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Review

Hybrid nuclear-renewable energy systems: A review

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ABSTRACT

Climate change and energy security have emerged as the biggest concerns of the present century. Renewable energy sources are not continuous, dependent upon geographical location as well as climatic conditions, and require a very large land footprint. Future of nuclear energy is also uncertain because of public apprehensions and subsequent government policies. To overcome the issues derailing these two virtually carbon-free energy sources, a new hybrid or integrated nuclear-renewable energy system is being proposed and seen as an attractive option. Such integrated energy systems are conceived as a nuclear power reactor coupled with renewable energy generation and industrial processes that may simultaneously tackle the concerns regarding grid flexibility, climate change, energy security, optimal return on invested capital, and settling public concerns. Apart from highlighting the key challenges associated with nuclear energy and renewable energy sources while operating as an independent power generation system, the present paper delineates the various aspects associated with integrated nuclear-renewable energy systems. It may be speculated that integrating nuclear energy and renewable energy into a single hybrid energy system, coupled through informatics linkages, would enable to overcome the demerits present when they operate individual.

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1. Introduction: the energy question

Energy is an intangible currency essential for sustaining the life. More than one billion people are expected to be added in coming 15 years, making world population about 8.5 billion in 2030 (Melorose et al., 2015). Energy consumption is anticipated to increase by 34 percent till 2035. Nearly one-third of expected increase in the energy consumption will be the result of rapidly rising global population and world economy. The major portion of the global energy demand is achieved from the conventional sources of energy for long. It is forecasted that conventional fuels will remain the central source of energy driving the global economy—satiating approximately 60 percent of the energy consumption increase and accounting for around 80 percent of total energy consumption in 2035; as illustrated in Fig. 1 (British Petroleum, 2017). Although coal slows and renewables advance in the next two decades, the increase in combined contribution of oil and gas in global energy production will follow trend similar to that of the last two decades. The trend of overdependence on fossil fuels for energy production is threatening the sustainability of life itself. Fossil fuels are not only unevenly distributed and depleting fast but also tampering the ecological balance necessary for existence (Upadhyay and Sharma, 2014). Climate change and energy security have emerged as the biggest concerns of the present century. It is now well accepted that unless far-reaching steps are taken to moderate global warming, economic development will be slowing and world could move towards human made environmental disaster (Apergis et al., 2010; Menyah and Wolde-Rufael, 2010; Sudhakara Reddy and Assenza, 2009; The Stern Review on the Economic Effects of Climate Change, 2006). The presence of a huge share of fossil energy sources in unstable region of the Middle East poses risks and raises concerns for different nations in terms of the dependability of energy supply and pricing (Gnansounou, 2008). Ecological challenges and concerns about energy security are compelling many nations to explore energy options other than fossil fuels. Both nuclear energy and renewable energy—virtually carbon-free energy sources—have emerged as promising solutions for ecological degradation and energy security problems. Consequently, many countries have started investing in nuclear and renewable energies as a means to a) reduce dependency on crude oil trade, b) ensure better energy security, c) curtail the price instability associated with foreign fossil fuels, and d) mitigate ecological degradation (Toth and Rogner, 2006; Vaillancourt et al., 2008). Few countries— which were uncertain about nuclear energy in the past— are also displaying a lot of inclination for developing nuclear reactors now in order to diversify sources of energy supplies, strengthen energy security, and deliver a carbon free alternative to conventional fuels

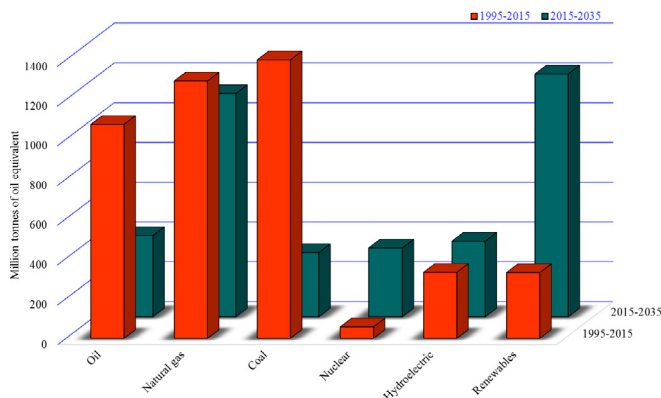


Fig. 1. Change in contribution of different sources in global energy production.

(Adamantiades and Kessides, 2009). There are currently 447 nuclear power plants in operation worldwide and 287 new ones are coming on line (including 28 in Japan) by 2035 (“World Nuclear Association,” n.d.). However, the future of energy is not so bright. Nuclear and renewable energies have their own issues. Renewable energy is not continuous, dependent upon geographical location and climatic conditions, and it requires a very large land footprint. Even though nuclear energy is a proven technology for generating electricity, many environmental groups and public have considered it unattractive since long. Such unfavourable attitudes and apprehensions are due to the possibility of accidents leading to meltdown of nuclear reactors. Meltdown of reactors has catastrophic social and environmental impacts. Lack of clear policies and regulations regarding the disposal of radioactive nuclear waste, and risk of fissile nuclear fuel being used for destructive purposes if diverted to radical groups add fuel to public fear (Adamantiades and Kessides, 2009).

There are drawbacks and risks associated with any power generation method. A sense of optimisation among energy wants, economic growth, safety, and sustainability has to be struck since each type of energy source has its own trade-offs. In light of reaping the benefits of both nuclear energy and renewable energy sources by attenuating their individual demerits, a new nuclear-renewable integrated energy system has been at the forefront of the wider issue of the energy debate. The objectives of the present article are to briefly highlight the drawbacks and challenges associated with both nuclear and renewable energy systems while operating independent and critically evaluate the hybrid renewable-nuclear energy systems. Renewable energy systems are seldom questioned while integrated nuclear-renewable energy systems are relatively new phenomenon; that is why it is expected that this review article will provide crucial understanding and contribute to the ongoing debate of sustainability.

2. Challenges for renewable energy

Renewable energy is the energy obtained from natural and persistent flows of energy occurring in the immediate environment (Twidell and Weir, 2015). Presently, power generation using renewable sources of energy stands well poised to fulfil new electricity requirement of the world. Renewable energy—accelerated by policies and strategies directed at reducing environmental degradation and enhancing energy security with sustainability—expanded at its fastest rate to date in 2014 and presently contributes above 45 percent of total energy additions. Extensive deployment of renewables continues to excel in energy-starved emerging economy and few nations such as China and India have ambitious plan. Furthermore, rapid progress in technology, growth of newer markets with better resources, and strengthening of financing scenario by government policies are enabling more cost-effective installation of dynamic renewable technologies like solar photovoltaics, solar-thermal plant, and onshore wind worldwide (International Energy Agency, 2015). However, there are various issues and challenges associated with it as discussed in subsequent sub-sections.

2.1. Scalability, commercialisation, and timeline

Scalability refers to the capability of a system or source to accommodate surge in production or number of users without a penalty in cost, performance, reliability or functionality. Alternative energy sources must be scalable within a fixed time frame at a competitive cost in order to be primarily dependent on them for power generation. Various non-conventional energy sources like thin-film solar, algae-based diesel, cellulosic ethanol etc. have been

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