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The impact of demand side management strategies in the penetration of renewable electricity

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ABSTRACT

High fuel costs, increasing energy security and concerns with reducing emissions have pushed governments to invest in the use of renewable energies for electricity generation. However, the intermittence of most renewable resources when renewable energy provides a significant share of the energy mix can create problems to electricity grids, which can be minimized by energy storage systems that are usually not available or expensive. An alternative solution consists on the use of demand side management strategies, which can have the double effect of reducing electricity consumption and allowing greater efficiency and flexibility in the grid management, namely by enabling a better match between supply and demand.

This work analyzes the impact of demand side management strategies in the evolution of the electricity mix of Flores Island in the Azores archipelago which is characterized by high shares of renewable energy and therefore the introduction of more renewable energy sources makes it an interesting case study for testing innovative solutions.

The electricity generation system is modeled in TIMES, a software which optimizes the investment and operation of wind and hydro plants until 2020 based on scenarios for demand growth, deployment of demand response technologies in the domestic sector and promotion of behavioral changes to eliminate standby power. The results show that demand side management strategies can lead to a significant delay in the investment on new generation capacity from renewable resources and improve the operation of the existing installed capacity.

1. Introduction

Demand side management strategies are of great interest to utility companies throughout the World, as they can help to ease the operation of the electrical system [7,21,35], and many governments are currently studying policies to promote their application [33,34], focusing on options that include promoting energy efficiency plans, behavior changes at the customer level or dynamic demand response.

Dynamic demand response is the ability to control end-user devices (appliances) by rescheduling their operation, and this enables the utilities to operate some of the appliances in periods where there is a large amount of renewable energy available, and not to operate them when demand levels increase drastically [17]. It is important to notice that these operations don't actually decrease the amount of electricity consumed, but merely shift it to when it is more convenient from the grid operation perspective [32]. However, several issues must still be addressed in order to guarantee the success of demand response [20].

While dynamic demand response is more oriented towards load shifting, energy efficiency plans have the primary goal of decreasing overall energy consumption in the medium/long-term. This can be achieved by educating people on how they can save energy through switching off unnecessary uses (eliminating standby power consumption or switching off lights that are not needed), promoting the change to more efficient devices (refrigerators, light bulbs, washing machines, and others) and pushing for a more sustainable construction and renovation of buildings so that they require less artificial lighting and heating/cooling (good insulation, better performing windows, etc.).

This type of strategies might allow increasing the penetration of renewable energies by creating the possibility of establishing a better match between electricity demand and the variations of renewable energy sources, enabling peak shaving and reducing the

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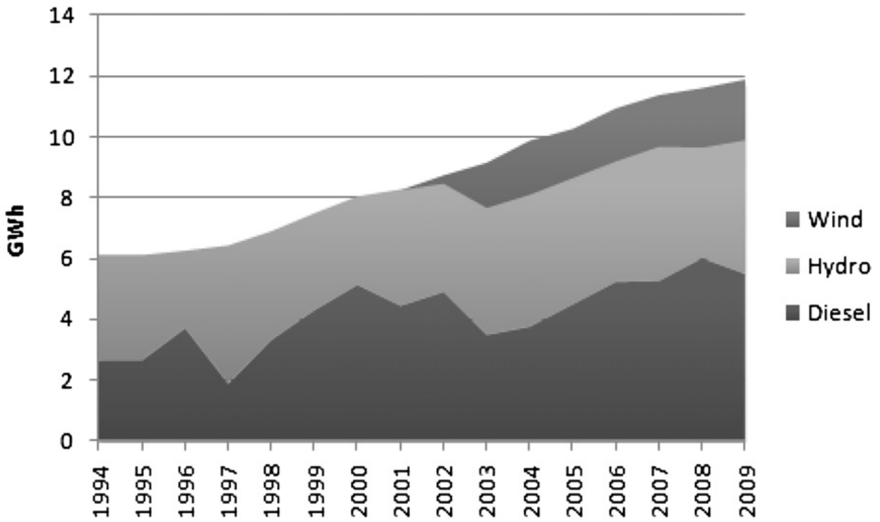

Fig. 1. Electricity production in Flores by source.

need for spinning-reserve supplied in general by power plants that use fossil fuels. Particularly in systems with high penetration of renewable energies, these options might compete with the more traditional use of energy storage systems (such as flywheels, batteries or reversible dams) that are often expensive or not available. This paper analyzes the impact of demand side management options, such as energy efficiency measures and dynamic demand response in the generation system of a closed system characterized by high renewable energy penetration, the island of Flores in the Azores.

The archipelago of the Azores is located in the middle of the North Atlantic Ocean and is composed of 9 islands of different sizes and population. The location of the Azores, as well as the large potential for renewable energies has led the Government of the Azores and Electricidade dos Açores (EDA), the local utility, to invest in renewable energies for the production of electricity. In 2009, renewable energies produced 26.0% of all electricity in the region and 54% in Flores [14]. Nevertheless, the Government of Azores is committed to increase further the use of renewable energies and thus it is promoting the Green Island Project [31].

The Green Islands Project is being developed in collaboration with the MIT Portugal Program [25] and has the purpose of developing sustainable pathways for the energy systems of the Azores islands. In Flores, the penetration of renewable energy in the electricity production mix is very high due to the use of a flywheel system that already allows the electric system to run exclusively on renewable energy during several hours on some days of the year [14]. The main problem is that the flywheel energy storage system installed in the island is expensive, has a relatively low efficiency, and requires a lot of maintenance which makes it an unattractive investment for the local electricity company. As a consequence, Flores becomes a very interesting case study to install and test load management strategies.

To analyze the energy system of Flores, a TIMES model was developed. TIMES - The Integrated Markal-Efom System - is a tool developed within the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency [15]. It is an optimization partial equilibrium bottom-up model generator that finds the minimal cost solution for an energy system over a certain time period [23]. The model is based on detailed and explicit information about available energy technologies (e.g. production capacity, efficiency and operation costs) and the description of end-use consumption for different sectors and types of energy. In this way, the model allows the testing of different policy options from the implementation of energy efficiency on specific end-uses to dynamic demand policies, in case the model uses an hourly resolution [26].

2. Flores case study

Flores is one of the most isolated islands of the Azores, with an area of around 141 km^2, and around 4117 inhabitants [30]. It is the island with the largest penetration of renewable energy in electricity production in the archipelago, as around 54% of all electricity produced in 2009 was based in either hydro or wind power. In fact, renewable energies have provided a large part of the electricity needs of the island for many years now, as shown in Fig. 1.

Due to its remote location and the small number of inhabitants, it is very expensive to transport the necessary fossil fuels to the island. Investing in local resources, not only for electricity production but also water and space heating, is a priority of the Government. Furthermore, the transition of a 4000 people community to an almost completely renewable society could promote ecotourism activities, which is already one of the main activity sectors in the region.

2.1. Electricity production system

Currently, the electricity system in Flores is a combination of wind turbines, hydropower and diesel engines, aided by a flywheel energy storage system. The system is composed of 4 hydropower generators, 2 wind turbines and 4 diesel engines. Table 1 shows the

Table 1
Installed generation capacity in Flores.

Plant	Group	Year	Capacity (KW)
Além-Fazenda (hydro)	I	1966	296
	II	1966	296
	III	1966	296
	IV	1983	512
Além-Fazenda (diesel)	VII	1991	500
	VIII	1995	500
	IX	2001	500
	XX	2005	810
Boca da Vereda (wind)	I	2002	300
	II	2002	300