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Regiones insulares y autosuficientes para reducir la huella ambiental
Island regions and self-sufficient to reduce the environmental footprint

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Resumen-- **Urge sustituir el actual modelo de construcción con materiales de origen local e innovar tecnológicamente los sistemas de construcción convencionales en busca de la sostenibilidad, la eficiencia y la calidad de los productos. Territorios frágiles como las islas, capaces de albergar hasta el 10% de la población mundial, son una prioridad en el cambio del modelo económico global, con el objetivo de independizarlas del exterior. Las nuevas directrices del marco europeo apuntan hacia la economía circular, la descarbonización y la sostenibilidad. Este cambio requiere un profundo análisis del pasado y de la particularidad del entorno para sentar las nuevas bases del desarrollo futuro.**

El tejido empresarial del lugar, la tecnificación, la independencia energética y la producción de calidad propia serán los artífices del nuevo cambio. Esto puede aplicarse a cualquier tipo de territorio con el objetivo común de reducir su huella de carbono.

Palabras clave— Construcción sostenible; resiliencia insular; economía circular; producción local.

Abstract—**A pressing need for replacement of the current construction model using locally sourced materials and technological innovation of conventional building systems in the pursuit of sustainability, efficiency, and product quality. Fragile territories such as islands, capable of hosting up to 10% of the world's population, are a priority in the change of the global economic model, with the aim of making them independent from the outside world. The new guidelines in the European framework point towards circular economy, decarbonization and sustainability. This change requires a deep analysis of the past and the particularity of the environment to set the new bases for future development.**

The business fabric of the place, the technification, the energy independence and the production of its own quality will be the architects of the new change. This can be applied to any type of territory with the common goal of reducing its carbon footprint.

Index Terms— Sustainable construction; island resilience; circular economy; local production.

I. Introduction

An incipient paradigm shift in the Braudelian view of industrial production has been triggered in the aftermath of the COVID-19 pandemic, coupled with the subsequent economic and financial upheaval and the ongoing Ukraine-Russia conflict (Helleiner, 2000, p. 14). This has consequently paved the way toward local self-reliant communities, self-sufficiency, and closed-loop manufacturing (Helleiner, 2021, p. 954).

Furthermore, the growing social consciousness regarding the limitation of natural resources on our planet, experienced in the second half of the 20th century because of the oil crisis in 1973, has exacerbated awareness of the significance of environmental issues in the global economy (Ontiveros & Guillén, 2012) transcending environmentalism (Cameron, 2012), given that a worldwide annual 1-3% of GDP decrease is projected up to 2050 (Nordhaus, 2007). Most importantly, there has been a global paradigmatic change in which resource scarcity is one of the fundamental aspects (Martins, 2016) and in which self-

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sufficiency is reinforced considering the current context where the origin of the most basic expendable goods and their environmental cost is still unknown (Guallart, 2012). This circumstance is also applicable to the building trade, posing one of the great challenges of the 20th century owing to the energy deficiency of the constructed building stock and the search for nearly zero-energy emissions in one of the major energy-consuming sectors. As a result, it has been addressed as one of the key aspects of the European Green Deal (de Gatta Sanchez, 2020).

The building trade is likely to be one of the key drivers of the world economy, with a percentage impact of approximately 10% of world GDP and a growth forecast expected in the coming years based on demographic increase and the factor. Nonetheless, it is predicted to be inequitable in terms of regional levels of development and place of location, since most of the population (86%) is in the temperate zone of the Northern Hemisphere, Europe, and Asia (Klasen & Nestmann, 2006). Data on the world's construction industry reveal an expenditure of US$ 10.7 billion in 2020. However, it is predicted that its growth may reach up to 42% of world GDP by 2030 (Graham Robinson et al., 2021). In the European context, this sector generates around 9% of Europe's GDP and directly accounts for 18 million direct jobs. Furthermore, it is striking to note that 70% of SMEs are the biggest beneficiaries of the renovation sector within the EU. Similarly, in the case of Spain, a slight increase in the industrial contribution to GDP has been noted because of the economic crisis in the building trade, whose critical point was in 2014 (Fernandez, 2021).

