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ENERGY, TOURISM AND COVID-19

AN ANALYSIS OF ENERGY CONSUMPTION TRENDS IN EU ISLANDS DURING THE PANDEMIC

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Abstract

This study analyses the linkage between electricity consumption patterns and tourism during the pandemic shock, investigating the real impact of touristic activities in terms of energy demand. It goes through the existing literature that connects tourism and energy consumption, focusing on the electricity sector, and is accompanied by a case study analysis. Nine islands and island groups with different touristic patterns and geographic representation were selected from six EU Member States and three marine regions. The results reveal correlations between reported lockdowns, drops in electricity consumption and tourist arrivals indicating the real energy impact of tourism. Tourism-related socioeconomic and energy indicators in the selected destinations show that the impact on electricity consumption was greater in those areas strongly characterised by a dependence on tourism (measured as a percentage of regional GDP).

1 Introduction

Tourism represents an important sector for employment and economic growth across the European Union (EU), and the environmental dimension of tourism is steadily gaining attention. The carbon footprint of tourism is somewhere in the order of 5-10% of global emissions, according to various estimates made prior to the COVID-19 pandemic, when the trend was still increasing (UNWTO, 2019). Thus, collaboration and research are needed to tackle the rising emissions of the sector, involving sustainable, responsible, and ethical tourism, and to understand the real impact of touristic activities in terms of energy demand and climate impact.

In the EU, tourism is a significant industry, making a significant contribution to the total economic activity. There are approximately 2.3 million businesses in the sector, primarily small and medium-sized enterprises (SMEs), employing an estimated 12.3 million people. In 2018, the 'travel and tourism' sector directly contributed 3.9% to the EU's Gross Domestic Product (GDP) and accounted for 5.1% of the labour force. Taking into account inter-industry spill-over effects with other sectors, the tourism sector may in fact account for an estimated 10.3% of GDP and 11.7% of total employment[1]. Currently, the European Commission as part of its industrial strategy and the European Green Deal seeks to improve the sustainability and resilience of EU tourism and unveiled the transition pathway plan for tourism in 2022[2]. Moreover, via the Clean Energy for EU Islands initiative, supports the clean energy transition of the more than 2,200 inhabited European islands.

The outbreak of the COVID-19 pandemic disrupted societies in an unprecedented way on a global scale. On the one hand, COVID-19 caused many deaths, putting great pressure on national health systems, while on the other hand, it was a shock to the economic and energy sectors, as well as to the physical environment. Within and across countries, the impact of the pandemic was highly unequal from region to region. Some territories and population groups have been affected worse than others: particularly those which are more vulnerable. In terms of economics, the effect of the crisis varied according to location, at least in its early phases. Exposure to tradable industries, exposure to global value chains, and specialisation, such as tourism, are all differentiating factors (Allain-Dupré et al., 2020). Indeed, the pandemic's toll of uncertainty regarding travel bans and sanitary obligations represents a challenge for the tourism sector, its economic model and its preparedness to absorb shocks, but also an opportunity to rethink and redesign the sector sustainably. The change of touristic patterns imposed by the pandemic offers a unique opportunity to study energy patterns in areas that attract significant numbers of tourists relative to the local population, as well as their regional economic effects. Several island regions of Europe, highly dependent on tourism activities, have come to a standstill, and their recovery to pre-pandemic levels is neither easy nor quick (McCann et al., 2021). The recovery may also differ in places with a strong focus on international tourism versus those with a strong focus on regional and national recreation. The type of tourism (such as mass tourism, relaxation or nature tourism), as well as geographic accessibility, will play a part in the recuperation (Böhme et al., 2020).

The electricity sector was deeply impacted by the pandemic as several factors contributed to reduced demand during the first wave of the pandemic. This was mainly evident with gig industrial electricity consumers that worked at minimum operation levels, while in some cases they were forced to close (Lazo et al., 2022). The pandemic restrictions represented a challenging combination of supply and demand shocks (del Rio-Chanona et al., 2020). This resulted from the restrictions to economic activity: restaurants, shopping malls, and, in some countries, factories were closed to prevent the virus from spreading (IEA, 2020). The restrictions' impacts were profound almost immediately; the reported daily data from mid-April 2020 showed that countries in full lockdown experienced an average 25% weekly drop in energy consumption, while those in partial lockdown experienced an average 18% weekly decline (IEA, 2020). Overall, electricity consumption globally faced a decrease of 7.6% (Buechler et al., 2022). The changes in everyday life due to the pandemic restrictions have affected where, when, and how energy – and electricity – is consumed. This disruption emerged during the peak of the pandemic, but is still apparent during the recovery (Ntounis et al., 2022).

[1] European Parliament Fact Sheets on the European Union: https://www.europarl.europa.eu/factsheets/en/sheet/126/toerisme

[2] See: https://single-market-economy.ec.europa.eu/news/transition-pathway-tourism-published-today-2022-02-04_en

Along with the electricity sector, the tourism sector, which is considered a key energy consumer, was negatively affected by the pandemic restrictions. Due to lockdown measures, travel prohibitions, cancelled bookings and local logistics, most tourist locations were forced to suspend operations during 2020 as a result of the COVID-19 epidemic (Orîndaru et al., 2021). In order to help the sector to recover, and to support tourism and hospitality companies, the EU proposed a series of economic instruments such as direct aid packages in the form of subsidies, tax reductions, and guarantees, and measures to protect employees (Sanabria-Díaz et al., 2021).

The specific characteristics of the pandemic period have given us the opportunity to investigate its impact on locations in six different EU member states (Cyprus, Denmark, Greece, Italy, Portugal, Spain) by analysing tourism-related socioeconomic and energy indicators in comparison with pre-COVID business as usual periods. In the context of this study, a thorough review was performed to investigate the existing literature that connects tourism and energy demand and consumption, focusing on the electricity sector. Many recent works have attempted to evaluate the impact of the confinement measures on the energy sector; nevertheless, the focus has not been on regions where tourism plays a significant role in the local economy. Thus, this study attempts to identify the disruption of patterns in energy consumption and tourism due to the pandemic, along with their drivers. This has allowed us to calculate, by using proxy indicators, the impact of the pandemic on the final energy demand of the selected locations. The results can be used as to gain an understanding over the real impact of touristic activities on energy demand, assist in assessments of sustainable tourist practices and set the base for discussion of energy decarbonisation projects in EU islands that face seasonal fluctuations in demand due to touristic activates.

The report is structured as follows. Section 2 offers an overview of the impacts (both negative and positive) of COVID-19 in terms of the economy, tourism, energy, and ecosystems within the EU. In Section 3, the connection between tourism and energy demand in touristic areas is investigated via analysis of the reviewed literature. Section 4 focuses on the key factors that link tourism and energy usage and provides evidence from selected case studies of EU islands. Section 5 discusses the differences and similarities in the observed trends, and finally, Section 6 summarises the outcomes of the study.

2 Impact of COVID-19

According to the United Nations World Tourism Organization (UNWTO), the pandemic created severe socio-economic impacts on every sector of the economy, and the tourism sector faced the greatest challenges, with all the segments of its value-chain affected. UNWTO has estimated that the total financial loss of the sector since the start of the pandemic is more than EUR 3 trillion. 100 million direct tourism jobs were put at risk, with women and young employees most at risk. It was also observed that the forms of sustainable tourism which are related to wildlife were also negatively affected by the pandemic, as ecotourism activities, in most cases, serve as a financing mechanism for conservation; consequently, there was a funding cut for biodiversity conservation (UNWTO, 2020).

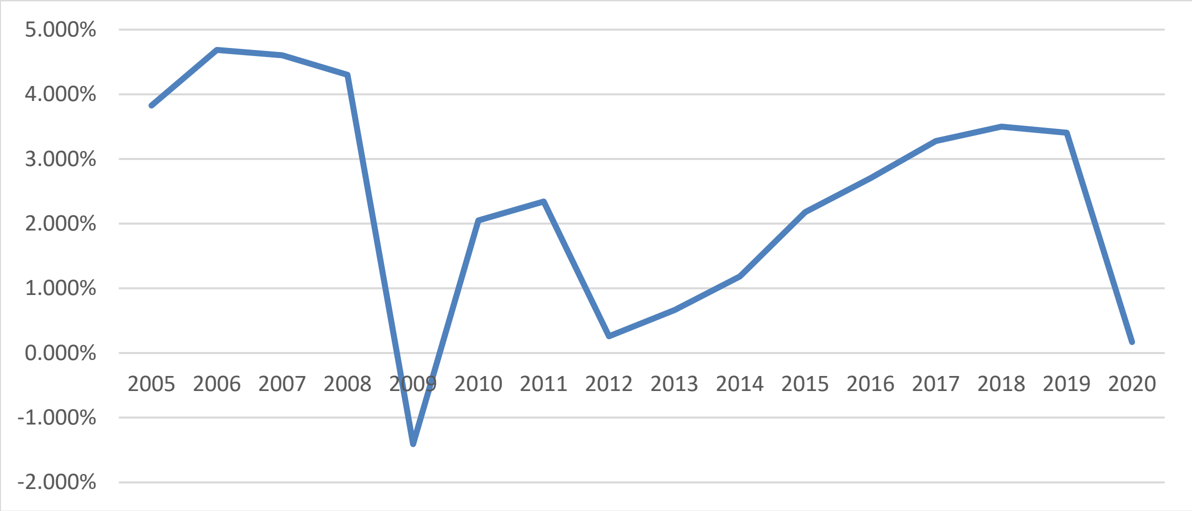
2.1 The socio-economic impacts

The pandemic resulted in a global recession. In the EU, the real GDP fell by 5.9% in 2020 while the impacts of recessions are not equally spread among demographic groups. Lessons learned from the 2007-2008 global financial crisis and recent scholarly work in Europe and the US confirm that there is a significant unequal distributional impact, with low earners suffering more than high earners (Bitler and Hoynes, 2015; Hoynes et al., 2012; Shibata, 2021). Consequently, the pandemic is expected to have similar economic and social impacts to those experienced during recessions, like growing income inequalities and unemployment. However, given its different anatomy – virus spread, deaths and containment measures – it also had great, and more evident, impacts on social fields like health and housing and, of course, human wellbeing (Darvas, 2021). Additionally, while economic shocks usually create stress on financial markets, the economic inertia of the pandemic impact may test the resilience of the real economy and institutions (Kolluru et al., 2021).

As recession was inevitable, European governments adopted emergency policies to protect household income, employment, and support the most vulnerable economic sectors that were hit hard by the pandemic. Projections show that disposable income in the EU will fall by 4.3% to 9.3%, depending on the macroeconomic scenario followed. It is also expected that there will be an increase in the number of poor households (Almeida et al., 2021). Energy poverty that was on a decreasing path since 2012 increased in 2020 on average across EU (Koukoufikis and Uihlein, 2022). While the EU median employment income is expected to fall by 5.2%, the income gap since the breakout of the pandemic is growing: it seems that low wage earners will suffer proportionally income losses 3-6 times larger than high wage earners (Darvas, 2021). Eurostat's data indicate that 8% of low educated workers lost their jobs, while there was a 3% growth in jobs for workers with university degrees. Workers with an intermediate education level suffered job losses of about 5% (Eurostat, 2020). In addition, income loss due to unemployment appears to be concentrated in vulnerable sub-groups, such as women and young and temporary workers. **Figure 1** shows the profound negative effect of the pandemic on the Gross Disposable Income (GDI) of households. While the growth rate of GDI has been rising since 2012, the year 2020 was characterised by a GDI growth rate of 0.172%, which is really low in comparison with the previous years.

Health inequalities also worsened during the pandemic. As there is strong evidence that social factors such as education, employment status, income level, gender and ethnicity have a strong influence on an individual's health, it is not surprising that health inequalities have escalated since the start of the pandemic. Research on health inequalities during the COVID era is still limited, however it is evidence that health inequalities escalated also as a result of the intensification of income inequalities Although the disease reached every group in society, the poorer income groups were more affected, and their physical and mental wellbeing put at greater risk (ALLEA-FEAM, 2021; Bush, 2018).

