for electrification of remote rural areas where the grid extension is difficult and not economical. Economic aspects of these technologies are sufficiently promising to include them in developing power generation capacity for developing countries (Deshmukh and Deshmukh, 2008). Hybrid systems can be considered as a reasonable solution, capable to support systems that cover the energy demands of both stand-alone and grid connected consumers. Several papers have studied the design and planning of hybrid renewable energy systems and its sustainable benefits (Paska et al., 2009; Ashok, 2007; Ekren and Ekren, 2008). In order to ensure the sustainability of the hybrid system and to address the mismatch between the intermittencies of wind and solar irradiation, an integrated system which consists of both internal storage system and a connection with the electrical grid has also been described (Dagdougui et al., 2010). Energy industries itself are highly energy-intensive processes with significant GHG emission. However, because of the high-density energy content of fossil fuel, we can still derive a lot of positive energy balance from these sources. But biofuel refineries might not derive a lot of positive energy balance because of the less-energy dense nature of bioenergy feedstocks. The wind and solar energy production might not require substantial direct energy input once after initial deployment. However, there is a lot of indirect energy input for the production of materials/infrastructure for installing these renewable energy infrastructure e.g. steel for wind towers, silicon solar harvesting materials, etc. (both steel and silicon production are incredibly energy-intensive processes). Reducing energy input of energy production with minimal GHG-emission is also imperative for the future energy production strategies. None of the proposed hybrid models take the GHG-emission reduction provision in their design concepts.

4. Scope of integrated industrial ecology for renewable energy production

Since the introduction of the industrial ecology concept and the apparent success of the Kalundborg Industrial Symbiosis project, attention to planned eco-industrial park (EIP) development projects has grown all over the world (Allenby, 2006). Global industrial ecology is focused on shifting of industrial process from linear open loop systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes become inputs for new processes (Ehrenfeld, 2004). In this idealized integrated industrial ecosystem, firms and organizations utilize each other's material and energy flows including wastes and byproducts to reduce the system's virgin material and energy input as well as the waste and emission output from the system as a whole, and contribute to sustainable development (Allenby, 2006). Advocates of industrial ecology suggest that by shifting the basis of industrial production from a linear to a closed loop system, these gains can be achieved. In recent years, concepts drawn from industrial ecology have been used to plan and develop eco-industrial parks (EIPs) that seek to increase business competitiveness, reduce waste and pollution, create jobs and improve working conditions.

Recently, Chinese government has taken the concept of industrial ecology and EIPs as a key industrial policy in their agenda 21 (Fang et al., 2007) and accepted by Chinese government for new wave of industrial development. Several case studies in China on eco-industrial for regional development with underlying principles of resource use, waste reduction, reuse, closed loop chains, industrial symbiotic webs have shown that this concept can bring both environmental and economic benefits (Wang et al., 2010; Geng et al., 2007). The EIPs in the USA are in their early stages and likewise their contribution to economic development and environmental policy, let alone social policies, is complicated and inchoate. The empirical material reveals that key features of industrial ecology such as inter-firm networking and collaboration in the form of materials interchange and energy cascading are either absent or in the early planning stages (Gibbs and Deut, 2005). While collaborative behavior between firms is central to EIP development if the potential benefits of industrial ecology are to be realized, it is important to realize that such behavior is difficult to develop from scratch through policy intervention (Gibbs and Deut, 2005). Another study indicated that the Dutch EIP projects are more successful than their US counterparts. This difference in success can be attributed to the fact that the US projects are initiated by local and regional governments that see the project as a way to improve the local/regional economy with access to substantial government funds. Because of this heavy government involvement, US companies are, in general, not interested in the project. The more successful Dutch projects, on the other hand, are mostly initiated by the companies themselves with financial and advisory support from the local and regional government (Heeres et al., 2004).

Integrated industrial ecology becomes particularly important for the future energy sector because of the complex and interconnected nexus of fuel, food and GHG-emission in a CO_2-constrained future industrial scenario. A future carbon-smart society will have sustainable ways to produce both food and fuel by integrating energy and food production sectors, which can