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The role of H_2 in the decarbonization of isolated electrical systems: challenges in the mobility

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Abstract

The decarbonization of the power sector is undertaking a global transformation with different roadmaps, inclusion of new generation technology and different legal frameworks. In the last years, the costs of renewables have dropped substantially allowing them economically competitive with conventional fuels, in most global markets.

However, the isolated electrical systems are facing a huge challenge to face the energy transition and at the same time, to reach the energy sovereignty, to avoid the external dependence of the energy importation. In this sense, the generation capacity by renewable energies requires the inclusion of enough accumulation capacity to accomplish the generation with the demand curve. Also, the mobility transition will play a remarkable role due to the transition to electrical, hybrid and e-fuels powered vehicles.

Materials and methods

A mathematical model based on EnergyPlan (Aalborg University in Denmark) models and economical dispatch in isolated systems have used to evaluate the current Tenerife's energy system and the specific objectives set for energy decarbonization for the island of Tenerife (future Tenerife-La Gomera electrical system).

PTECan inputs

2040 scenario with a total decarbonization of the electrical system has been defined considering the current state and according to the Canary Island Plan for decarbonization (PTECan):

i. Sectorization of the electricity demand into three main groups depending on the final use sector: services, domestic and industrial.
ii. Land transport we have considered the demand for the vehicle fleet on the islands of Tenerife and La Gomera. The load profile and average consumption (published in the PTECan strategies) have been considered.
iii. Non-manageable renewable energy (wind, offshore and photovoltaic): Using these three technologies, a modelling of resource patterns (wind and solar radiation) has been proposed over the years of simulation.
iv. For self-consumption, the photovoltaic resource pattern profile has been used, and self-production of energy has been integrated into a hybrid system with batteries.
v. Network losses are assigned to the latter, which are estimated through trend modelling of the history of annual network losses by month.

Table 1. Generation technologies in Tenerife in 2040

Generation technologies	Power (MW)
Conventional generation	0.0
On-Shore Wind	1700.0
Off-Shore Wind	505.3
On-shore photovoltaic	1650.0
Off-shore photovoltaic	27.0
Self-consumption photovoltaic	829.0
Minihydraulics	2.6
Medium/high enthalpy geothermal	20.0
Biomass	17.8
Wave drive	5.0
Solar thermal	0.0
Total installed capacity	4756.7

Table 2. Energy consumption of the electrical fleet

Vehicle type	Number of vehicles	TWh/year
Truck	220451	0.6160
Van	150927	0.2711
Bus	5845	0.2733
Utilitarian	1077767	1.2899
Motorcycle	108427	0.0226
Others	24922	0.0382
TOTAL	1588339	2.5111

Results

Table 3. Hydrogen production systems to meet demand in 2040.

Electrolyzer	90	MW
Total wind production	861316	MWh
Total photovoltaic production	508906	MWh
EERR production destined for hydrogen	612837	MWh
Hydrogen produced	1057	kgH_2/h
Hydrogen produced annually	9260	tH_2/año
Maximum production	1360	kgH_2/h
Capacity factor	78	%
Average electrolyzer power	69959	kW
Hydrogen Storage	477,482	GWh