With a view to minimising the construction sector, the Ministry of Public Works is focused on several areas. Firstly, use-related energy curtailment is sought by limiting energy demands to nearly zero-energy buildings, both new and renovated, in accordance with the regulation that will come into force in 2023 (Dir. 2010/31/UE, 2010 del Parlamento Europeo y del Consejo, de 19 de mayo de 2010; Dir. 2012/27/UE, 2012 del Parlamento Europeo y del Consejo, de 25 de octubre de 2012). A further goal is the improvement of product and system durability incorporated in buildings and the reduction of the negative impact associated with the life cycle and manufacturing, i. e. closed-loop manufacturing (Comisión Europea y Dirección General de Medio Ambiente, 2020), which is another key aspect in the transition to an eco-friendlier economy intended to reduce the environmental footprint of new construction projects. In this respect, the building trade, especially the residential sector, absorbs around 50% of all the materials extracted and is directly responsible for more than 35% of all waste generated in the EU. To address this issue, innovative measures should be undertaken to exploit existing materials at a local level.

II. ISLAND REGIONS

Island regions become a peculiar case of this need for resource efficiency and effectiveness (Vargas, 2018), whose self-sufficiency has been primarily determined by the physical condition of the location, the population, the rate of urbanisation and the proximity to a continent (Boudon, 1983).

When considering the world's island population, limited to towns with over 100,000 inhabitants, it is estimated to be home to 10% of the total population of our planet. It is therefore the habitat of more than 768 million people. In terms of islands, this corresponds to a total of 200 units of different sizes and nature scattered around the globe (Vargas, 2018).

