Carbon Footprint study of Green Hydrogen production plant in the Canary Islands

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Abstract

Green hydrogen must be the energy vector of the future, according to several communications from the European Commission. Its use as a clean fuel must help reducing greenhouse gas emissions of multiple sectors. The present article presents the results of the avoided carbon footprint study associated with the production, distribution, and commercialization of green hydrogen in the Canary Island compared to current model (consumption of diesel fuel and electricity from the grid). The emission factors published by the Ministry for Ecological Transition and the Demographic Challenge of the Spanish Government have been used for this calculation. The improvement has been calculated at 26,302 t of CO_2e annually.

1- Introduction

In recent years, emphasis has been placed on the energy crisis, which is twofold: on the one hand, the use of non-renewable and, consequently, finite fossil fuels, and on the other hand, the effects caused by the combustion of these resources on the planet's atmosphere and climate change due to the increase in the greenhouse effect. According to multiple European Commission communications, hydrogen is an energy vector that must help reducing greenhouse gas emissions of multiple sectors (European Commission, 2020). Furthermore, the Canary Islands have abundant renewable resources within their reach (mainly wind and sun) (Red Eléctrica de España, 2020).

The aim of this carbon footprint study is to quantify the impact on climate change of a new energy model based on green hydrogen in the Canary Islands. To this end, a comparison will be made between the current scenario based on fossil fuels and the proposal based on green hydrogen as a fuel. This study is part of a project for the decarbonization of the Canary Islands. Action will be taken on different activities essential for the economic development of the Canary Islands that currently involve the consumption of fossil fuels, mainly diesel, liquified natural gas (LNG), propane air and electricity. These activities include, among others: (i) terrestrial transportation (public transport and vehicle fleets); (ii) industry, hotels, and ports; (iii) propane air grid.

The use of a carbon footprint study is justified because it is the only standardized tool for assessing this environmental impact. It is the indicator of one of the impact categories evaluated by the life cycle assessment (LCA): the global warming potential. According to ISO 14067:2018 regarding carbon footprint quantification: the carbon footprint is defined as the sum of greenhouse gas (GHG) emissions and GHG removals in a product system, expressed as CO_2 equivalent (Guinée et al., 2002; ISO 14067, 2019; Muñoz, 2006).

2- Description of the system (current and future)

The impacts associated with the following scenarios are studied and compared: (i) the current system, based on fossil fuels (85%) and the electricity mix (15%) of each Canary Island; and (ii) the future system, based on green hydrogen as a fuel.

In table 1, the percentages of electricity and fuel use from the current system which are covered by green hydrogen in the future system are presented along the 3 implementation stages of the project.

Table 1. Electricity-fuel ratios in the fossil scenario

		STAGE 1	STAGE 2	STAGE 3
Gran Canaria	Electricity	37.88%	37.88%	8.44%
	Diesel	62.12%	62.12%	91.56%
Tenerife	Electricity	7.47%	39.50%	15.98%
	Diesel	92.53%	52.90%	66.22%
	LNG	0.00%	0.00%	14.72%
	Propane air[a]	0.00%	7.60%	3.08%

[a] Ducted air network with high propane composition used as fuel for hotel and restaurant facilities in Tenerife Island

Table 2 shows the specific hydrogen production demands according to island and project stage for the future green hydrogen scenario.

Table 2. H_2 demand (t/year) depending on the island and phase of the project

	STAGE 1	STAGE 2	STAGE 3	TOTAL
Gran Canaria	224	0	783	1007
Terrestrial transport	130	0	783	913
Sea transport (Cold Ironing)	12	0	0	12
Hotels	82	0	0	82
Tenerife	436	306	1092	1830
Terrestrial transport	98	0	792	890

Terrestrial transport[a]	6	250	300	556
Propane air	0	56	0	56
Ports[b]	332	0	0	332

[a] STAGE 1: Cold Ironing / Stage 2: Auxiliar engine / STAGE 3: LNG use in ships
[b] Electricity consumption and diesel consumption in cranes and other machineries

The green hydrogen in the future system is produced from desalinated water with electrolysis. The oxygen produced as by-product has been considered as a waste since at the moment of the study it is not planned to valorize it. Figure 1 presents flow diagram of the future system.