Figure 1. Growth rate of household's Gross Disposable Income (EU-average)

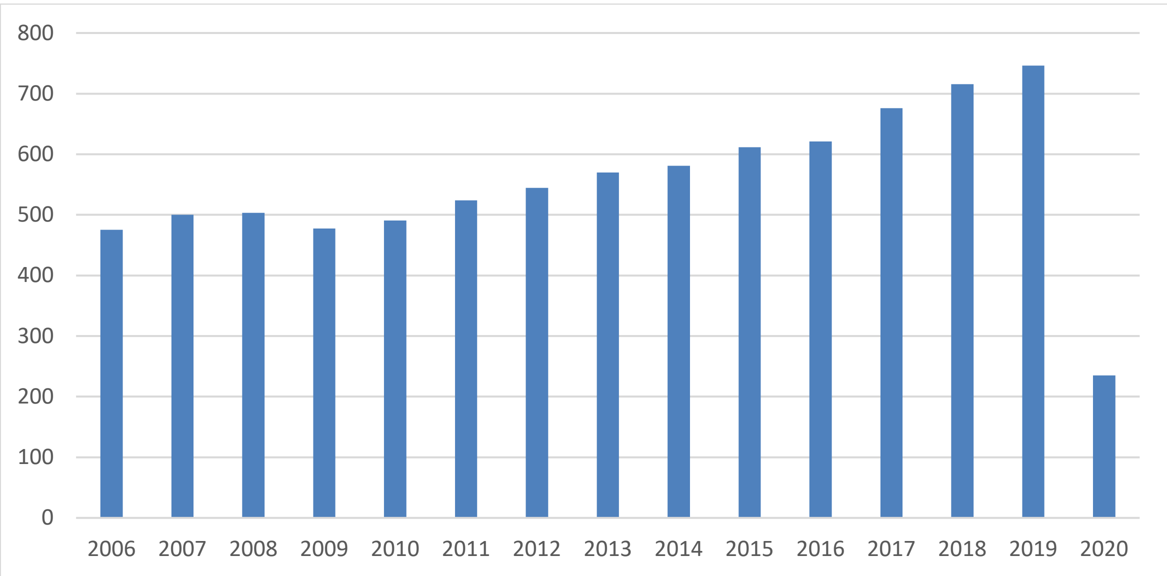


Source: Author's elaboration on Eurostat data

2.2 Impact of COVID-19 on the tourism industry

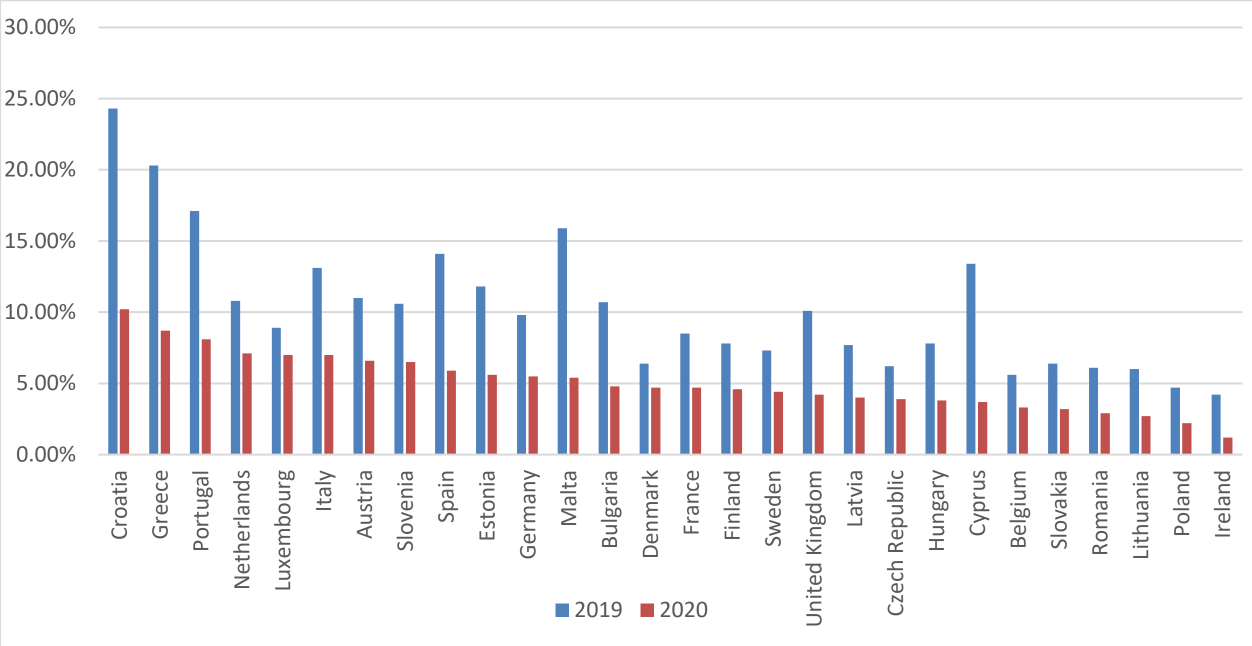
In the EU, from January 2020 until May 2020, tourism faced a decrease in revenues of about 58%; during the whole year of 2021 the revenue decrease was about 70%. In this context, 100 million direct tourism jobs were put at risk, with women and young employees at most risk. International tourist arrivals in Europe from April 2020 to March 2021 decreased by 82%. It is expected that tourist arrivals will not recover to pre-COVID levels earlier than 2024 (ETC, 2021).

Figure 2. Share of travel and tourism's total contribution to GDP in European Union Member States (EU 28) in 2019 and 2020



Source: Statista data retrieved from World Travel & Tourism Council

Figure 3. Share of travel and tourism's total contribution to GDP in European Union Member States (EU 28) in 2019 and 2020

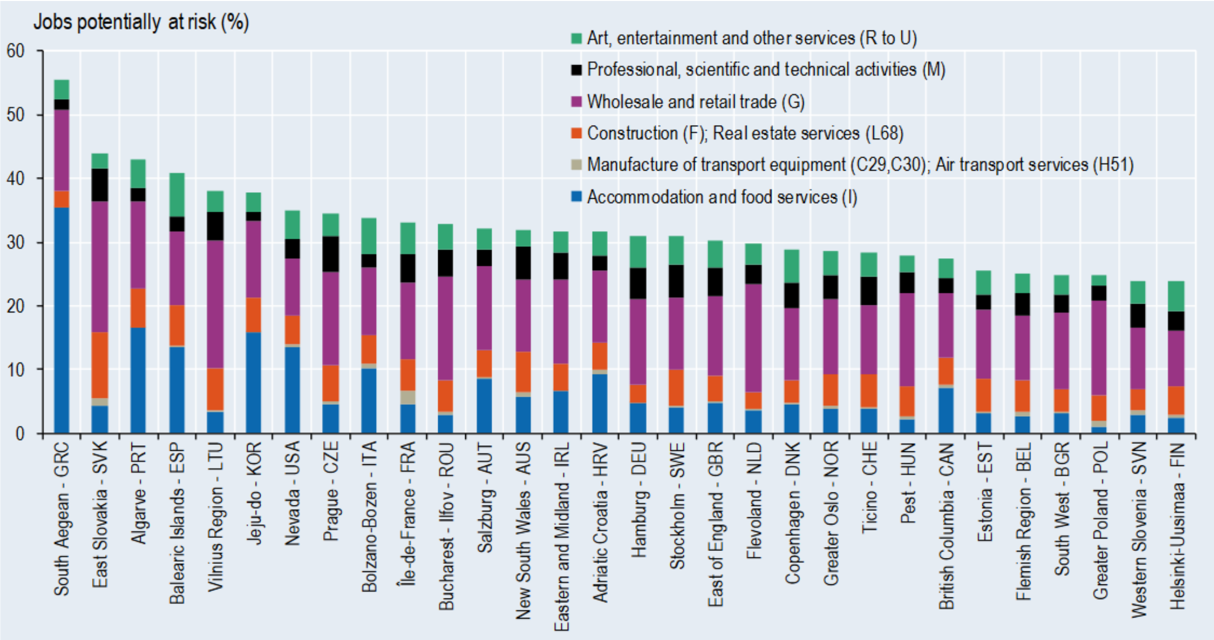


Source: Statista data retrieved from World Travel & Tourism Council

The impacts of the pandemic on tourism were not equally spread among European countries, or among regions within countries. The pandemic had the most devastating economic effects on regions where the local economy is dependent on trade and global value chains. So, touristic regions of European countries were more economically affected than the others (Allain-Dupré, et al., 2020). In **Figure 4**, it is interesting to observe the most affected regions – regarding the share of jobs potentially at risk – by country, along with their sectoral composition. The largest share (55%) of jobs potentially at risk, was observed in the South Aegean in Greece, with most jobs at risk positioned in the tourism sector (accommodation and food services), while in Central Greece, only 22% of jobs were potentially at risk. In touristic regions of Spain and Portugal, similar patterns were also observed. It is clear that most of the regions facing the greatest unemployment risk are characterised by heavy tourism, indicating the higher impact of the pandemic on the tourism industry. A crucial element of the unemployment risk posed by the pandemic can be found in the aftermath of economic crisis; in Europe, and almost in every economic sector during the recovery period of 2012-16, temporary employment contracts increased greatly. So, the deterioration of the quality of regional employment, along with the fact that the tourism sector is often characterised by unregistered work, can explain the great shares of jobs at risk in tourism regions. However, the tourist regions of northern and eastern European countries appear to be less affected than those of southern Europe. This difference may be attributed in the importance of Small and Medium-sized Enterprises (SMEs) in local economies as SMEs have been more vulnerable to the effects of the pandemic, facing greater revenue losses due to global value chain pressures and smaller reserves (Allain-Dupré, et al., 2020).

Finally, it was also observed that the forms of sustainable tourism which are related to wildlife were also negatively affected by the pandemic, as ecotourism activities in most cases functions as a financing mechanism for conservation; this meant, in effect, a funding cut for biodiversity conservation.

Figure 4. Jobs potentially at risk



Source: OECD, 2020

2.3 Impact on Energy Demand

Government policies to face COVID-19, impacted human lives and changed peoples' activities worldwide. The everyday change that the pandemic brought is reflected in the electricity systems, and in general in energy demand patterns.

Looking some years back, electricity demand from the 1990s until 2008 was increasing in Europe (Bahmanyar et al., 2020). However, the first EU policy[3] on reducing energy consumption was adopted in 2007, including the first directive on energy efficiency aiming to 9% energy saving until 2016. Crucial energy efficiency policies at EU level, were also, the introduction of Energy Label Directive[4] and Ecodesign Directive[5], as well as the EU Emissions Trading System[6]. So, in this landscape of energy policies, it is inevitable that especially after 2008 energy demand/consumption patterns are driven, to a large extend, by EU policies; keeping the levels of energy demand relatively steady, except of a small reduction in 2009, as an aftermath of the economic crisis of 2008 (Tsemekidi Tzeiranaki et al., 2019). Apart from the energy policies that determine to a great extend energy demand, socio-economic characteristics of households, such as disposable income, household composition, demographics etc., play a significant role in national energy demand profiles (Borozan, 2018).

In this complex reality, that the pandemic caused a shock in every aspect of socio-economic life, the energy demand in EU decrease relative to 2019 for about 6% in 2020 and 3.5% in 2021 (IEA, 2021). Nevertheless, the drop in demand did not affect equally the various fuels and regions. Moreover, energy commodity prices have reached unprecedented high levels across Europe. Gas prices in October 2021 were 400% more expensive

[3] The energy and climate '20-20-20' targets aiming at smart, sustainable and inclusive growth. The '20-20-20' targets were aiming at: reducing GHG emissions by 20% compared to the 1990 levels; increasing renewable resources to cover 20% of the final energy consumption; and, reducing by 20% the final energy consumption especially through energy efficiency improvements.

[4] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU.

[5] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

[6] A carbon market aiming in reducing GHG emissions: [https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en].

than in April 2021. According to IEA (IEA, 2021), EU is expected to see rapid recoveries in economic output and energy demand across most sectors. However, recoveries will not begin in earnest until the second half of 2022 because of continued impacts of the pandemic.

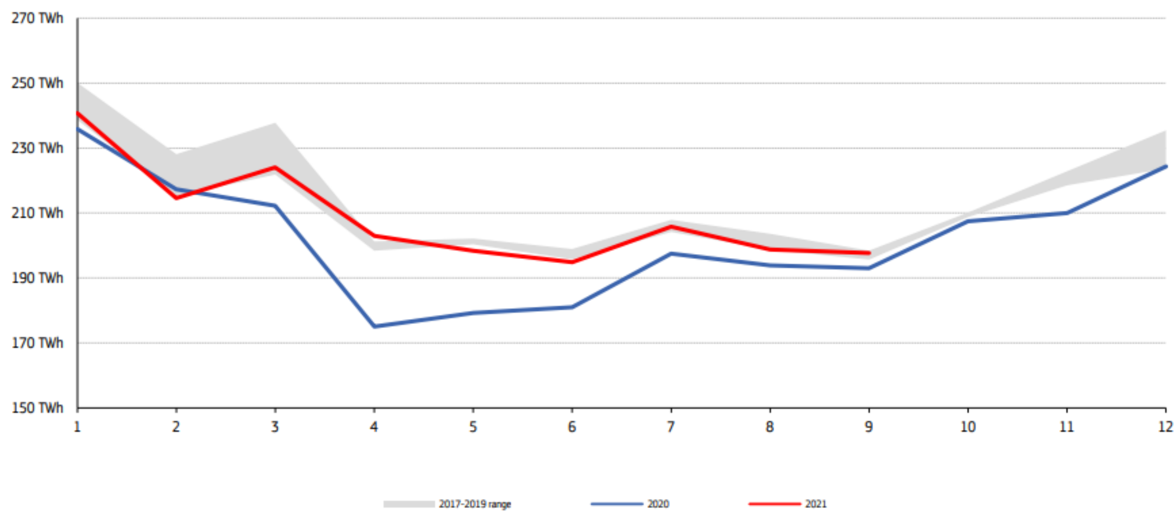
2.4 Impact on Electricity

The lockdowns, curfews, business closures and travel restrictions had an impact on the energy system in EU. Many countries reported a significant reduction in electricity consumption in both the commercial and industrial sectors, which introduced numerous challenges to electric utilities and system operators CEER, 2021).

Despite, the adverse trends of energy demand cause by the pandemic: on the one side, shutting down of production sectors (industrial and commercial sector) reduced electricity demand, while on the other side, working from home increased household electricity demands; overall, the demand in EU decreased by 7% (CEER, 2021; Hauser et al., 2021). The impact is most visible in the first half of 2020; in March, April, May and June, when strictest lockdown measures underwent. **Figure 5** shows the monthly electricity consumption decreased sharply, compared to the corresponding months in 2019. In the second half of 2020 and in 2021, the correlation between reported lockdowns and drops in electricity consumption is less visible. The third quarter of 2021 brought electricity consumption in Europe at pre-pandemic levels of the third quarter of 2019 (Quarterly Report on European Electricity markets, 2022). The energy demand decline was greater in regions were the lockdowns last more and in regions with more stringent measures 2019 (IEA, 2020). On the contrary, Sweden, which was the only EU country that had no lockdowns, had the same levels of energy demand in 2020 as in 2019, and in fact, in certain points in time energy demand levels were even greater than the same period of 2019 (Bahmanyar et al., 2020).

COVID-19 had also an unprecedented impact on electricity market prices across several countries. The electricity wholesale market prices had fallen over the first half of the 2020 by 40%. However, after the third quarter prices have been recovered to the pre pandemic levels. In 2021 electricity prices reached all-time highs in European markets, registering a 200% increase from October to April 2021 (Quarterly Report on European Electricity markets, 2022). Although other factors such as the weather conditions have been highlighted. It noted that the price surge was largely driven by global gas demand following the recovery of economies worldwide from the COVID-19 pandemic, and to a lesser extent by an increase of the CO2 price CEER, 2021).