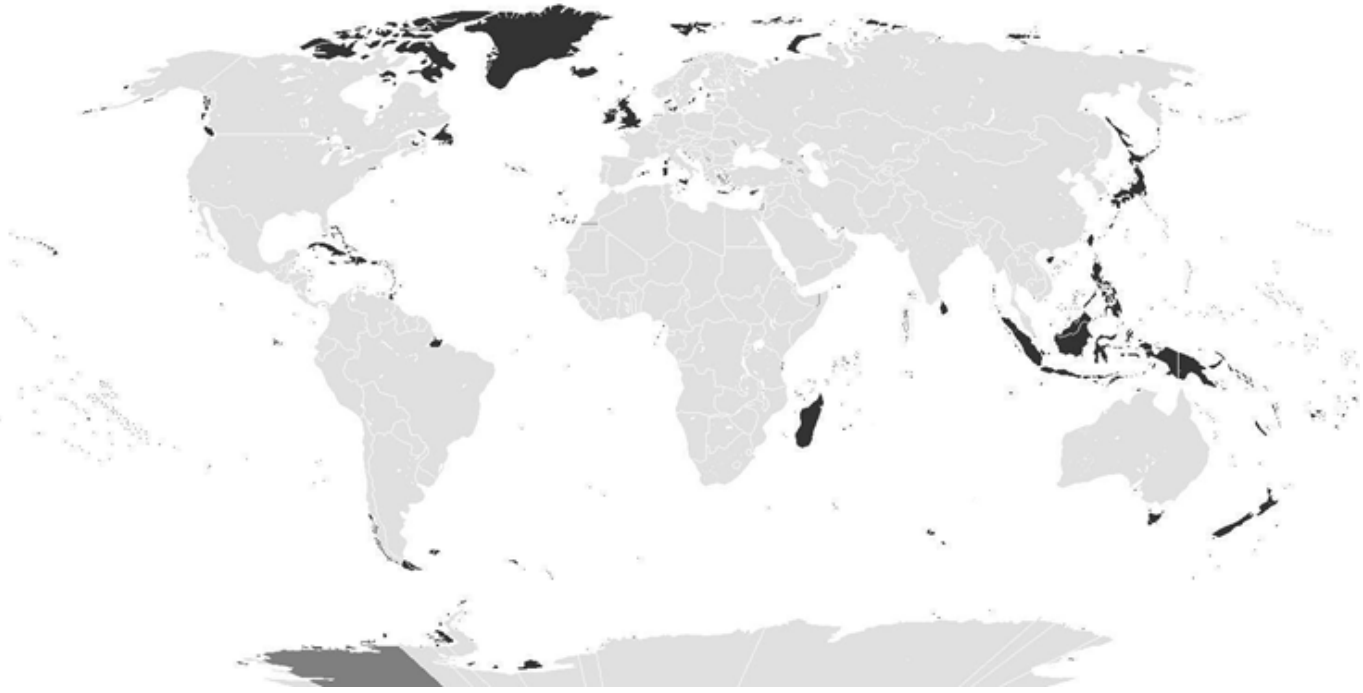


Fig.1. Global overview of island regions. Adapted from black-Map-Word and Borj

Fig. 2. European outermost regions.

Within the European Union, these island regions are the so-called outermost regions of the European Community, comprising islands from different countries which are distant from the mainland such as the Spanish territory of the Canary Islands, the Portuguese Azores and Madeira archipelagos, and the French overseas departments of Saint Martin, Guadeloupe, Martinique, French Guiana, Mayotte and Réunion, among others.

These island regions, with a joint population of 4.5 million inhabitants, benefit from differentiated treatment by the European Union, enabling legal guarantees to be strengthened and recognising the singularities of the islands.

Considering the specific status of the Outermost Regions (ORs) in the Treaty on the Functioning of the EU (European Union, 2004), the Commission presented for the first time a Strategy for the ORs (2022) with the aim of structuring and consolidating the cooperation between the EU institutions and these regions. The Strategy has been updated in 2007, 2008, 2012 and 2017, which has resulted in the Commission formulating proposals for adapting the legislation in line with the specific characteristics of the ORs in the various common policies. Recognition as exceptional regions is evident in an EU Communication entitled Putting People First, Securing Sustainable and Inclusive Growth, Unlocking the Potential of the EU's Outermost Regions (2022). Such Communication, once renewed, has strengthened the Strategy for the ORs given the serious repercussions of the coronavirus pandemic in these island regions, and it seeks to take advantage of the values of each area, maximising the potential of renewable energies and advancing toward the implementation of an economic sector based on the distinctive nature of these territories.

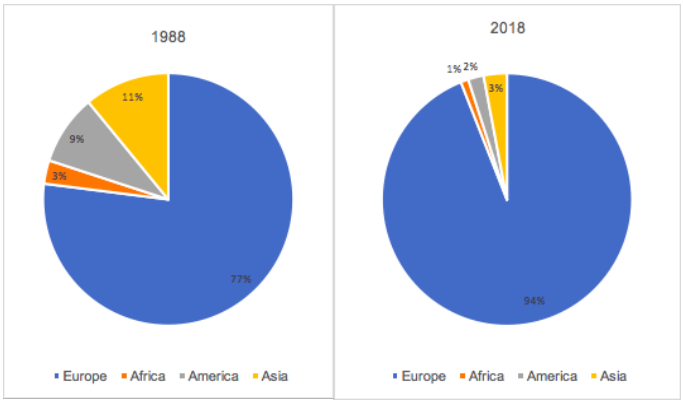


Fig. 4. Import share by continent in 1988 and 2018. CEOE-Tenerife/Corporación 5. ISTAC (Statistics on external trade in the Canary Islands).

These regions are frequently fragile due to the ecosystem vulnerabilities and their external dependence. Along with this, it can be noted a clear predominance of imports over exports, which account for 19-25% thereof. Likewise, their continuous growth, which quadrupled, shows the high level of external dependence of these islands as can be observed in the following Fig. 3.