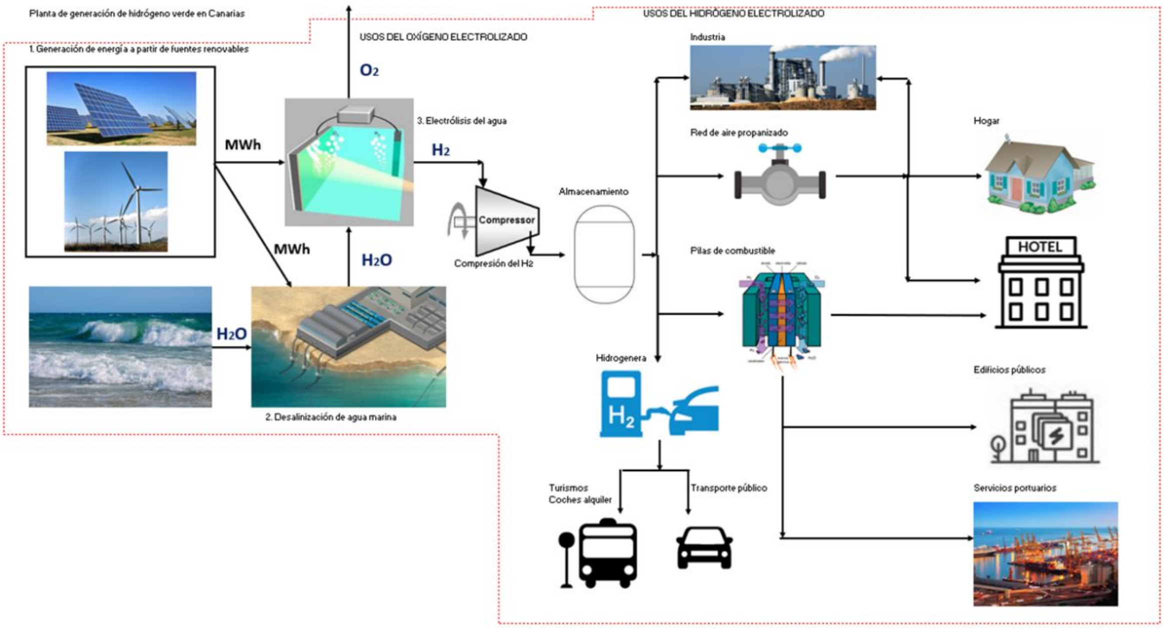

Figure 1. Flow diagram of the green hydrogen system

2.1- Logistic system

The logistics system associated with fuel transport is the main source of the carbon footprint of the green hydrogen scenario. Therefore, this section is important in the comparison of emissions with the current scenario based mainly on diesel, electricity, LNG and propane air network.

Tube-trailer trucks (500 kg) with hydrogen compressed to 300 bar are used. It takes 16.49 trucks carrying H_2 to move the same amount of energy as a truck carrying diesel. The factor is calculated from the payload and energy density of each. Diesel trucks with a payload of 23500 kg are assumed (Barckholtz et al., 2013; Webfleet Solutions B.V, n.d.).

The carbon footprint associated with fuel imports for the diesel scenario has been calculated taking into account a shipping transport from the port of Huelva, where the nearest refinery would be located, to the port of Las Palmas de Gran Canaria, 700.11 nautical miles (SeaRoutes, 2022).

3- Methodology

3.1- Functional Unit (FU)

The intended purpose of the product (H_2) is the generation and use of energy. A valid substitute for the fossil fuels currently used (mainly diesel) is sought. Therefore, the function that will be used to compare the impacts associated with the two scenarios will be: **"Impacts associated with the amount of energy generated".**

With the FU defined for each case studied as: (i) 660 tn/year of H2 for the carbon footprint of stage 1; (ii) 966 tn/year of H2 for the carbon footprint of stage 1 + 2; and (iii) 2841 tn/year of H2 for the carbon footprint of stage 1 + 2 + 3.