Figure 5. Monthly EU electricity consumption 2017-2021



Source: (*Quarterly Report on European Electricity markets*, 2022)

Table 1. Fall in electricity consumption per month in March-June 2020, compared to the same month of 2019 in selected EU countries

	March 2020	April 2020	May 2020	June 2020
Austria	-6.5%	-11.8%	-7.1%	-6.5%
Belgium	-6.8%	-13.2%	-9%	-3.8%
Czech Republic	-1.2%	-11.6%	-11.6%	-4.8%
Germany	-3.1%	-9.3%	-10.6%	-6.9%
Greece	n/a	-9.8%	-6.9%	-13.5%
Hungary	n/a	-9.1%	-10.5%	-8.7%
Lithuania	-3%	-7.2%	-6%	-3.9%
Malta	-1.6%	-9.8%	-8.3%	-17.9%
Portugal	n/a	-14%	-16%	-8%
Slovenia	n/a	-16.5%	-15%	-13%
Spain	n/a	-18%	-13%	n/a

Source: (Effects on the Energy Sector, 2021)

2.5 Impacts on Environment, Biodiversity and Wildlife

Apart from the socio-economic impacts of Covid on societies, it ultimately affected the environment and climate. The slowdown or even the shutdown of many productive activities such as industries, factories, and businesses, as well as the restrictive measures on humans' transportation and activities (anthropause[7]) caused a drop in greenhouse gas emissions. As transportation accounts for around the 20% of global CO2 (Akinsorotan et al., 2021; Ritchie, 2020; Rutz et al., 2020) - on the one hand, cars, motorcycles, buses, trucks and taxis, contribute over 74% of the transportation sector's total greenhouse gas (GHG) emissions, and, on the other hand, airplanes contribute over 11% to the sector's total GHG – it is not a surprise that by restricting societies those emissions would drop down (Ashraf et al., 2021; Ibn-Mohammed et al., 2021; Ritchie, 2020). More precisely, according to International Air Transport Association (IATA) estimated that in 2020 there was a 65.2% reduction in air passenger kilometres in Europe.

Consequently, as GHG emissions dropped, the air quality in European countries improved. The European Environment Agency (EEA) claim that a greater decrease was noticed in the concentrations of nitrogen dioxide (NO2), the gas which is highly produced by road transport (EEA, 2020).

In harmony with the reduction of air pollutants and the improved air quality, there was also, a noticeable reduction in environmental noise, especially road traffic noise, which is highly correlated to devastating health impacts. Additionally, there is evidence that the reduced traffic, combined with the lockdowns, increased the rate of people exercising outside (EEA, 2020). Finally, during the restraining period, tourist destinations, which usually generate great emissions because of energy consumption, generated less emissions from energy consumption, as well as less waste and less water consumption (Ashraf et al., 2021).

[7] Anthropause refer specifically to a considerable global slowing of modern human activities, notably travel (Rutz et al., 2020).

On the negative side, the most profound effect of Covid is the increase in the amount of medical waste. The use of protective equipment (gloves and masks) by every single person around the world, as well as the extensive use of self-testing kits, is raising great concerns about waste management. Pressure on waste management authorities is also posed by the increased internet shopping, which increased the domestic waste of each household during the lockdowns (Ashraf et al., 2021). Great concerns are also raised by the extensive use of disinfectants on roads, shopping centres and commercial or even residential properties; research shown that extensive use of these kind of substances may result in ecological imbalances, even in urban areas (Ashraf et al., 2021; "COVID-19 and EEA, 2020; Ibn-Mohammed et al., 2021).

Physical ecosystems are characterized by great complexity, consequently, the impacts on ecosystems and wildlife are complex at local and regional levels. The anthropause inevitably allowed animals to travel and roam freer across the natural environments including the oceans (Rutz et al., 2020). However, the pandemic created new challenges; as governments had to financially support national health systems, to balance the 'loss' they had also to cut the budget from other sectors. If we add up the economic loss from the ecotourism activities that in most cases work as a financing mechanism for conservation, it is inevitable that biodiversity conservation faced a great shock. Thus, the environmental protection agencies faced a great funding deficit, creating great pressure and unemployment on conservation sites, and surrounding communities. On the one hand, much of the management/supervision staff got fired because of the funding drop, on the other hand, the staff that should continue working and patrolling the protected areas went home due to lockdowns. In these circumstances, along with the socio-economic impacts and inequalities, we already discussed, many local communities - especially those facing food scarcity – had no other choice to survive rather than the illegal poaching of the wildlife, which was unattended (Akinsorotan et al., 2021; Anand and Kim, 2021; McNeely, 2021). Except from poaching, the nature exploitation in poor areas increased with devastating effects on local ecosystems (McNeely, 2021).

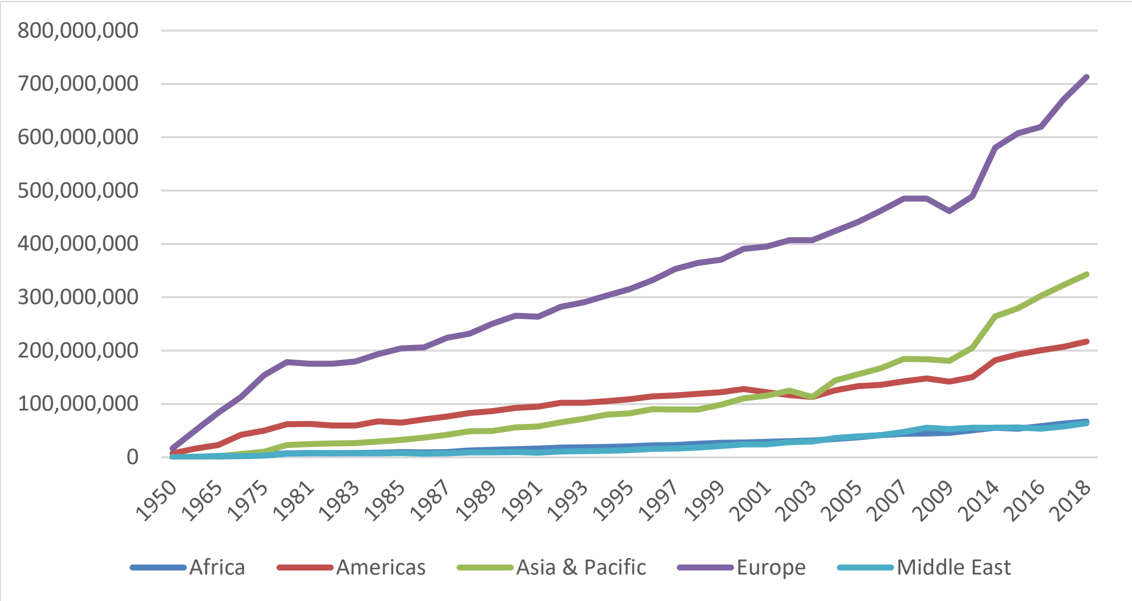
3 The connection of tourism and energy demand in touristic areas

Expectedly, the impact of COVID-19 on aviation and transport services in general has led to a knock-on effect on the tourism industry, which has been affected severely by the confinement measures. To deeper understand the impacts of touristic activities, it is important to depict the multitudes of social and economic aspects as well as the interrelation with other sectors. Following this consideration, we investigate various aspect of tourism impacts on society. The impact of tourism and the related energy consumption, as part of the touristic activities, is the subject of the next subsection.

3.1 The socio-economic aspects of tourism and energy consumption

The past decades, globally, and more specifically since the end of World War II, tourism has been a key driver of socio-economic progress. Job and income generation are the main aspects of this progress. Since the mid-20th century EU countries acquired the largest share of international tourist arrivals and as a sector leader EU has a key role to play on sustainable tourism policies formulation (**Figure 6**).

Figure 6. International Tourist Arrivals by World Region



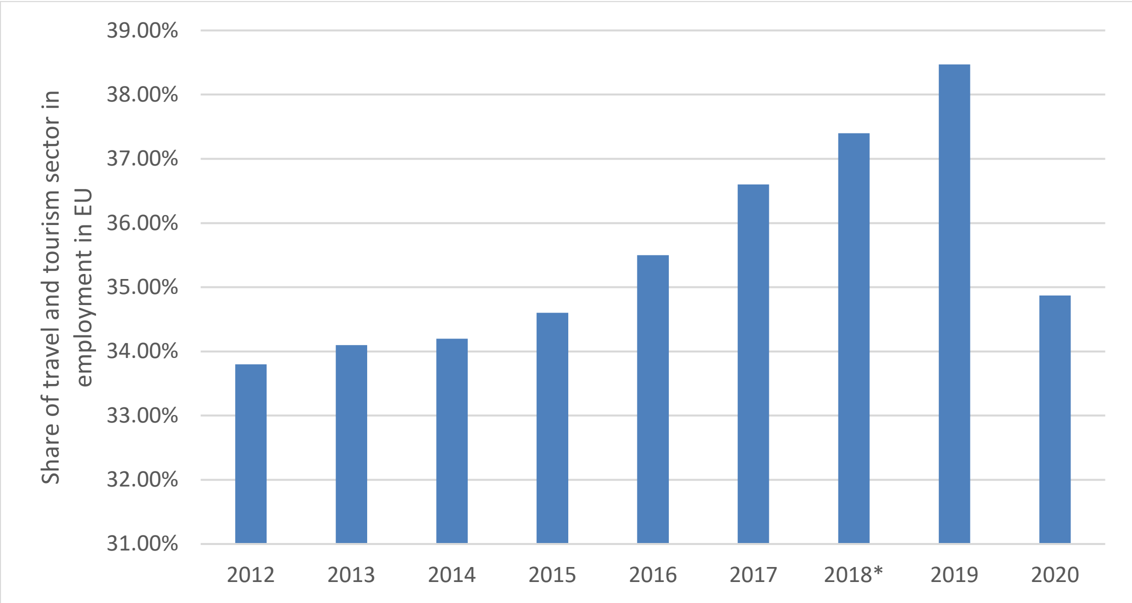
Source: Our World in Data

To assess the contribution of tourism sector to economic development in certain areas, it is required a deep understanding of the linkages between tourism and other sectors, as well as the identification of its impacts.

The impact of tourism in economic development has been an issue of examination for several researchers (Alfaro Navarro et al., 2020; Antonakakis et al., 2019; Haller et al., 2021). Tourism inevitably contributes to economic development in EU. In 2019, it is estimated that 2,191 billion euros was contributed to EU gross domestic product (GDP) by travel and tourism sector. Greece's and Croatia's tourism sector seems to have the greatest contribution in GDP, with a share of 20.03% and 24.3% respectively for 2019. Other EU countries with a remarkable share of tourism in GDP is Portugal (17.01%), Malta (15.9%) and Spain (14.1%). Additionally, tourism sector in EU is of great importance regarding employment. In 2019, tourism enterprises employed about 38.47 million persons.

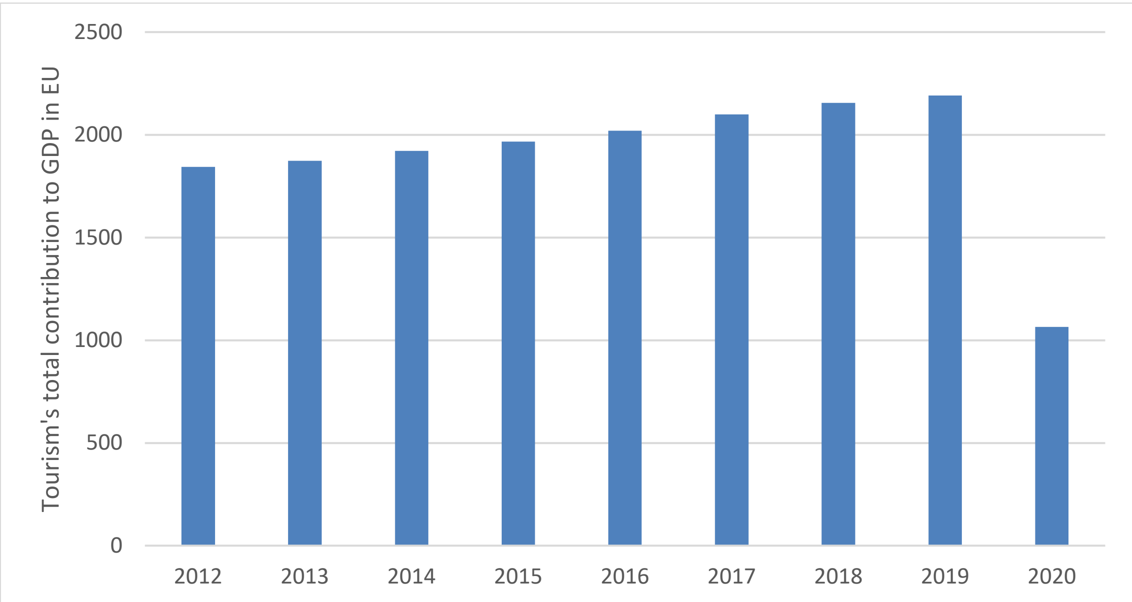
However, employment in the tourism sector should also be analysed through the perspective of Sustainable Development Goals and more specifically goal 08: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all". In this context, some researchers tried to focus on the impacts of tourism growth in terms of wage inequality. It is observed that Eastern EU countries have lower wages - as a share of the contributed GDP - in the sector compared to the rest EU, while at the same time the wages of the tourism sector are even lower compared to the other sectors of each country (Peña-Sánchez et al., 2020). In this context, according to the last available data of 2020, accommodation and food services activities in the EU is characterized by 14% of unregistered work. For some countries the percentage of undeclared work in tourism is disturbing: 50% in Cyprus, 37% in Malta and 33% in Greece (Williams and Horodnic, 2020). So, despite that the contributions of the tourism sector in GDP are great, in terms of decent employment, we should say that the tourism sector is characterized by inequalities among EU countries as well as by inequalities within the countries. Even though the tourism sector is characterized by locality, there are insufficient indicators that evaluate the impact on the regional economy.