Imports from the Canary Islands come predominantly from the European continent, a circumstance that has been consolidated over time, as could be shown in Fig. 4. The following graphs illustrate this trend, showing data from 1988, two years after Spain became a member of the European Union and the corresponding figures for 2018.

Whilst carriage of goods by road has the most significant impact at a national level, the insular nature of the Canary Islands allows maritime transport to play a leading role in commercial dealings. This could be observed in the map below at the global level (Fig. 5a) and, more specifically, at a local level (Fig. 5b).

As can be noted in Figure 6, traffic has intensified substantially with the buoyant economic situation of 2005, dropped with the economic crisis which peaked in 2009, and has progressively re-emerged until the present.

Regardless of marine transport as the most efficient means of transportation and its increase experienced between the years

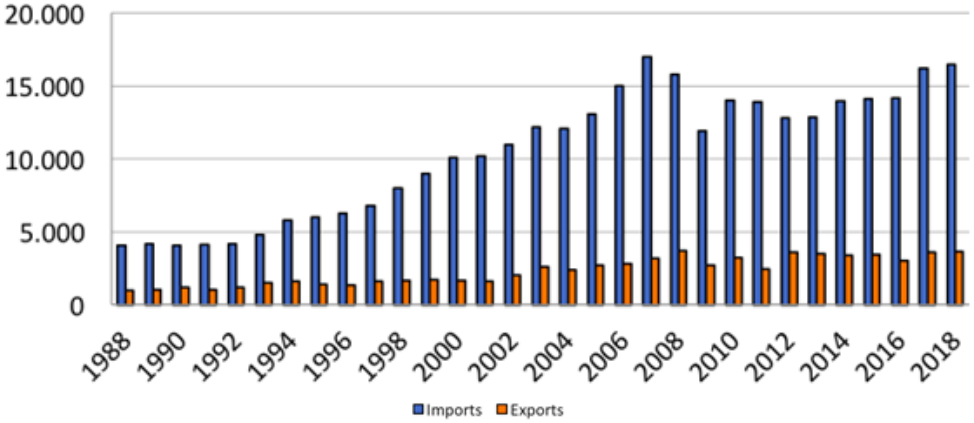
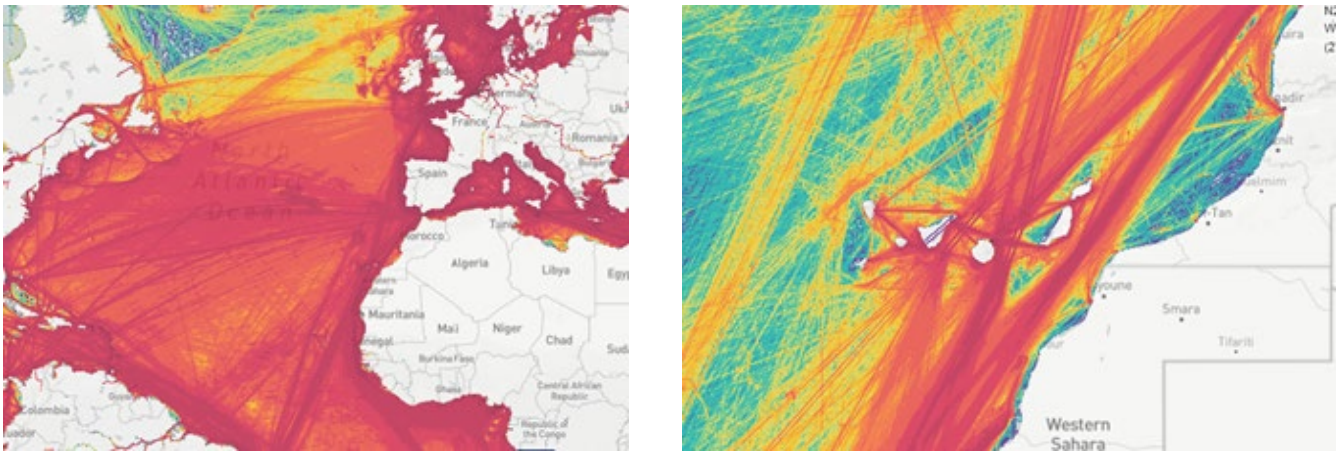


Fig. 3. Imports and exports in the Canary Islands (1988-2018).