3.2- Quality of data

The most widely used international benchmarks for Carbon Footprint calculation are: (i) the British PAS 2050 standard for products or services (British PAS 2050, 2012); (ii) the GHG Protocols for organizations and for products, developed by the World

Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (WBCSD/WRI, 2004); and (iii) the ISO 14064 (organisation) (ISO 14064-1, 2019; ISO 14064-2, 2019; ISO 14064-3, 2019) and ISO 14067 (product and/or service) (ISO 14067, 2019) standards.

Essentially all these references classify assessments according to their scope (the first three refer to the organization):

- **Scope 1 (direct emissions).** This refers to GHGs emitted directly, for example, from the use of fossil fuels in machinery or company-owned vehicles, from the loss of refrigerant gases, or from chemical reactions that take place in the organization.
- **Scope 2 (indirect emissions associated with electricity consumption).** This refers to GHG emissions emitted by the production of energy required by the organization. They depend on the contracted electricity mix.
- **Scope 3 (other indirect emissions).** Refers to other GHG emissions attributable upstream or downstream of the organization. This includes, for example, emissions from procurement of materials and fuels, emissions from commercial travel, logistics or waste management of the products it sells.
- **Product scope (emissions over the entire life cycle of a product).** The rules derived from product life cycle standards, such as the ISO 14040 series, apply here, taking from each organization in the production chain the part of its environmental impact attributable to each product, in a differentiated manner and without double counting.

In order to maintain a complete, consistent, transparent and accurate study, all data for this carbon footprint calculation has been obtained following the methodology of

ISO 14064-1 (October, 2019) and the Greenhouse Gas Protocol corporate accounting and reporting standards.

4- Results

Table 3. Results of the carbon footprint in the Canary Islands

	Process	STAGE 1 (tn CO2eq)	STAGE 1+2 (tn CO2eq)	STAGE 1+2+3 (tn CO2eq)
Future system	Truck transport	121	184	518
	TOTAL:	**121**	**184**	**518**
Current system	Diesel production	477	1,151	3,166
	Propane air production	0.00	51	51
	LNG production	0.00	0.00	263
	Diesel use	2,335	5,638	15,509
	Propane air use	0.00	258	258
	LNG use	0.00	0.00	2,071
	Electricity use (Produced by third company)	3,644	3,644	3,644
	Truck transport	7	11	31
	Ship transport	425	622	1,828
	TOTAL:	**6,888**	**11,374**	**26,820**
	Decarbonization	6,767	11,190	26,302

As expected, the result of this carbon footprint study shows a higher CO_2e impact in the fossil fuel scenario than in the case of green hydrogen.

5- Conclusions and recommendations

From the point of view of the carbon footprint, it is concluded that the green hydrogen scenario is more favourable than the use of fossil fuels. Therefore, from this perspective, the development of the "CLUSTER HUB HIDROGEN RENEWABLE HYDROGEN CANARY ISLANDS" project is recommended. In any case, it would be advisable to carry out a more in-depth study including other environmental impacts that may also be affected by the project, such as: Cumulative Energy Demand (CED), Land Use (LU), Water Use (WU), etc.

The use of a seawater desalination plant implies: (i) a high energy demand (which is forecasted to be provided with green energy); and (ii) that the green hydrogen production system must be centralised. This is one of the main causes of the carbon footprint associated with the green hydrogen scenario and the transport of this fuel to meet the demand of the entire island. We need 16.49 times more trucks to transport hydrogen than diesel. In terms of transport, logistics and distribution, much research work remains to be done to achieve similar efficiency to that of fossil fuels. Therefore, it is recommended to consider the feasibility of liquefying hydrogen or using pipelines to facilitate transport and reduce its associated carbon footprint.

6- References

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