Figure 7. Travel and tourism's total contribution to employment in EU 2012-2020



Source: Statista data retrieved from World Travel & Tourism Council

Figure 8. Travel and tourism's total contribution to GDP in Europe 2012-2020



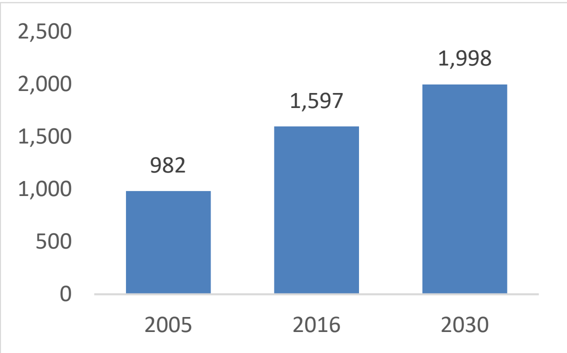
Source: Statista data retrieved from World Travel & Tourism Council

Another aspect of tourism impacts on societies refers to environmental quality. Tourism is a significant contributor to greenhouse gas (GHG) emissions. In 2016 75% of the tourism GHG emissions is generated by traveling activity, while 20% comes from accommodation activity (through heating, air conditioning, maintenance of bars, restaurants, pools, etc.) (Halleux, 2017). On the one hand is the impact of tourism activities on the environment, on the other hand, the climate crisis causes great pressure on tourism activities leading to greater energy demands for heat or cooling. Along with the constantly growing energy demand due to the long-term trends of energy consumption growth, assessing the link between tourism and electricity consumption seems essential.

The research that indicates the correlation between electricity consumption and tourism is vast (Katircioglu et al., 2014; María del P. Pablo-Romero et al., 2017; Qureshi et al., 2017), as well as the correlation between electricity consumption and economic growth (Antonakakis et al., 2019). However, despite the undeniable correlation, the causality between electricity consumption and economic growth is still a matter of research. We may say that the first interest in exploring this causality emerged in the 1970s, as it was triggered by the energy crisis at that time (Zhang and Zhang, 2020). In the last decades, where environmental policies and new energy development are redirecting scenery in the energy sector, examining correlation as well as causality seems rather essential.

Following the previous literature, we focus on the relationships between electricity consumption and tourism in the light of the pandemic. More specifically, tourism is regarded as one of the most fossil fuel-dependent industry. Indeed, is small islands it is observed that tourism-related use of fossil fuels is critical (Nepal et al., 2019).

Figure 9. Carbon footprint of tourism-related transport worldwide 2005-2030 in million tonnes



Source: Statista data retrieved from UNWTO; Various sources (ITF, IEA, IATA, Amadeus, 2019)

3.2 Patterns linking tourism and energy usage

The tourist sector as an economic activity, from an energy needs perspective, primarily includes the services of transportation and hosting of tourism consumers, along with the required infrastructure. The tourism-induced energy consumption can have a direct and significant impact with respect to the carbon dioxide emissions and the overall energy consumption of a region, as shown for the case of Cyprus (Katircioglu et al., 2014), an island nation highly dependent on tourism (direct and indirect contribution on Cyprus' economy accounting for nearly 14% of GDP in 2019). The energy consumption of the tourist sector, the evolution of it over the years and the driving forces that influence it are not homogeneous across countries, as studies have shown. Note that methodological differences and deviations in the statistical reporting framework do now allow for direct comparison between different countries, as regards the impact of the tourist sector. Meng et al. (2017) showed that the tourism industry has low carbon and energy intensities with respect to the other Chinese industrial sectors, while Tang et al. (2018) concluded that tourism is the most efficient of all the industrial sectors of the Wulingyuan area in China. On the contrary, (Sun, 2014) found that the tourism sector performs worse than the average economy of Taiwan while Perch-Nielsen et al. (2010) concluded that the tourism sector was four times more carbon intensive with respect to the average of the Swiss economy. The high reliance on air transport as a major contributor to the carbon intensities of the sector was underlined in the latter studies. Transport and accommodation are recognized as the two main contributors to tourism CO2 emissions (75% and 21%

respectively, as of 2008), therefore the structure and operation of these two subsectors in a region have a high impact on the overall performance of the sector with respect to energy usage.

Apparently, the link between energy usage and tourism is more significant in tourism-based economies. As IRENA points out the intensive use of energy in tourism is a serious concern for the long-term sustainability of the sector, as many tourism-based economies rely heavily on fossil fuels for the energy supply (Taibi et al., 2014). In the study of Trull et al. (2019) the authors incorporated an index that relates the arrivals and departures of passengers on a daily basis into an electricity forecasting model and tested it on the Balearic islands. Using the developed electricity forecasting model the electricity demand predictions were notably improved leading to an increase in the supply of electricity from sustainable sources and an equivalent reduction in CO2 emissions of around 200 Kg/hour (note that for the Balearic Islands the tourism activity reaches up to 45% of the GDP and the fossil fuelled power stations represent half of the electrical generation). Worldwide, the island economies where tourism represents a fundamental economic driver and where the energy supply is dominated by fossil fuels (especially for non-interconnected islands) have a particular interest in investigating alternative and more sustainable pathways.

The energy mix of the power sector is crucial when assessing the impact of tourism since electrical consumption is strongly linked to it and, specifically, to the structure of the hospitality sector. The study by Pablo-Romero et al. (2019) shows that there is a growing relationship between electricity consumption in the hospitality sector and overnight stays. Increased overnight stays in hotels with higher star ratings, increased presence of foreign tourists and higher income levels tend to the increase the electricity consumption in the hospitality sector, while electricity prices have no significant effects. In Bianco (2020) authors highlighted the impact on electricity consumption of the increase of alternative hospitality structures from 2000 onward in Italy. Both studies proceed to similar recommendations with Tsai et al. (2014), who highlighted the high carbon footprint of international tourist hotels compared to other typologies of hotels in Taiwan, that is the necessity of rethinking the accommodation structure and business model.

An important factor that affects the electricity consumption of tourism is the regional weather conditions. Temperature is among the most influential exogenous variables, especially for short term load forecasting, and the relationship between temperature and load is suggested to be non-linear and asymmetric. Regarding the non-linearity of the relationship, this is due to the fact that there is an interval where the electricity load hardly changes with temperature variations while outside this interval electricity demand changes with both increasing and decreasing temperature (Valor et al., 2001). The asymmetric relationship is based on the fact that one degree increase in the case of high temperature is not necessarily equal to the effect of a one-degree decrease for a low temperature. Also, it has been observed that temperature has a different effect on the load in the case of working and non-working days and different in workplaces and private residencies. This is one of the reasons that electricity demand time series exhibit significant seasonal variation. In the study of Pablo-Romero et al. (2019) authors considered the effect of temperature in their models by using the indices Cooling Degree Days (CDD) and Heating Degree Days (HDD) and concluded that global warming will induce not only increasing electricity use by the hospitality sector of tourism but also that higher temperature increases will tend to strengthen these effects.

4 Analysing the disruption of patterns linking tourism and energy usage during the pandemic

4.1 Case studies and method of analysis

In this section, we will try to highlight the dynamics between tourism and electrical energy consumption, as they emerged within the pandemic, for selected locations around Europe. The selection of the case studies locations resulted from the preceding literature review that indicated that tourism, in specific regions, although being a sector of high socio-economic importance, at the same time it generates great pressures, primarily environmental, through energy consumption. In the pandemic era, characterized by the restrictions of human mobility all over the world, we hypothesized that the tourism-energy dynamics would be signified and the patterns more clearly identified.

To assess this hypothesis, European regions, which are known as "tourism destinations" were selected. The case study locations are all islands, as their geographical isolation allows for better monitoring of the input and output touristic fluxes and the visitors' mobility; they are restricted within the boundaries of the islands or the archipelago. Furthermore, touristic islands tend to be regions highly dependent on the tourist industry and, often, on fossil-fuel electricity generation (primarily for the electrically isolated islands). The selected case studies (9 islands or island regions across 6 EU countries (see **Figure 10**) vary in terms of geographical location, size, climate, economic dependency on tourism, type of tourism, and electrical power system infrastructure.

As a first step of the analysis, we go through a concise description of each location, focusing on the demographical, climatic, touristic, economic, and electrical power characteristics, and then we present regional Covid-19 indices (stringency index[8] and mobility) that define the specific circumstances. The Covid-19 stringency index is directly related to the restrictions that each country imposed as a response to the pandemic and, therefore, varies from place to place. Due to these restrictions, tourist visits around the world changed significantly affecting the regional mobility, which is represented by the mobility index.

The impact of the pandemic era on the tourism–energy dynamic is then highlighted by presenting the electrical energy and the visitors' arrivals, per case, for the period from 2016 to 2021. For the case of electricity consumption, the historical data of the period from 2016 to 2019 are compared to the pandemic years 2020 and 2021 to expose their differences in the trends. To decouple the influence of regional weather conditions from electricity consumption, regression analysis with heating and cooling degree days[9] was performed. A baseline regression model was created, per case study[10], over the baseline period (2016-2019). We use this model to "predict" the energy that would have been used over the period of active restrictions measures (2020-2021) if the selected island had been operating as it did over the baseline period. In that way we were able to diminish the weather effect on the energy data, so we could better assess the impact.

For the touristic activity in the selected regions, we choose to use the proxy index of the visitor's arrivals by air which sufficiently captures the regional tourism seasonal and annual trends. Comparing the arrivals and the electricity consumption data over the years of the study we aim to highlight the occurring pattern and the extent of its disruption during the two pandemic years.

The investigation of the disrupted pattern is accompanied by an attempt to determine how this disruption differs from one location to another. It is expected that the unique characteristics of each region, and primarily the economic structure and tourist model, can result in a different impact on the pandemic and responses from the

[8] The stringency index is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest) (Hale et al., 2021).

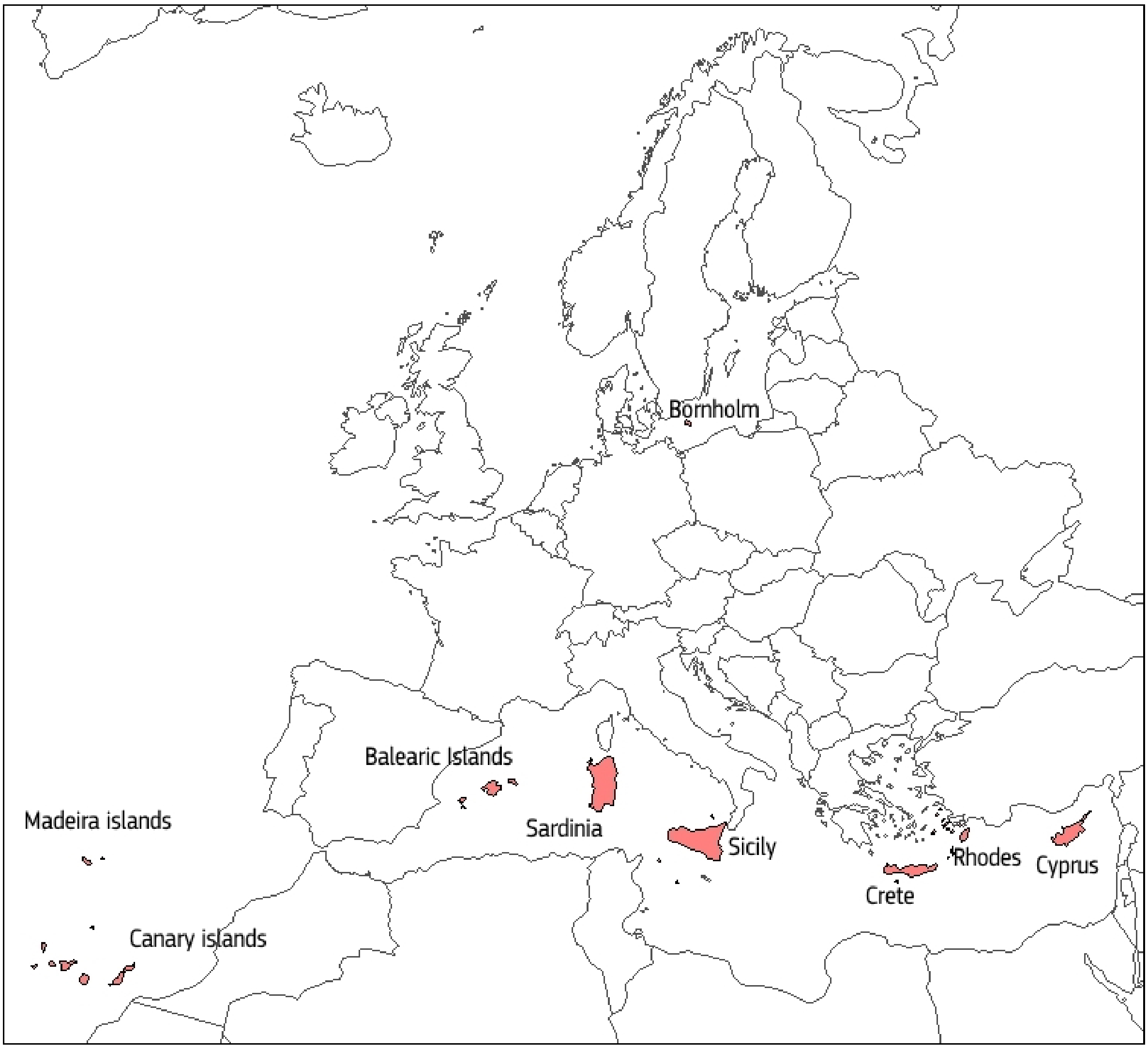
[9] A 'degree day' is a unit of measure for recording how 'hot' or how 'cold' it has been over a specific period. Heating degree days give an indication of the energy consumption required for heating (in cold weather); cooling degree days give an indication of the energy consumption required for cooling (in hot weather).