(a) (b)

Fig. 5. Map of the maritime traffic intensity (a) in the North Atlantic; (b) in the Canary Islands archipelago

2013-2019, which has almost doubled its presence in the national final energy consumption by mode of transport (Ministerio de Transportes, Movilidad y Agenda Urbana, n.d.), it poses different environmental risks. These range from municipal and industrial dumpings to ecocatastrophes such as those suffered on different occasions on the Spanish coasts due to the Prestige, Mar Egeo, Urquiola or New Flame ships, which dumped large quantities of oil into the sea. Nonetheless, it can be extrapolated to all the outermost regions of the European Community and island regions of the rest of the world.

Regarding the Canary Islands, the environmental risks involve both transport embarking in the Canarian harbours and those travelling through the nearby maritime routes (Duran-Grados et al., 2018). In view of the external dependence of these regions, this mode of transport may also be considered as part of the construction process, given that the raw materials or processed products required for the sector are imported, being highly damaging to the environment (Blasco et al., 2014).

III. AN ECONOMIC MODEL: THE KEY TO CHANGE

This situation is exacerbated depending on the economic model. As can be seen in Fig. 7 (Piackova, 2013), the model in the Canary Islands is essentially geared towards tourism, with high rates of temporary employment and unemployment in comparison with other regions of Spain and the European Union. Hence, the predominance of the service sector has maintained its growth in a context of low industrial presence, after the economic crisis of the early 21st century.

The population ratio has doubled in the last sixty years to 2.2 million people, while the influx of tourists has reached 15.2 million in 2018, resulting in a 17-fold increase in population density.

In this regard, a housing shortage in the Canary Islands is contradictorily caused by this population increase (Parreño Castellano, 2002). A housing demand which affects 18,000 families has arisen due to the high unemployment rate, the lack of public investment in the last decade and the new tourism models such as holiday rentals, which have incorporated real estate properties originally designed for residents into the hospitality industry. Similarly, the infrastructure deficit illustrates the major role that the building trade plays in the local development of the Canarian archipelago. Whilst it is evident that the island territory may be fragile and limited, it will not be able to sustain the growth rates of the last seventy years, and it is therefore imperative to reflect on the limits to growth (Meadow et al., 1972).

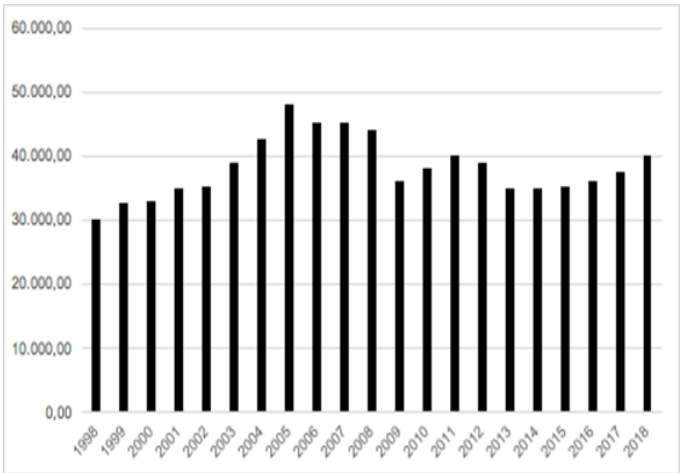


Fig. 6. Sea freight transport in the Canary Islands (kt). CEOE-Tenerife/Corporación 5. ISTAC (Compilation of maritime transport statistics).

