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Renewable energies for Graciosa Island, Azores – Life Cycle Assessment of electricity generation

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Abstract

The Graciosa project combines a large scale battery energy storage system with renewable electricity generation from wind power and photovoltaics in a hybrid power plant to reduce the environmental impacts caused by the previous electricity generation by 100 % diesel combustion on Graciosa Island, Azores. The results of a Life Cycle Assessment show a reduction of environmental impacts of approx. 43 % due to the transformation to the hybrid electricity supply system with high shares of renewable energies (65 %). In the new electricity supply system, the majority of environmental impacts (> 60 %) is still caused by the remaining diesel based electricity generation. Environmental impacts, which are associated with the construction of the large scale battery energy storage system, account for only 6 % of total impacts. Wind power and photovoltaics account for 18 % and 14 %, respectively.

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Keywords: Electricity generation on islands; Life Cycle Assessment; Battery energy storage systems; Renewable energies; Lithium titanate battery cells; Diesel generators

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1. Introduction

On a worldwide level, there are a lot of activities to increase the utilization of renewable energies on islands and to reduce their dependency on fossil fuels to support the implementation of and the transformation towards more sustainable energy systems [1-3]. A number of islands follow these initiatives and have set ambitious goals for the transformation of their energy systems. Furthermore, a multitude of renewable energy projects has already been realized or is currently in the planning state [4-6]. In this regard, the Regional Government of the Islands of the Azores has decided to invest more than 85 million € by 2017 to increase the rate of penetration of renewable electricity generation in the region to about 53 % [7]. To reach this goal, energy storage systems supporting increased penetration of renewable electricity generation are fundamental for security of supply and independence from fossil fuels [7]. So far, occurring instabilities in the weak electricity grids on the Islands of the Azores have limited the share of fluctuating renewables (Wind, photovoltaics (PV)) and hindered the further development of renewable energies [8]. Therefore, energy storage technologies play a key role to support and integrate fluctuating renewables especially for weak, isolated, island power systems.

In 2004, the local energy utility EDA (Energia dos Açores) launched a first project to maximize the energy production from renewable energy sources on Graciosa Island and Flores Island. Objectives of the project were to increase wind energy production, improve the efficiency of the diesel generators and increase the grid stability. In a first step, two flywheels (500 kW, 30 s) have been installed on Flores (2005) and Graciosa (2006) [8]. Parallel to this first initiative, another project, which aims to significantly increase the share of renewable energies on the electricity generation to reduce the dependency from diesel generation, has been in discussion since 2005/2006 [9]. The idea of this so called “Graciosa project” is to combine a large scale battery energy storage system (BESS) with renewable electricity generation from wind and PV in a hybrid power plant approach.

2. Literature review

Islands provide favorable conditions for the utilization of renewable energies especially due to favorable wind and solar conditions [10, 11]. Depending on the site-specific conditions there are also prospects for hydropower, biomass, geothermal or ocean energy utilization [6, 12-16]. The existing power systems on islands mostly depend on the utilization of fossil fuels which have to be transported to the islands accompanied with high costs and environmental impacts. In this context an increasing utilization of renewables is a great opportunity to reduce these issues. However, the integration of fluctuating renewables, especially in small and weak island grids is a technical challenge [17]. Energy storage is one technical solution to decouple electricity supply and demand thus providing flexibility and the ability to provide system services (e.g. spinning reserve, frequency regulation and voltage control) [18]. By combining renewable energies and storage systems in hybrid power plant approaches [19], it is possible to replace fossil electricity generation up to 100 %. Recently, comprehensive reviews on the utilization of renewable energies on islands are provided [20, 21]. Techno-economic aspects of applying storage systems on islands have been discussed in a number of papers [16, 22-27]. Regarding environmental impacts, an overview of Life cycle assessment (LCA) studies focusing on different batteries prior to 2012 is given by [28]. In the last two years numerous LCAs for lithium ion batteries [29-33] and other battery types [34-37] have been conducted. Most of the LCA studies on batteries focus on automotive applications [38-42]. In [43] a comparative LCA of battery systems for different stationary applications is carried out. Recently, an exhaustive LCA of a sodium-ion battery and the comparison with lithium-ion batteries has been published [44]. In [45] a LCA study on primary control provided by a BESS is presented.

3. Research objectives

Graciosa Island is part of the central group of the Autonomous Region of the Azores and belongs to Portugal. Graciosa Island has an area of 60.65 square kilometers, a length of 10 kilometers and a width of seven kilometers. The population is 4,391 people (2011) [46].

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