[10] Only exception is the island of Madeira where degree days data were not available at Eurostat database (nrg_chddr2_m).

society. The data gathered for each case study are, thus, used to identify these characteristic factors that led to the different disruptions and responses observed in the previous analysis.

For this study, data were retrieved from various sources. Electrical consumptions are estimated using data available from national/regional system operators. The data concerning the contribution of the tourist industry in electrical, or generally, the energy consumption of each region was not available in most cases, or when available it was not at the required granularity. Degree day data retrieved from Eurostat for the period from 2016 to 2020; the monthly data used for the training of the regression models. The missing data series of 2021 were filled from degreedays.net using similar assumptions regarding the base temperature[11]. Flight arrivals were available for most of the cases through the EUROCONTROL dataset, nevertheless, for Sardinia the arrival data were retrieved from the Italian national statistical agency, and for Bornholm from Eurostat.

Figure 10. EU Islands under study



Source: Authors' elaboration

[11] The calculation of CHDD relies on the base temperature, defined as the lowest/highest daily mean air temperature not leading to indoor heating/cooling.

4.2 Balearic Islands (ES)

4.2.1 Overview

Balearic Islands (Spanish Islas Baleares, Catalan Illes Balears) is an archipelago in the western Mediterranean Sea and an autonomous community of Spain coextensive with the Spanish province of the same name. The archipelago lies 80 to 300 km east of the Spanish mainland. There are two groups of islands. The eastern and larger group forms the Balearics proper that includes the principal islands of Majorca (Mallorca) and Minorca (Menorca) and the small island of Cabrera. The western group is known as the Pitiusas and includes the islands of Ibiza (Eivissa) and Formentera. The total area of the Balearic Islands is 4,992 km^2 with a population of 1,215,174 (population density 240/km^2).

On the Balearic Islands, the climate is Mediterranean, with mild winters and hot, sunny summers, a bit sultry but tempered by sea breezes. At sea level, the average low temperature is around 8 °C in January and February while the average high reaches 30 °C in July and August.

Balearic Islands are one of the main tourism regions in Europe with 68.4 million nights spent in tourist accommodation (located 7th at the relevant list)[12] and 16.8 million visitors in 2019. Tourism model is sun and beach, and is dependent on international tourism - especially from northern Europe (in 2019 84% of the visitors were international primarily from Germany, United Kingdom and Northern Europe)[13] while the main transport preference is by air (around 96% of arrivals as of 2016).

The region has a crucial role to the Spanish tourism economy, and it is among the largest in terms of international visitors and in terms of tourist accommodation. In 2016, one out of five tourists who visited Spain, chose the Balearic Islands[14]. Tourism has been the fundamental economic activity of urban growth and financial development of the archipelago. The largest value-added contribution in Balearic Islands stems from tourism, with 36% in the sector of wholesale and retail trade, transport, accommodation, and food activities in comparison to 26% of Spain, for the years 2016-2019[15]. As the contribution of the tourism sector in regional GDP is stable (33% in 2019), during the years 2016-2019, the employment rate in tourism related jobs is, also, stable at 40%[16].

The whole Balearic archipelago is currently electrically connected with Spain peninsula electricity grid. As of 2020, most of the locally produced energy was coming from combined cycle power stations (natural gas), followed by gas/fuel generation. The renewables had a share of 6.7% followed by coal-fired generation (which in 2019 had a share of 45.2%)[17]. The contribution of the link between the Spanish Peninsula and the Balearic Islands covered almost a third of the Islands' electricity demand in 2020.

4.2.2 COVID-19 Restrictions

In Balearic Islands the restrictions imposed to restrain the pandemic expansion, had no major differences from the restrictions imposed by the central government of Spain.

In **Figure 11.** Stringency Index and Mobility for Balearic Islands 2020-2021, we observe the trends of mobility[18] in transportation, parks, and recreation in comparison with the stringency covid index[19] of Spain for the period

[12] Tourism statistics at regional level, Eurostat, September 2022, https://ec.europa.eu/eurostat/statistics-explained/

[13] https://www.dataestur.es/en/global/tourism-movement-at-borders-frontur/

[14] Balearic Islands Regional Context Survey, Balearic islands tourism board, 2017

[15] National Institute for Statistics of Portuguese

[16] National Institute for Statistics of Portuguese

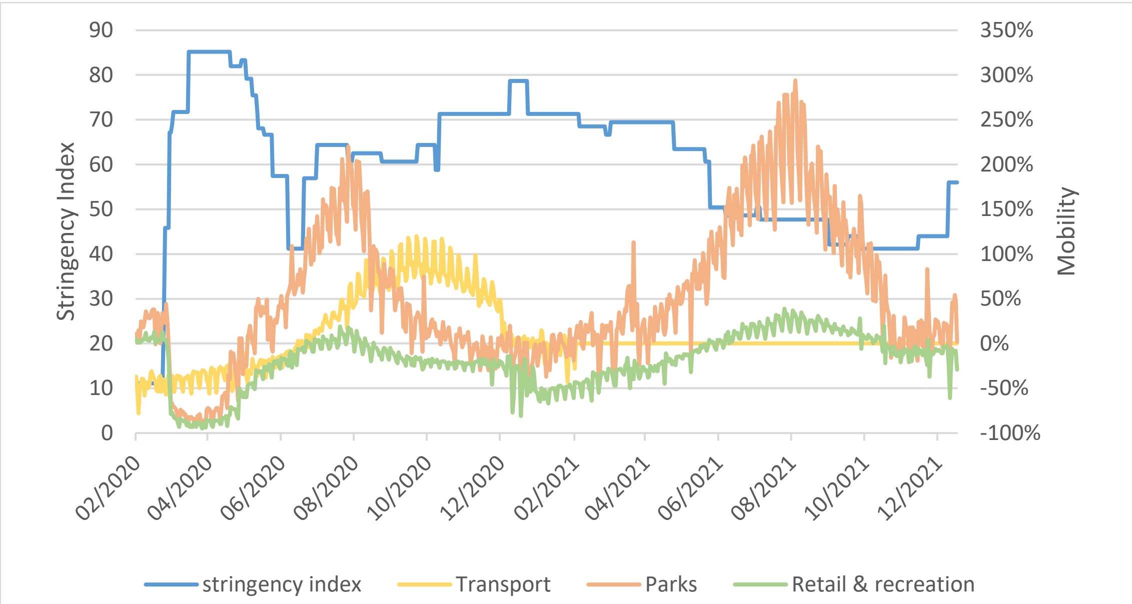
[17] Electricity production on the Balearic Islands with coal fell by almost 90%, Press release, RED Electrica de Espana, March 2021

[18] Data retrieved from Community Mobility Reports of google available at: https://www.google.com/covid19/mobility/

[19] Stringency index available at: https://ourworldindata.org/grapher/covid-stringency-index

from 15/02/2020 until 31/12/2021. The baseline used to interpret the mobility data was the median value for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020 (Hale et al., 2021). During this period, the mobility for public transportation (subway, bus, and train stations) was reduced on average for 28%, the mobility for visiting public places (national parks, public beaches, marinas, dog parks, plazas, and public gardens) was reduced on average by 27%; and finally, mobility for recreation (restaurants, cafes, shopping centres, theme parks, museums, libraries, and movie theatres) was reduced on average by 29%, which is the highest observed reduction for this period. By closely observing the data, we can claim that as Balearic Islands are a famous tourism destination, so, it was expected that places of recreation and retail to have the greatest mobility reduction for two reasons: first and foremost, restriction measures were applied mainly in places with high rush of people and, secondly, as traveling was either prohibited or restricted, tourists were not arriving in the region. The effect of tourism is obvious if we look in the summer period of 2020, where, despite that the stringency index was in the same levels as the autumn period of 2020 the mobility trends were higher.

Figure 11. Stringency Index and Mobility for Balearic Islands 2020-2021

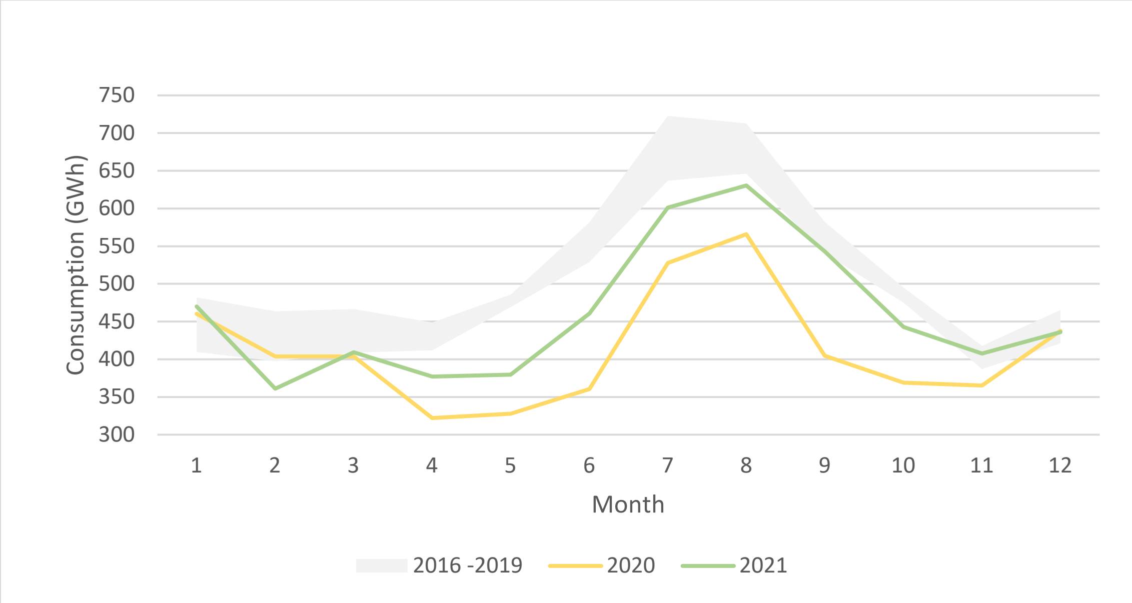


Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.2.3 Tourism and electricity linkage in Balearic Islands

The electricity consumption in the Balearic Islands during the period 2016-2021 is presented at **Figure 12** where a significant reduction is obvious in 2020, especially during the beginning of the touristic season. The consumption in June 2020 decreased 33.5% compared to the same month in 2019 and it is the largest decrease (compared to 2019) during the examined period. In 2021 the reduction in consumption was much less compared to 2020, indicating a rebound to the 2016-2019 levels. In September 2021 energy consumption increased 34% compared to September 2020 levels, which is the largest increase in month consumption since 2016.

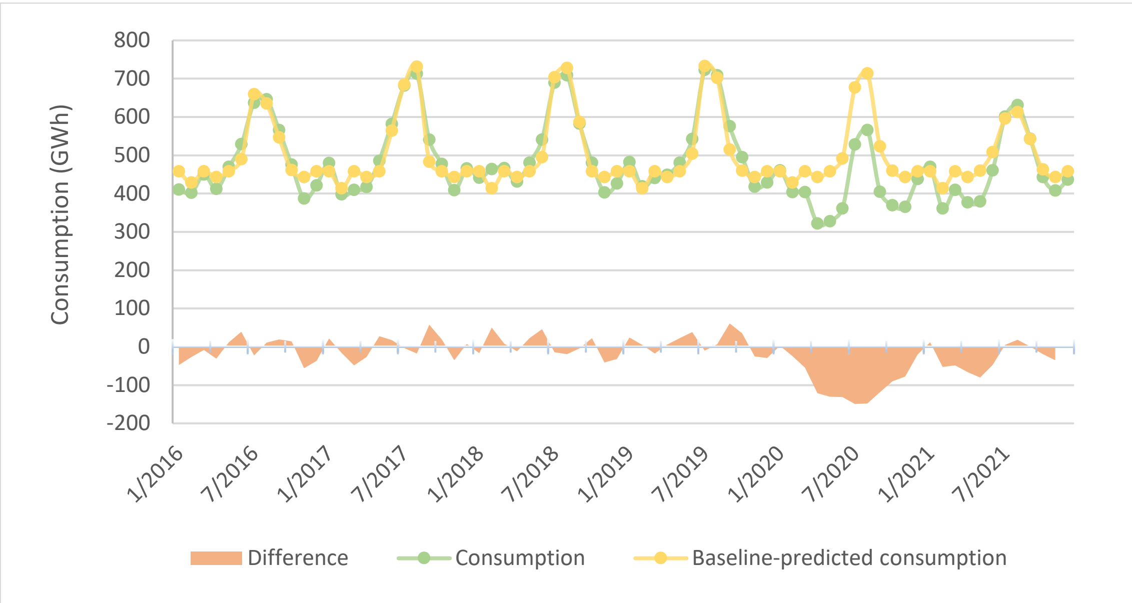
Figure 12. Electricity consumption in Balearic Islands for 2016–2021



Source: Author's elaboration on Red Eléctrica de España data

To better assess the actual impact of the pandemic on the electricity consumption, a mathematical model that incorporates the influence of the weather events and the historical data of the period 2016-2019 was developed. Indeed, **Figure 13** shows that the difference between the actual data and the predicted consumption is significant during 2020, indicating that pandemic restrictions and influence on local activities had a strong influence on the electricity consumption of Balearic Islands.