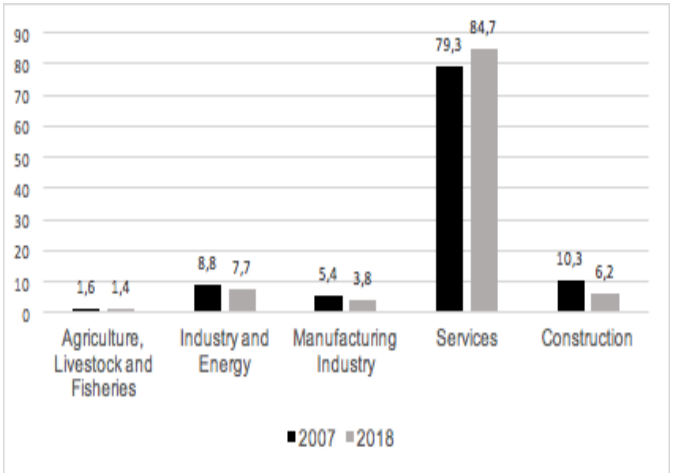


Fig. 7. Sectoral contribution to the 2007-2018 GVA of the Canary Islands. Note. Adapted data from Informe anual de economía Canarias 2018 de la Confederación Canaria de empresarios (Annual Report on the Canary Islands economy 2018 of the Canarian Confederation of Employers) and Istac.

IV. NEW PRODUCTIVE MODEL: INDUSTRY, ENERGY AND CONSTRUCTION

In view of the above, discussing a future with a circular or self-sufficient economy implies a global and integrating vision that must include more productive sectors than the building trade. This idea is triggered by the following factors: a need to import raw materials, the residential and infrastructure deficit, the physical isolation that an island region entails, and the absence of a business network that competes with the hospitality industry.

In this regard, the present circumstances demand the pursuit of higher levels of economic productivity through diversification, technological upgrading, and innovation in all productive sectors in the Canary Islands, inter alia, targeting labour-intensive, high-value-added industries. As a matter of fact, these are some of the key elements in the development and change of paradigm and vision that the Agenda Canaria de Desarrollo Sostenible 2030–Canary Islands Agenda for Sustainable Development 2030– is committed to (Gobierno de Canarias, 2021).

There are two crucial sectors to attain self-sufficiency: the building trade and the energy independence. The former is essential because is the driving force of the global economy and the latter because all industrial sectors, including construction, depend on it.

A. Energy independence

The energy sector in the Canary Islands is part of the industrial field and is less dependent on economic cycles. It is distinguished by the high cost of electricity generation and distribution, since, except for two of its islands (Tenerife and Gran Canaria), the other five are independent units. Production mainly relies on conventional energy sources, gas oil and gas diesel oil. All 13 installed power stations of the islands are thermal and only 2 of them are combined cycle ones.

In 2018, renewable energy sources accounted for only 11.8% of total energy consumption in the Canary Islands, of which 67% corresponded to wind energy and 29% to photovoltaic energy (Consejería de Transición Ecológica, Lucha contra el Cambio Climático y Planificación Territorial, 2019). This sector's potential to reduce its environmental impact is significant in view of the Canarian Government's 2030 goal of reducing energy consumption by up to 27% through an energy-efficient use as well as increasing the proportion of renewable energy sources (Gobierno de Canarias, 2021).

