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Renewable energy and nuclear power towards sustainable development: Characteristics and prospects

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ABSTRACT

Today there are several opportunities for Renewable Energy Sources (RES), as well as for nuclear technologies to contribute to mitigating climate change and to promote sustainable development (SD). In this framework, the main scope of the present study is to provide an analysis and a direct point-to-point comparison of five promising renewable energy technologies, namely, biomass gasification, molten carbonate fuel cells fed with wood gas, Solar Photovoltaics (PV), solar thermal and offshore wind, in contrast to two advanced nuclear technologies, European Pressurized Reactor (EPR) and European Fast Reactor (EFR). The examination was made with regards to technology characteristics, sustainability factors and potential deployment drivers and barriers, obtained from relative studies. The analysis indicated that the examined RES and nuclear technologies both offer substantial contribution to climate change by effectively producing limited amounts of GHG emissions, which are close to zero for the nuclear technologies. The RES produce no significant waste and are generally favored by policy incentives, but some of them are plagued by high production costs and low efficiency. On the contrary, the examined nuclear technologies, despite their enhanced safety, reduced costs and minimized waste, still have to face the major issues of weapons proliferation, safety, waste handling and high costs as well as public acceptance, which have been affected by the recent Fukushima accident.

Contents

1. Introduction

Global warming is currently considered as one of the most critical problems that the environment may be faced within the

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next 50 years [1]. One of the most important factors of today's global energy production system are Greenhouse Gas (GHG) emissions from power plants around the world, which are considered to be one of the main factors leading to climate change [2]. GHG emissions include carbon dioxide (CO_2), methane, nitrous oxides, chlorofluorocarbons and water vapor which, upon release, contribute to heating up the lower layers of the atmosphere. Attempts to tackle global warming require the increase of use of energy sources alternative to traditional fossil fuels, such as lignite, coal and gas, which release large amounts of GHG [3]. Both nuclear and renewable energy are believed to be able to provide partly solutions to climate change.

Electricity generation from RES is today a promising option, which contributes to the reduction of high dependence on imported energy and provides additional environmental benefits with regards to GHG emissions, thus playing an important role in mitigating climate change [4,5]. The deployment of RES has been large during the last decade [6]. National policy incentives, such as the feed-in-tariff, and mechanisms of the Kyoto protocol, such as the Clean Development Mechanism (CDM), have aided to this deployment. Actually, the ratification of the Kyoto protocol has made the use of RES more advantageous in the race to cut back on GHG emissions [7]. Many countries have included RES investments in their strategy towards reducing dependence on oil and gas imports and the respective price volatilities, as well as mitigating GHG emissions [8]. RES can also be suitable for less developed countries as relatively low capital demanding and decentralized options. However, a large-scale basis deployment of RES faces important economic and technical feasibility limits, even if effective potential reserves are well documented [9].

Nuclear energy plays an important role today in meeting the energy needs of many countries and at the same time in mitigating GHG emissions. Adamantiades and Kessides [10] argue that nuclear plants worldwide contribute significantly to mitigating GHG emissions, whereas they save about 10% of CO_2 emissions from world energy use. Nuclear power plants have played a major role in reducing the amount of GHG produced by the electricity sector in OECD countries [11]. Furthermore, it is claimed that without nuclear power, the EU power plant carbon dioxide emissions would have been about one-third higher [12]. In contrast to North America and most countries of Europe, where nuclear power capacity has remained almost steady for the last two decades, the nuclear capacity in Asia has been growing significantly, as a number of countries in East and South Asia, most notably China, India and South Korea, are planning and building new reactors [10].

Nuclear power and renewable energy are perhaps two of the most powerful tools to bring down the carbon intensity of commercial energy supply today. The majority of the world's electricity in 2010 was produced via fossil fuels, as seen in Fig. 1, while RES accounted for 18% and nuclear power for 14% [13]. Taking into consideration the growing energy demand under the volatile energy prices for traditional fossil fuels (coal, gas, and oil), the need for alternative energy sources exists. This is strengthened by the fact that fossil fuels is not an infinite source of energy, since various studies have indicated for example that the time peak of crude oil production is very near or has passed, although the exact timeframe is under discussion [14–18]. As the global energy needs are constantly increasing, countries have the option to invest in nuclear and/or renewable technologies, in order to satisfy growing energy demands and at the same time contribute to climate change mitigation.

A number of studies in the international literature focus on the integration of renewable energies and nuclear power in the energy market [19,20]. Adamantiades and Kessides [10] explored the current status and future prospects of nuclear energy for sustainable development. Apergis et al. [21] used causality and data from 19 countries

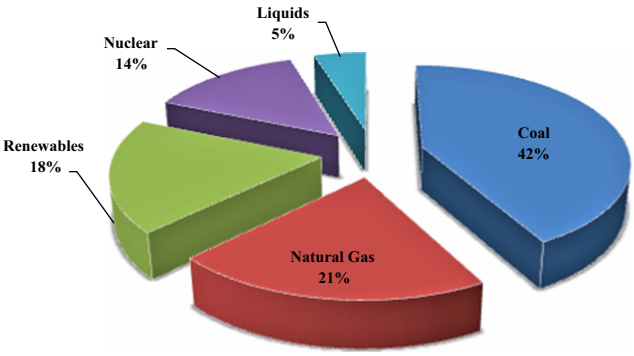

Fig. 1. World net electricity generation by energy source.
Source: Ref. [3].

to show that the use of nuclear energy has contributed to the reduction of CO_2 emissions, while renewable energy has not yet reached a significant level of contribution. Menyah and Wolde-Rufael [8] agree on the previous statement, having used Granger causality on data regarding the United States. In addition, Forsberg [4] and Verbruggen [22] explored the common future of electricity production from a possible coupling of renewable sources and nuclear power by providing real and full priority to the sustainable options. However, to the best of our knowledge, there is no paper presenting a transparent point-to-point comparison and approach of promising RES and nuclear technologies taking into consideration their potential and perspectives for deployment and enhancement of global sustainability. In this context, the main scope of this study is to analyze and compare specific promising RES options and new nuclear technologies, in terms of their potential of contributing to climate change mitigation and sustainable development, as well as to discuss their differences and possible future trends. For this purpose, two new nuclear technologies, the European Pressurized Reactor (EPR) and the European Fast Reactor (EFR), and five promising renewable technologies, biomass gasification, molten carbonate fuel cells fed with wood gas, offshore wind farms, solar photovoltaics and solar thermal power plants have been chosen.

Apart from the Introduction, the paper is structured along four sections. The approach followed is presented in Section 2. Sections 3 and 4 focus on the analysis of the five renewable energy technologies and the two nuclear energy technologies, respectively. Further on, Section 5 discusses the differences and potential of these technologies to contribute to GHG emission reduction and SD. Finally, Section 6 presents the conclusions that summarize the main points arisen from this study.

2. Presentation of comparison approach

The general philosophy of the proposed approach adopted for the coherent presentation of the technology options is shown in Fig. 2. In order to compare the different technologies, certain characteristics of each have been assessed and presented, as mentioned in the bullets below. Data for the presentation has been partly based on research conducted within the framework of the FP-6 project "New Energy Externality for Development and Sustainability (NEEDS)", as well as taken from the literature. Each technology presented is not country-specific, but universal, according to the geology and climate potential.

In particular, the investigation focused on the following aspects:

- *Technology characteristics and cost details*: Basic technical characteristics of each technology, such as fuel type, electric