Figure 13. Baseline-predicted consumption and actual consumption for Balearic Islands 2016-2021. The change in electricity demand is shown in area graph



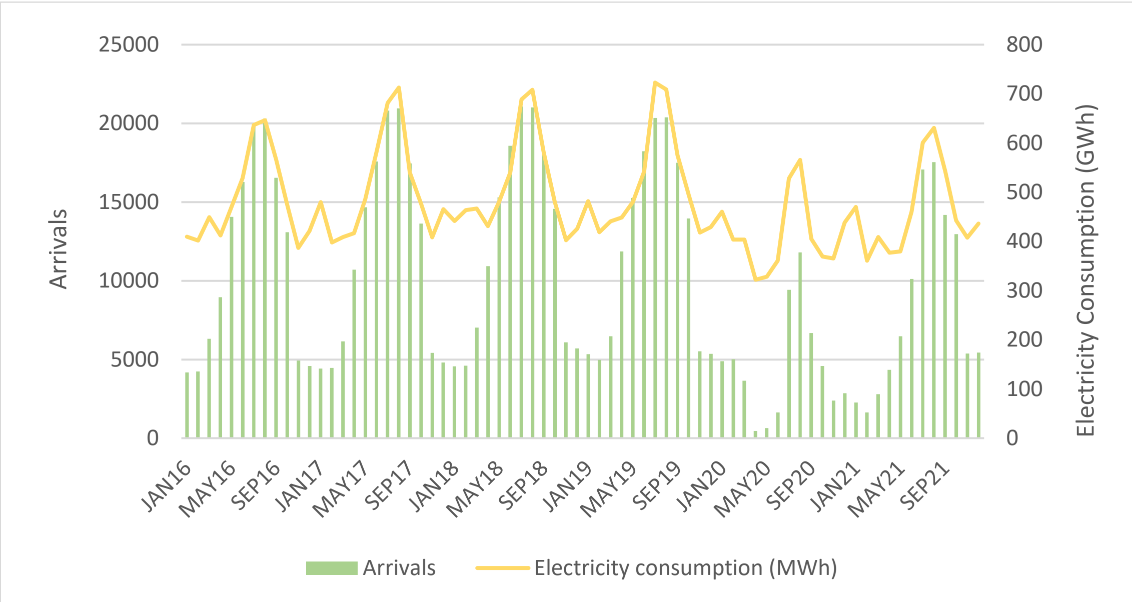
Source: Author's elaboration on Red Eléctrica de España data, Eurostat and degreedays.net

To investigate the linkage between tourism and energy consumption in Balearic Islands we used airport traffic data from EUROCONTROL[20], and more specifically the Daily IFR arrivals and departures by airport dataset, as a strong indicator of tourism presence in the region.

In **Figure 14** it is apparent that there is a seasonal increase during the months of great tourist activity validating the literature[21] which signifies that the link between tourism sector and energy usage, especially in tourism-led economies, is rather critical. Thus, from 2016 to 2019, in Balearic Islands, which is a growing tourism destination, we observe that as airport arrivals start to rise around May electricity consumption starts to rise as well. In July and August, in every year of our examination, when there is the maximum electricity consumption are also the months with the maximum airport arrivals. On the contrary, off-season months are characterised by a much lower energy consumption with no significant fluctuations.

During 2020 and 2021, the pandemic impact is evident; as a result of reduced tourism, electricity consumption does not reach the peak levels of previous years at any point, while at the same time, the peaks and the electricity fluctuations follow parallel paths with the arrivals, as in the previous years. The period from April 2020 until June 2020 when the stringency index was at the highest level, we also observe the lowest electricity consumption and, the lowest arrivals.

Figure 14. Arrivals and electricity consumption for Balearic Islands 2016-2021

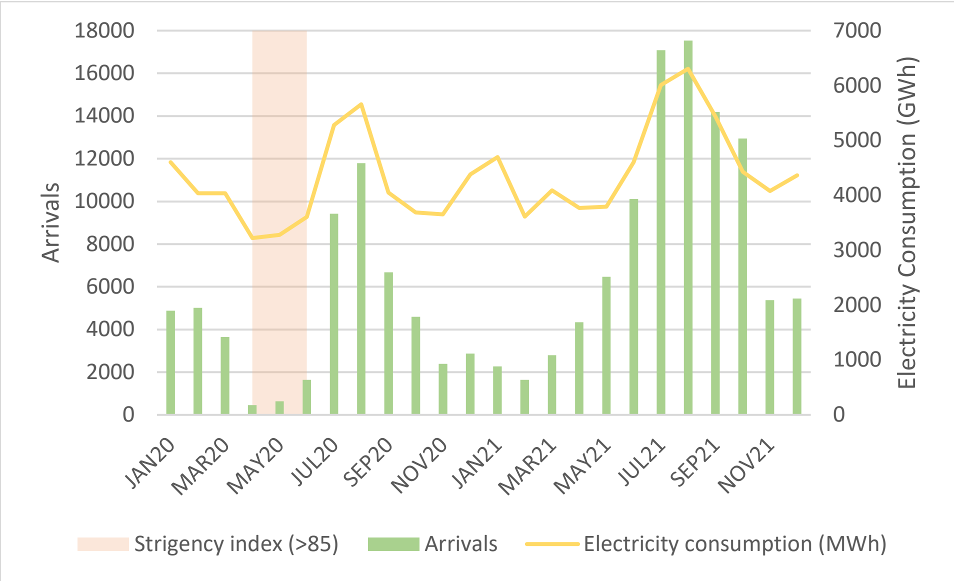


Source: Author's elaboration on Red Eléctrica de España and EUROCONTROL data

[20] EUROCONTROL is a pan-European, civil-military organisation dedicated to supporting European aviation.

[21] See Section 3.2

Figure 15. Arrivals and electricity consumption with stringency index for Balearic Islands 2020-2021



Source: Author's elaboration on Red Eléctrica de España, EUROCONTROL & stringency index data (Hale et al., 2021)

4.3 Canary Islands (ES)

4.3.1 Overview

Canary Islands (Spanish, Islas Canarias) is an archipelago in the Atlantic Ocean and an autonomous community of Spain, the nearest island of which is 108 km off the northwest African mainland. The Canary Islands are separated into two groups. The western group, which includes Tenerife, Gran Canaria, La Palma, La Gomera, and Ferro islands, and the eastern group of Lanzarote, Fuerteventura Island, and six islets. The total area of the Canary Islands is 7,493 km^2 with a population of 2,153,389 (population density 290/km^2).

In terms of temperature the Canary Islands experience a subtropical climate which means that temperatures are mild and stable throughout the year within the range (daily mean) 18-24 °C. In summer, temperatures do not become very high due to the cooling influence of the surrounding waters of the Atlantic Ocean, reaching an average high of 28ºC in August. Winters in the Canary Islands are mild, with an average low at 15ºC, and the rainfall varies between islands and is higher in the northern parts of the archipelago which are more exposed to the northeast trade winds.

Canary Islands is the top tourist destination in Europe in terms of nights spent in tourist accommodation (96.1 million nights in 2019)[22]. In 2019 15.1 million tourists visited the archipelago, 85% of which were international visitors with the majority from Great Britain and Germany and then from Netherlands and Belgium[23]. The prevailing tourism model of Canary is sun and beach tourism, with very characteristic feature, which is the absence of pronounced seasonal behaviour, primarily related to the weather conditions.

Similar to Balearic Islands, service activities related to tourism, that is wholesale and retail trade, transport, accommodation and food service activities, have predominant contributions to regional GDP. The last few years, from 2016 to 2019, the share of tourism activities in regional GDP is estimated around 32%, with small fluctuations[24]. The touristic model is that of high dependence on massive tourism packages and all-inclusive deals. In this context, foreign companies control a large part of tourist services. This domination, along with the economic restraints that local companies are facing, as well as, the fact that the majority of tourism's labour force are non-residents of Canary, lead to no significant positive impacts on the living standards of the local communities, despite the high contribution of tourism in regional GDP[25]. The tourism employment data of the region is surprisingly stable - the 41% of total regional employment - during the period 2016-2019, validating the previous argument, and demonstrating how this tourism model is not favourable for local communities

The electric power system of the Canary Islands is made up of six small-sized electrically isolated systems and a network of electricity infrastructure that is weakly meshed. As of 2020, combined cycle power stations (natural gas) were the leading technology in terms of generation, followed by diesel generator and gas turbines. Renewables share reached a 17.5% of the archipelago's total electricity production, the highest share since 2007[26].

4.3.2 COVID-19 Restrictions

In the Canary Islands, just like in Balearic Islands we investigated previously, the restrictions imposed to restrain the pandemic expansion, had no major differences from the restrictions imposed by the central government of Spain.

[22] Tourism statistics at regional level, Eurostat, September 2022, https://ec.europa.eu/eurostat/statistics-explained/

[23] Tourist arrivals, Historical data (2010-2020), Turismo de Islas Canarias, https://turismodeislascanarias.com

[24] National Institute for Statistics of Portuguese

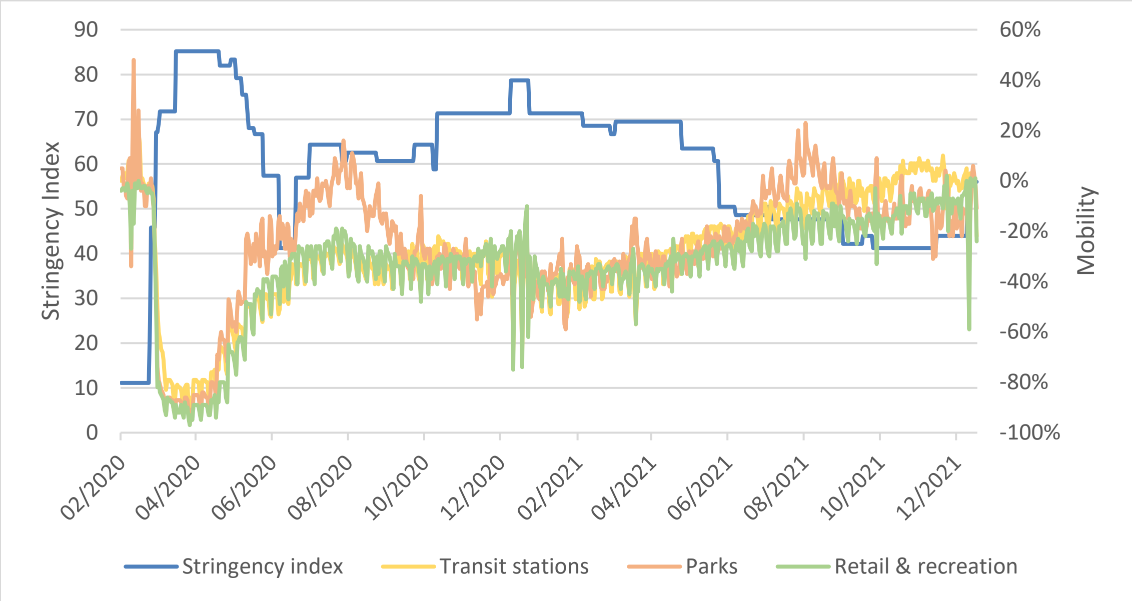
[25] Tourism observatory of the Canary islands, preliminary report, 2021

[26] Renewables generate 17.5% of the total electricity on the Canary Islands in 2020, press release, RED Electrica de Espana, March 2021

Following the same methodology as before, in the diagram below, we observe the trends of mobility[27] in transportation, parks and recreation in comparison with the stringency covid index[28] of Spain. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was reduced on average for 41%, the mobility for visiting public places was reduced on average by 32%, and finally, mobility for recreation was reduced on average by 42%, which is the highest observed reduction for this period (**Figure 16**).

By investigating both Balearic Islands and Canary Islands, the assumption that, the higher the dependence of a region in tourism, the higher the impacts due to covid, seems to be validated. As Canary Islands have greater tourist flows than Balearic Islands[29], the impacts on mobility are also much greater.

Figure 16. Stringency Index and Mobility for Canary Islands 2020-2021



Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.3.3 Tourism and energy linkage in Canary Islands

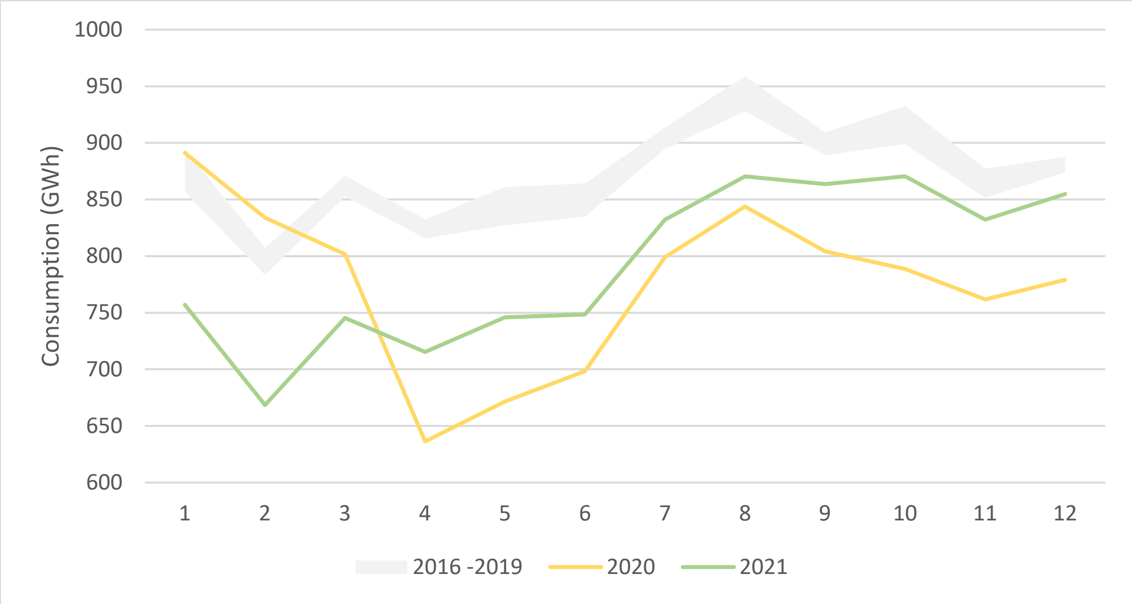
The electricity consumption in the Canary Islands for the period 2016-2021 is presented at **Figure 17**. In 2020 consumption falls rapidly from March and onwards and never manages to reach the levels of the previous years. For Canary islands the largest decrease during the two years of the pandemic, compared to 2019 levels, occurs in April and reaches 23%. Similar to Balearic Islands, in 2021 the reduction in consumption is less and only at the end of the year almost recovers at the 2016-2019 levels.