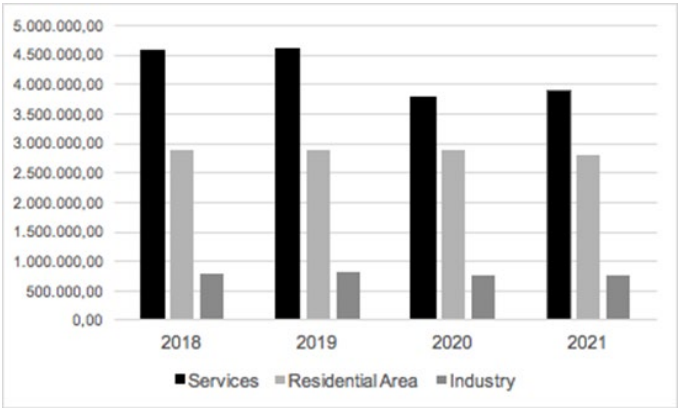


Fig. 9. Power consumption in the Canary Islands (2018-2021). Adapted from ISTAC (total power consumption by sector).

Although this is the aspiration and the objectives set, the current energy consumption figures indicate a long way from energy self-sufficiency.

From this perspective, a need arises regarding cutting the energy impacts associated with its consumption. Moreover, self-sufficient energy production is sought to be economically sustainable over time, while generating employment and causing a minimum environmental effect. In this respect, different island regions have been experimenting with this idea over the last decades and may serve as a good model. This list comprises, inter alia, the following:

- ToKelau Archipelago in New Zealand, generating energy from solar panels (Weissbach, 2017).
- Findhorn in Scotland, offering an ecovillage whose ecological footprint is half that of the UK national average. This self-sufficiency is achieved by different natural means, wind turbines and biomass (Temesgen, 2020).
- Masdar City, the world's first self-sufficient, eco-friendly city (Grey, 2018). It is in the desert, 17 km from Abu Dhabi and relies on an innovative strategy of wind protection and electricity generation through solar panels (Kumar et al., 2018).
- Samso Island in Denmark, North Sea. It provides energy through a combination of wind turbines and biomass power plants (Ramiller & Schmidt, 2018).
- The island of El Hierro in the Canary Islands archipelago. A world reference for its Corona del Viento power plant, whose hydro-wind power station supplies the whole island, thus making it self-sufficient in terms of energy (Frydrychowicz-Jastrzębska, 2018).

Consequently, there is an energy alternative in the interest of energy efficiency and autonomy in an insular framework, namely the territory of the Canary Islands, in which cases such as the Gorona del Viento power plant on the island of El Hierro can be extrapolated to other islands.

Aside from the research is constantly being conducted into renewable energy alternatives that may be of interest in different areas, for instance, geothermal energy (García de la Noceda Márquez & Instituto Geológico y Minero de España, 2015).

B. Industry and construction

Building trade is another sector of great relevance in the national context and in the Canary Islands. The service sector, in which the tourist economy plays a key role, employs 75% of the population. The agricultural sector and manufacturing industry, on the other hand, have little impact on the Canary Islands' GDP. Together with the former, the construction sector accounts for a large part of the island's active population, despite the economic crisis at the beginning of the 21st century and the health crisis of the year 2020. This is due to the dynamic nature of civil engineering, which accounts for a large part of public investment in housing construction, rising by 20% in 2018 compared to the previous year (Decreto 160/2021, de 30 de diciembre de 2021).

Nevertheless, the implications of the building trade go beyond energy consumption and show a high dependence on building materials regarding manufacturing, transport, installation, maintenance, and demolition consumption, along with the waste generated. Accordingly, the focus has shifted to two key aspects over the last few decades, meeting the paradigm shifts mentioned in the previous sections.

Firstly, it raises the issue of recycling existing resources and exploiting local natural resources present in each of the regions as an alternative for obtaining raw materials and reintegrating them into the commodity chain.

From a closed life-cycle production scenario, construction and demolition waste in the Canary Islands has increased by 13.6% during the period 2011-2018. This shows the potential for these materials to be reused and incorporated into the commodity chain. However, reuse and recycling practices are still far from a circular economy, with a recycling rate of only 36% in 2018 (Decreto 160/2021, de 30 de diciembre de 2021).

