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A green electrical matrix-based model for the energy transition: Maine, USA case example

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ABSTRACT

Nowadays, climate change is a major global societal challenge that significantly increases environmental stress. Most international organizations and policies have promoted initiatives to minimize emissions, reduce fossil fuel dependence and increase renewable energy resource integration into different sectors. An energy transformation towards more renewable systems is thus a priority. Under this scenario, the present paper describes and evaluates an alternative energy conversion matrix-based model to combine sector electrification, power generation units from renewables, and new clean technologies. The proposed green matrix-based model allows analyzing future scenarios, including electricity participation in end-use consumption and electric power generated by renewables – potentially integrated into different sectors –. The proposed model is evaluated in the state of Maine (United States). This case study is focused on decarbonizing both residential heating and transport sector through the integration of large offshore wind power plant. Results and discussion is also included in the paper, providing expected energy demand reductions and decreasing emissions through the integration of renewables. This energy transition integration case study is proposed in three road-maps with different penetration rates and time scales. The proposed green matrix-based model can be also applied to other areas and energy resources, as an alternative way to analyze and estimate renewable integration into different sectors.

1. Introduction

1.1. Background & significance

The energy transition, the decarbonization of the economy, and the reversal of climate change are aligned with the Paris Agreement, which agreed to keep the increase in global temperature well below 2 °C above pre-industrial levels during the 21st century [1]. The global replacement of the energy model based on the use of fossil fuels, with high greenhouse gas (GHG) emissions, towards a model powered by Renewable Energy Sources (RES) is key to achieving this objective [2]. Energy includes various sectors (power generation, heating & cooling, and transportation) each of which should minimize their GHG emissions to fulfill the Paris Agreement and foster strong interconnections to maximize synergistic effects and efficiency [3].

The global electricity evolution of RES is accelerating in terms of new nominal power added to the total capacity and generation. Total installed capacity grew by 111% in 2020 compared to 2010, without suffering stages of decline during those years [4]. Indeed, it is expected that the total installed capacity will reach, approximately, 18 000 GW by 2050, where more than 14 000 GW will come from wind and solar resources. Moreover, 86% of the generation is forecasted to have renewable origins, being the wind resource contribution more than 50% of the total [5,6] (see Fig. 1).

Regarding the transportation sector, it is largely responsible for GHG emissions [7]. According to the European Environment Agency [8], transports refer to international and domestic aviation, international and domestic shipping, railways, and road transport (exhaust and non-exhaust). Among them, the exhaust of road transport is the one that contributes the most to the total emissions of the main air

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