[27] Data retrieved from Community Mobility Reports of google available at: https://www.google.com/covid19/mobility/

[28] Stringency index available at: https://ourworldindata.org/grapher/covid-stringency-index

[29] See Annex. Diagram A

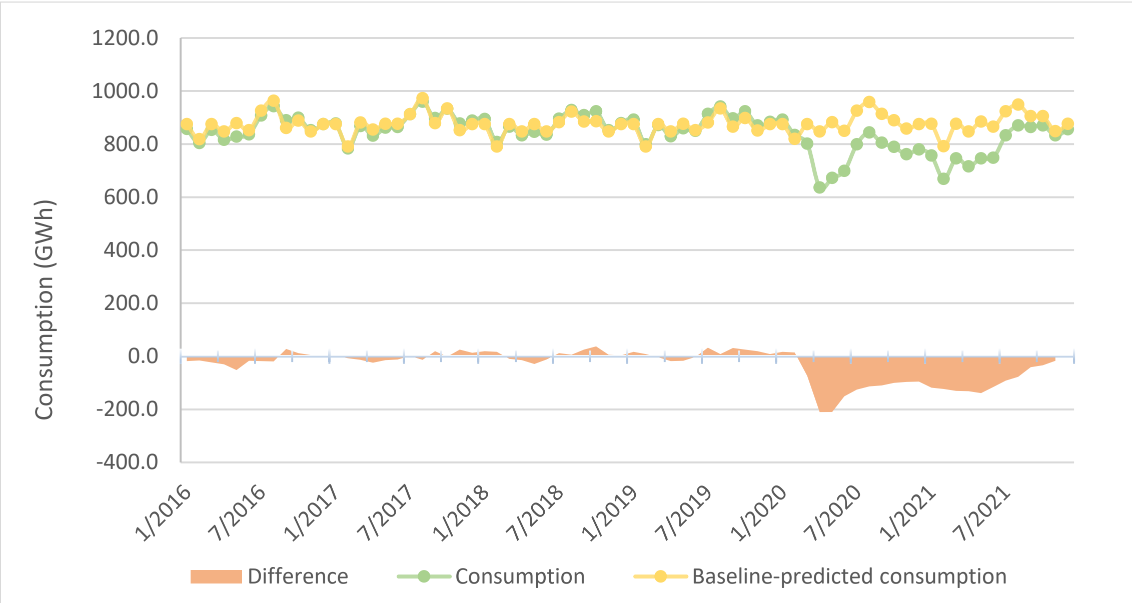
Figure 17. Electricity consumption in Canary Islands for 2016 – 2021



Source: Author's elaboration on Red Eléctrica de España data

Using the developed mathematical model that incorporates the influence of the weather events and the historical data of the period 2016-2019 the pandemic impact on the consumption of Canary Islands is clearer. After April 2020 until the second half of 2021 pandemic results to a reduction to the electricity consumption which is more intense during the period April to June of both years (**Figure 18**).

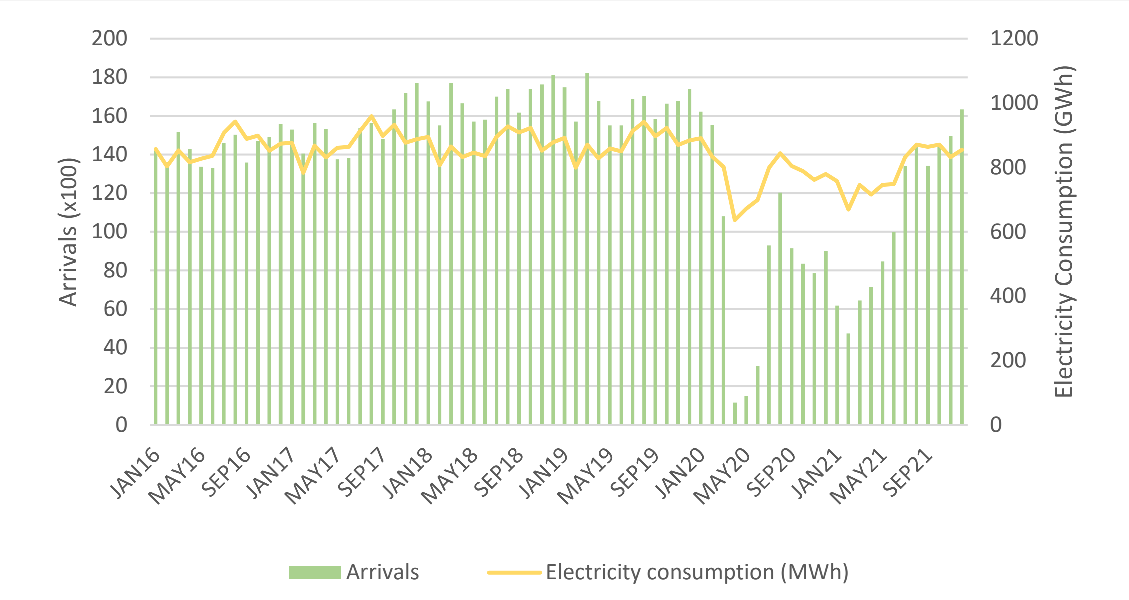
Figure 18. Baseline-predicted consumption and actual consumption for Canary Islands 2016-2021. The change in electricity demand is shown in area graph



Source: Author's elaboration on Red Eléctrica de España data, Eurostat and degreedays.net

In the Canary Islands, we see the airport arrivals and the electricity consumption in the Canary Islands, for the period from 2016 until 2021 (**Figure 19**). As we see in the graph Canary Islands does not appear seasonality in tourism. Lack of seasonality is due to the good weather conditions of the area during every season of the year. So, from 2016 until 2019 the arrivals and the electricity consumption were following parallel paths, until the pandemic shock which is evident during 2020 to 2021.It is interesting, that until 2019 where both arrivals and electricity consumption were higher, their relationship was not so obvious, while for the years 2020-2021, when the pandemic reduced arrivals, their relationship becomes more obvious to notice.

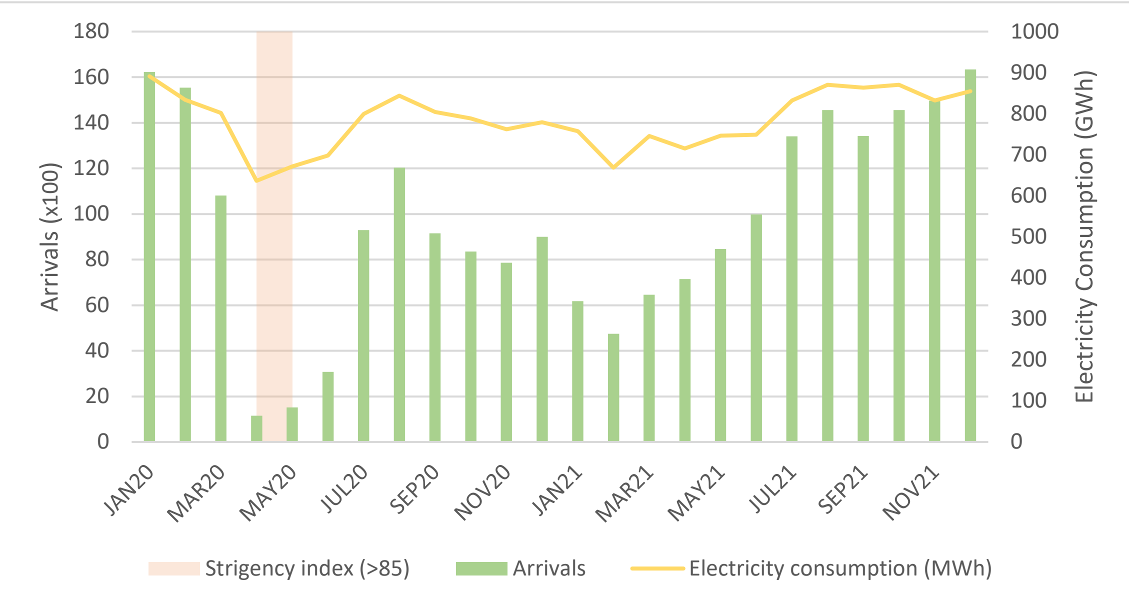
Figure 19. Arrivals and electricity consumption for Canary Islands 2016-2021



Source: Author's elaboration on Red Eléctrica de España and EUROCONTROL data

In more detail, in **Figure 20**, we see that the months that the first major restrictions were applied - with stringency index higher than 85, April and May of 2020, is the period with the lowest energy consumption and lowest arrivals.

Figure 20. Arrivals and electricity consumption with stringency index for Canary Islands 2020-2021



Source: Author's elaboration on Red Eléctrica de España, EUROCONTROL & stringency index (Hale et al., 2021) data

4.4 Madeira Islands (PT)

4.4.1 Overview

Madeira Islands (Portuguese Arquipélago da Madeira) is an archipelago of volcanic origin in the North Atlantic Ocean, belonging to Portugal. It comprises two inhabited islands, Madeira, and Porto Santo, and two uninhabited groups, the Desertas and the Selvagens. The islands are the summits of mountains that have their bases on an abyssal ocean floor. Administratively, they form the autonomous region of Madeira. The regional capital, Funchal, is located on Madeira Island. The total area of the Madeira Islands is 801 km^2 with a population of 251,060 (population density 313/km^2).

Madeira's sub-tropical climate consists of hot and dry summers with very mild winters. Its geographical location, the mountainous topography and the warm ocean currents around the island give to Madeira diverse microclimates where extreme hot or cold temperatures are absent. The cooling winds that brush across the islands help keep summer temperatures more comfortable. In summer the average high temperatures reach 26°C in August and September and in winter the average low is around 13°C

In 2019 Madeira archipelago was visited by 1.38 million guests with around 8.12 million total overnight stays and an average length of stay 5.1 days. More than 80% of the passengers who use the Madeira airport reside outside the archipelago, and from them the majority came from Germany, England, and France but domestic tourists are also a noticeable part. Europe is also the origin of the majority of ship cruise passengers arriving in the Port of Funchal, with the majority being from the United Kingdom and Germany. Tourism sector is the main driving force of the regional economy of Madeira as it represents approximately 27% of the regional GDP while its economic structure is characterized by the development of service activities[30]. The service activities of accommodation, restaurant and other activities-related sectors represent 32% of the total regional Gross Value Added (GVA). The growth of the tourism sector is captured - to some extent - on the annual growth, of almost 3%, of the disposable income of Madeira's households, during the period 2016-2019[31]. In 2019, tourism created a total revenue of 407.5 million euros.

The power systems of Madeira Islands (Madeira and Porto Santo) are electrically isolated since there is no interconnection either between them or with the mainland. The largest share of the electrical energy comes from fossil fuels (66.2% in 2021) followed by wind energy (14.9% in 2021), hydro, solar and biomass (municipal solid waste – msw) – in total around 33%. To increase the share of renewables in Madeira Island the hydro power plant was upgraded by adding the Calheta III pump storage system[32].

4.4.2 COVID-19 Restrictions

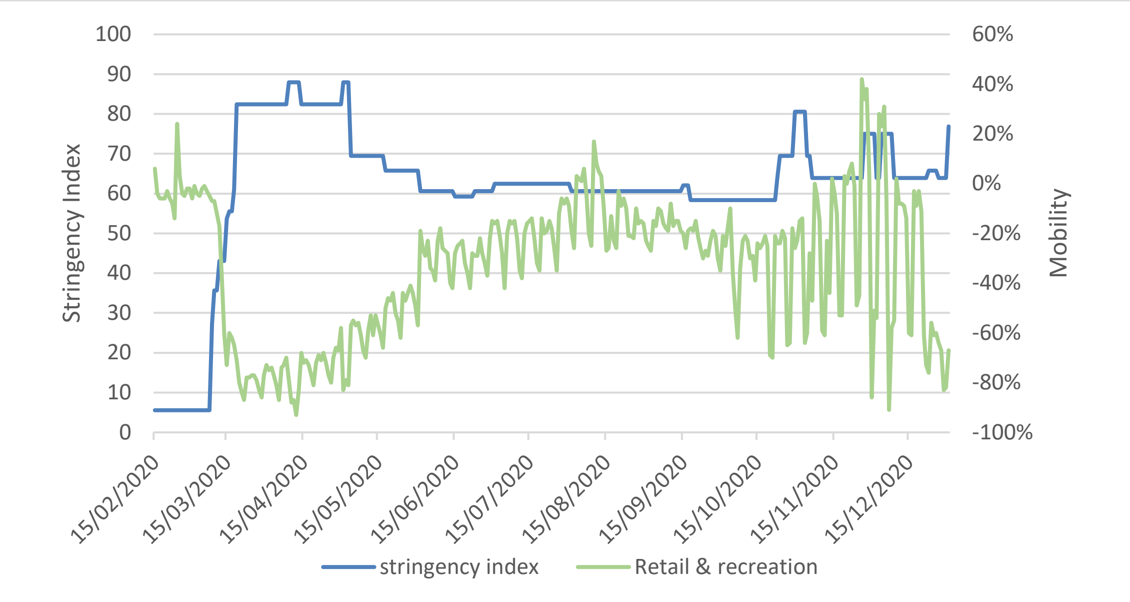
Following the same methodology as before, in order to see the restriction impacts, in the diagram below, we observe the trends of mobility in recreation and retail, in comparison with the stringency covid index of Portugal, for the period from 15/02/2020 until 12/06/2020 (Hale et al., 2021). During this period, the mobility for recreation was reduced on average by 32%, which is the highest observed reduction for this period.