The other major challenge would be to reduce the impact associated with the construction and manufacture of components to a minimum. The building systems most used in the Canary Islands are reinforced concrete frame structures and enclosures of vibrated concrete block masonry. These have traditionally been in use from the 20th century to the present day. The extent of innovation has been very limited, except for the pertinent modifications to comply with the applicable regulations.

Building materials are therefore among the aspects that could be better addressed to reduce the environmental impact, in which concrete is the composite material most widely used and hence it is the material with priority for innovation. In relation to the latter, the cement clinker is the main imported material, although it shares the same tariff code as cement and therefore cannot be unbundled from each other. As for aggregate, it is imported even though the Canary Islands is the region with the lowest consumption per capita. It is mainly used as supporting structures of buildings which are fabricated with mixed-at-site reinforced concrete arcades using locally-manufactured prefabricated elements. Notwithstanding the potential interest in local aggregate extraction and the mitigation of environmental damage caused using concrete, local aggregate production is unable to satisfy the needs of this sector.

TABLE I
AGGREGATE CONSUMPTION IN CONSTRUCTION BY SPANISH REGION (KT)

Year	2017	2018	Δ 17/18	t *per capita*
Andalusia	14,3	15,1	5,9	1,8
Aragon	3,7	4	7,6	3,1
Asturias	2,7	2,9	7,9	2,9
Balearic Islands	2,7	2,9	7,1	2,6
Basque Country	5,5	5,8	6,3	2,7
Canary Islands	3	3,2	7,2	1,5
Cantabria	2,1	2,2	3,3	3,7
Castille and Leon	12,1	12,5	3,7	5,2
Castilla-La Mancha	6,3	6,6	5,2	3,3
Catalonia	20,1	21,4	6,3	2,8
Madrid	8,7	9,4	8,6	2,8
Extremadura	2,4	2,4	0,8	2,3
Galicia	8,5	9,6	13,3	3,5
La Rioja	1,3	1,4	8,1	4,5
Navarre	4,2	4,5	8,3	7
Region of Murcia	3	2,9	-5,8	1,9
Valencia	12,9	14	8,6	2,8
Total	**113,5**	**120,8**	**6,6**	**2,6**

V. CONCLUSIONS

Aiming to minimise natural and energy resource consumption with a view to meeting Europe's decarbonisation objective by 2050 involves seeking alternative economic models in response to the market's demands, albeit in an eco-friendly way.

More than 10% of the world's population resides on islands dependent on nearby mainland regions, and therefore efficiency-seeking is bound to positively impact these regions. In the Canary Islands, resource optimisation could be achieved given the high demand for imports in the early 20th century, the lack of business networks and the global market, which enables affordable goods on the market regardless of their origin.

The two sectors with the greatest impact on greenhouse gas emissions on such islands are the energy and construction sectors. Whilst significant progress has been accomplished in the energy market with the implementation of efficient renewable energy systems and local production, the building trade is still highly dependent on the exterior and the pressure on real estate development is still very heavy. This situation is founded on an economic model of tourism that emphasises the necessity of establishing limits to growth in accordance with the general directives of the Estrategia de Turismo Sostenible de España 2030–Spain's Sustainable Tourism Strategy 2030– (Ministerio de Industria, Comercio y Turismo & Gobierno de España, 2019) . In view that most constructions are made of concrete mixed at site and cast stone, hence optimising these two methods seems to become the major challenge to be tackled to reduce the environmental impact of the next building projects and its adaptation to circular economies.

In the Canary Islands, there is not enough local production to cover the demand for aggregates, so they must be imported from the mainland. As for cement, it is efficiently manufactured on the islands using the pozzolanic materials available, although clinker cement is still imported. In this regard, it is likely that the main challenges lie in restricting the use of cement by maximising the use of natural pozzolans, which are abundant on the islands. Along with this, the dependence of aggregates from external sources could be reduced by seeking alternatives to their use and incorporating recycled aggregates or similar materials from other industries, thereby reducing its associated carbon footprint.

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