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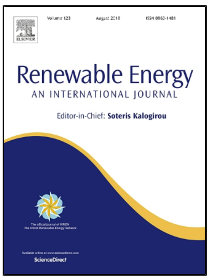

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Abstract—This work describes a methodology to optimize a grid-connected hybrid renewable energy system (HRES) that hybridizes photovoltaic, wind and forest biomass energy sources taking into account cost and environmental impact criteria from a life-cycle perspective. The developed model has been tested in a sample township in central Catalonia. The results show that life-cycle cost and life-cycle environmental impact are contradicting criteria. Low environmental impact layouts highly dependent on RES have higher costs than the ones more reliant on the electricity from the public grid, which present high environmental impact. A sensitivity analysis has been performed to analyze the trade-offs between different energy sources of the system, showing that wind power is the RE source with higher impact on the system since it presents lower cost and lower environmental impact, compared with biomass and photovoltaic power. Another important conclusion that can be drawn from such sensitivity analysis is that improving the rate of return on investment in HRES would be a very beneficial measure to encourage the use of renewable energies for electricity production, as it has significant positive outcomes in terms of both cost and environmental impact reduction.

Keywords—Grid-connected hybrid renewable energy system; multi-objective optimization; solar photovoltaic power; wind power; biomass.

I. Introduction

Renewable energies (REs) are an appealing alternative for tackling the climate change global issue, which is widely recognized as the major challenge that is going to be faced in the upcoming future due to the major implications in terms of water resources stress increases [1], [2] or global air and ocean temperature increases [3], among others. These major changes in climate patterns are already being observed and there is scientific consensus on being particularly affected by the anthropogenic global greenhouse gases (GHG) emissions increase [3], including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In particular, the current anthropogenic GHG emissions could already be beyond planet boundaries [4], hence being of critical importance to deal with such issue in a quick and effective manner.

In this context, REs are an alternative worth exploring, as they are effective means for climate change prevention and mitigation [5], with undeniable external benefits in terms of environment quality and economic value, especially in the case of photovoltaic (PV) power, wind power and biomass power [6], which are the focus of the present work. Moreover, they are indigenous energy sources [7], allowing countries that position for them to reduce energy dependency whereas taking a transition path to a decentralized energy generation scheme that could be the basis for smart grid implementation. This is so because RE are not only a suitable alternative for microgrid implementation [8], but also efficient in transmission since energy generation can be placed close to consumption nodes [9]–[11] while allowing a modular structure [12]. Despite these benefits, it is noteworthy to mention that main benefits of REs are in terms of environmental performance, as these sources are carbon-free (PV or wind power) or carbon-neutral (biomass), being thus a viable alternative to de-carbonize the energy generation. Another remarkable benefit from REs use is the revaluation of local resources currently misused as well as the creation of local job opportunities [13], especially in the case of forest wood biomass resource, which requires labor force in the fields of forest management, harvesting, biofuel production storage and distribution [14] and helps preventing landscape quality, landslides and biodiversity [15].

However, REs have an inherent stochastic nature, which is their main drawback. Whereas fossil fuel-based