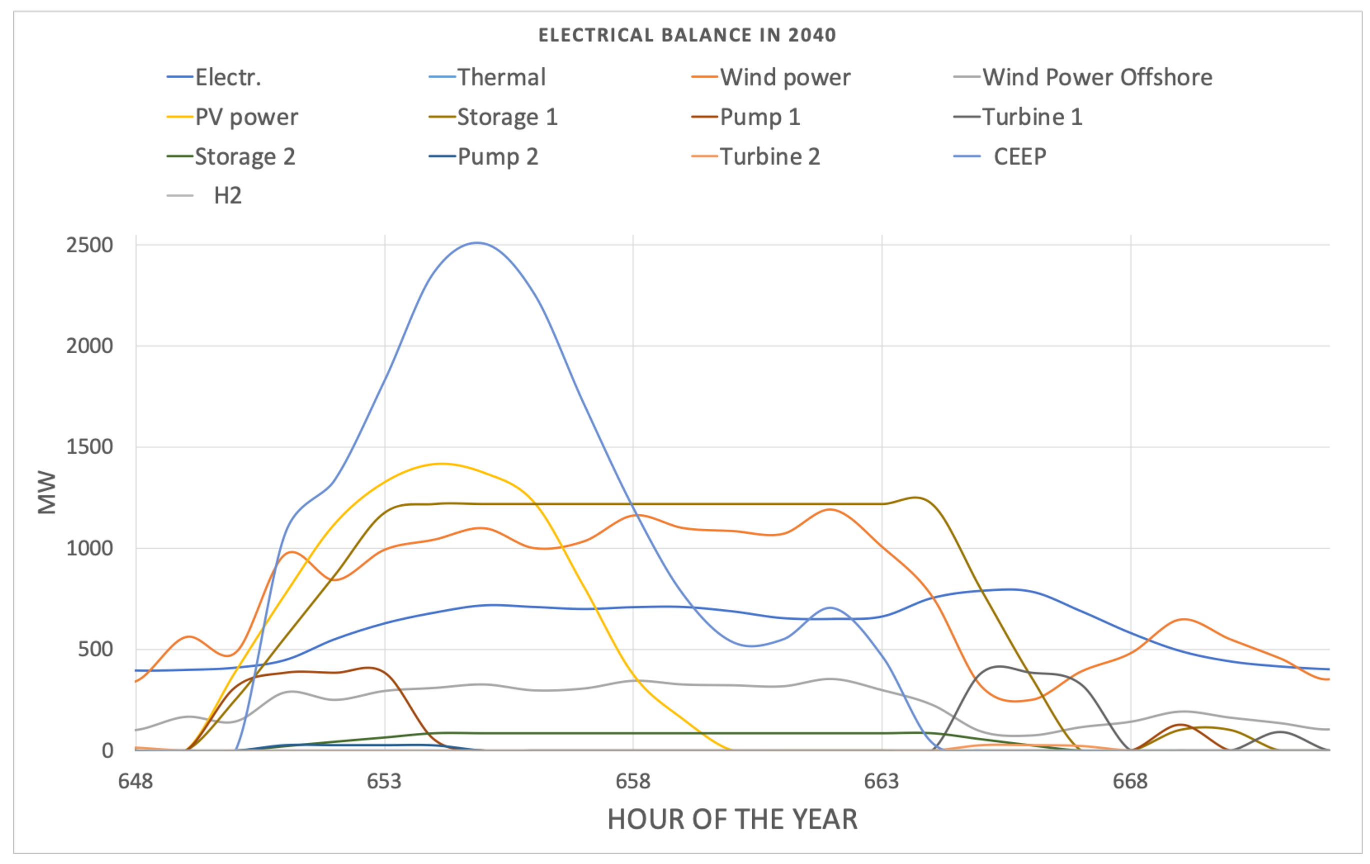

Fig.1. Results obtained from the EnergyPlan simulation of the 2040 year.

The influence of hydrogen on the system has been considered considering the need of the minimum technical value, and therefore, the critical excess of the energy will increase and consequently the accumulation needs or electrolyser power increment to manage the energy excess detected during the year.

The simulation of the year 2040 reveals that higher values of renewable generation and the aggregated demand, greater accumulation is necessary to guarantee the energy requirements of Tenerife electrical system.

Furthermore, by containing 100% renewable generation and the electrified vehicle fleet, CO_2 emissions take on minimum values of 18.27 Mt, solely due to air and maritime transport.

Conclusions

In this sense, the analysis of the results reveals the energy demand for land transportation represents almost the 50% of the required energy of the island for 2040, which requires that the installation of renewable energy be increased to be able to supply the total demand required by the year 2040. The decarbonization of the generation parks on the island of Tenerife requires having to install a greater amount of equipment to generate the energy needed, mainly due to the variability of renewable resources, which implies massive storage within the system.

Until now, in literature and energy planning in isolated territories it has been considered that there is a gradual dismantling of conventional generation equipment and therefore, an absence of the existence of a technical minimum of generation, but if we want to make the use of hydrogen in electrical systems, hydrogen turbines must be used. Therefore, it is relevant to consider the size of these teams and consider their technical minimums.

On the other hand, in a first approximation, if hydrogen is used to generate electricity, the efficiency of the process is around 20%. If instead of considering a complete electrical transition in an isolated electrical system, as seen in this work, a partial transition is considered, where cars that run on hydrogen cells are introduced, where the efficiency is 40%, it would be reduced. considerably the total demand for electrical systems.

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