[30] Tourism strategy for Madeira 2017-2021, SRETC

[31] National Institute for Statistics of Portuguese

[32] https://www.apren.pt/en/renewable-energies/production

Figure 21. Stringency Index and Mobility for Madeira Islands

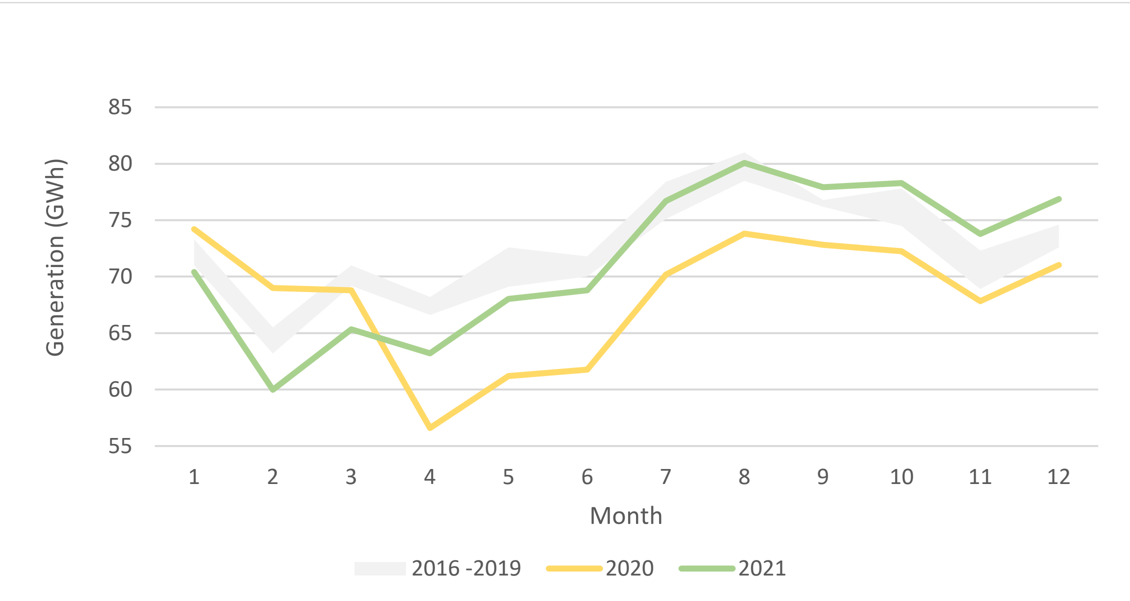


Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.4.3 Tourism and energy linkage in Madeira Islands

In 2020 electricity consumption in Madeira Islands follows a similar trend with the previous locations, which is a decrease in total consumption after March with the largest decrease during the two years of the pandemic, compared to 2019 levels, occurring in April 2020, and reaching 17%. In Madeira, however, consumption seems to reach the "normal" levels already in May of 2021 (and onwards) indicating a fastest recovery, at least from this point of view.

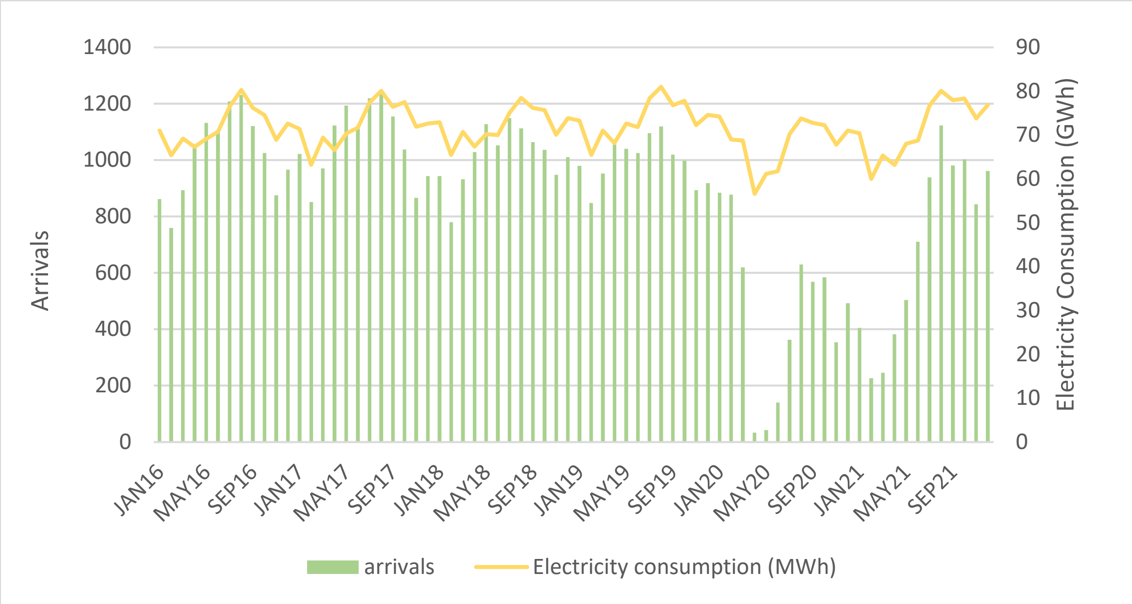
Figure 22. Electricity consumption in Madeira Islands for 2016 – 2021



Source: Author's elaboration on Electricidade de Madeira data

In **Figure 23**, we observe the trends of arrival and electricity consumption in Madeira for the period from 2016 to 2021. Madeira and Canary Islands have similar patterns, with no periods of high tourism seasonality. Madeira seems to have some seasonality, but the fluctuations are not so big compared to other tourism destinations, while the linkage between arrivals and energy consumption is also evident for all the investigated periods.

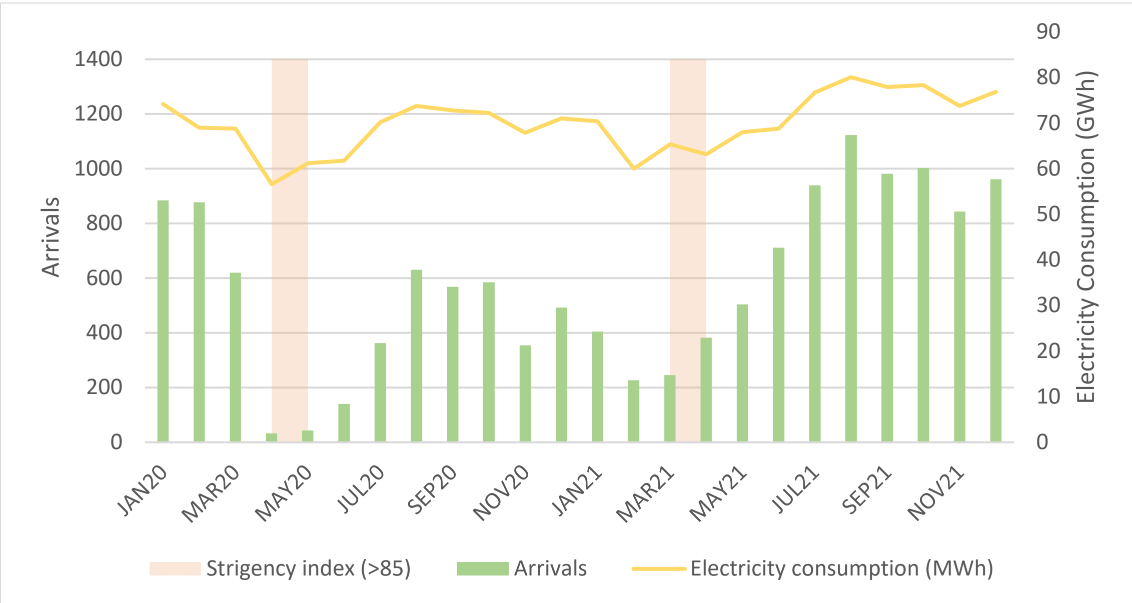
Figure 23. Arrivals and electricity consumption for Madeira Islands 2016 -2021



Source: Author's elaboration on Electricidade de Madeira and EUROCONTROL data

If we look more closely to the pandemic years (2020-2021) this relationship is even more obvious (**Figure 24**). Madeira, as Portugal, had two periods of high stringency index: in April-May of 2020 and in March-April of 2021. These periods, with the greater restrictions, are also the periods with the lowest arrivals and energy consumption, which continue to follow parallel paths.

Figure 24. Arrivals and electricity consumption with stringency index for Madeira Islands 2020-2021



Source: Author's elaboration on Electricidade de Madeira, EUROCONTROL & stringency index (Hale et al., 2021) data

4.5 Sardinia (IT)

4.5.1 Overview

Sardinia (Italian Sardegna) is an island and region (regione) of Italy, second in size only to Sicily among the islands of the western Mediterranean. It is located west of the Italian Peninsula, north of Tunisia and immediately south of the French island of Corsica. Sardinia is one of the five Italian regions with some degree of domestic autonomy. The total area of Sardinia is 24,090 km^2 with a population of 1,628,384 (population density 67/km^2).

The climate of Sardinia varies from place to place because the island is extended both in terms of latitude and in terms of elevation (over 1000m). In general terms it has a Mediterranean climate (but with a large variety of different isobioclimates), with mild, short, and fairly wet winters and hot, long and sunny summers, occasionally sultry but fed by breezes. At sea level the average high temperature exceeds the 30°C in July and August while the average low can fall to 5°C in January and February. At the elevation of 1000m the temperatures are correspondingly 26°C and 1°C.

Tourist sector in the primarily service-led economy of Sardinia is quite of an important economic sector, contributing approximately 22% of the regional value added in 2019, but remaining stable since 2016. Additionally, the regional GDP is increased annually in average by 2%. At the same time, and while tourism is growing, from 2016 the disposable income of households is minor, indicating that the tourism sector does not play a significant role in improving the residents' standards of living[33]. Tourist arrivals have been steadily growing the past two decades with an average rate of 3.86%[34]. Sardinia, in 2019, attracted 2.44 million visitors with a total number of nights spent 10.67 million and an average length of stay 4.4 days[35]. It is interesting to note that 50% of the total amount of the arrivals on the Island was in the North of Sardinia and strictly along the coast (93% are in coastal municipalities, and just 7% in inner ones)[36]. Also, the islands attract a large number of domestic (Italian) tourists (almost half in 2019) with the majority of the rest coming from Europe.

Sardinia is electrically connected with the Italian continent through two direct-current power lines while a further alternating-current connection connects Sardinia and Corsica. Local generation is mostly based on thermoelectric plants (almost half on coal and the rest on gas, diesel, and fuel oil) which was responsible for 75% of gross electricity production in 2020, with the rest coming from renewable sources – mainly wind and photovoltaic. Sardinia is a net exporter of electricity, primarily to Italian mainland and to Corsica as well[37].

4.5.2 COVID-19 Restrictions

In **Figure 25** we observe the trends of mobility[38] in transportation, parks, and recreation in comparison with the stringency covid index[39] of Italy. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was reduced on average for 20%, the mobility for visiting public places was reduced on average by 63%; and finally, mobility for recreation was reduced on average by 22%, which is the highest observed reduction for this period.

[33] Italian National Institute of Statistics

[34] Macroeconomic outlook for the islands´ economic systems and pre-testing simulations, Deliverable 6.2, Soclimpact H2020, 2019

[35] Italian National Institute of Statistics

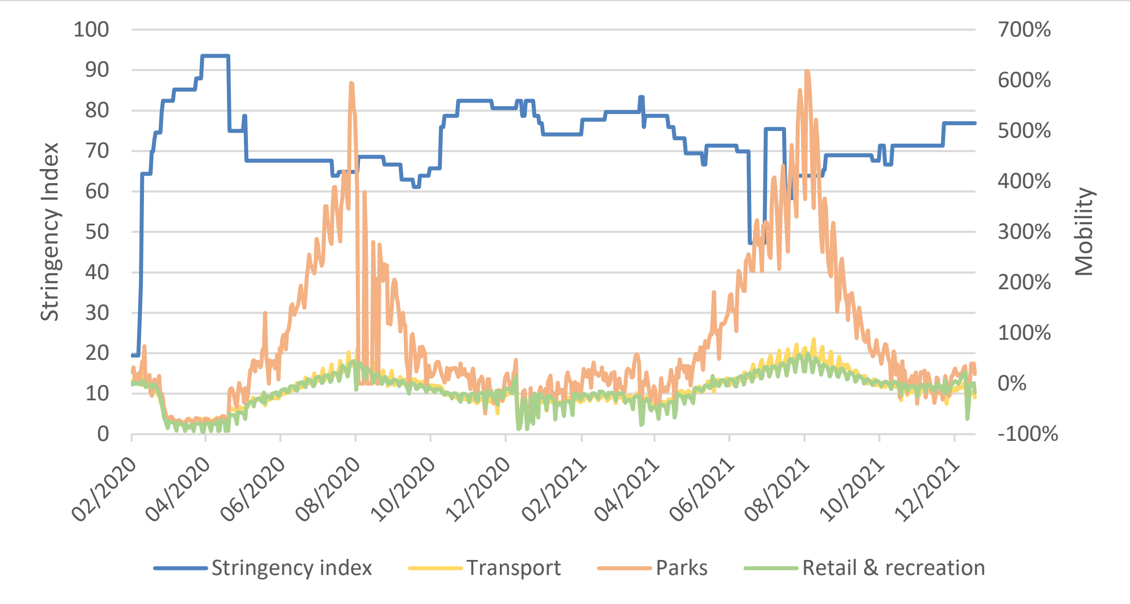
[36] Sechi, L., Moscarelli, R. & Pileri, P. Planning tourist infrastructures to regenerate marginalised territories: the study case of North Sardinia, Italy. City Territ Archit 7, 5 (2020)

[37] Multi-stakeholder Energy Compact: Sardinia Electrification, Rossi-Doria Centre of Economic and Social Research – Roma Tre University, available at: https://www.un.org/sites/un2.un.org/files/20210904_energy_compact_sardinia_electrification_un_requested_integrations_2.pdf

[38] Data retrieved from Community Mobility Reports of google available at: https://www.google.com/covid19/mobility/

[39] Stringency index available at: https://ourworldindata.org/grapher/covid-stringency-index

Figure 25. Stringency Index and Mobility for Sardinia

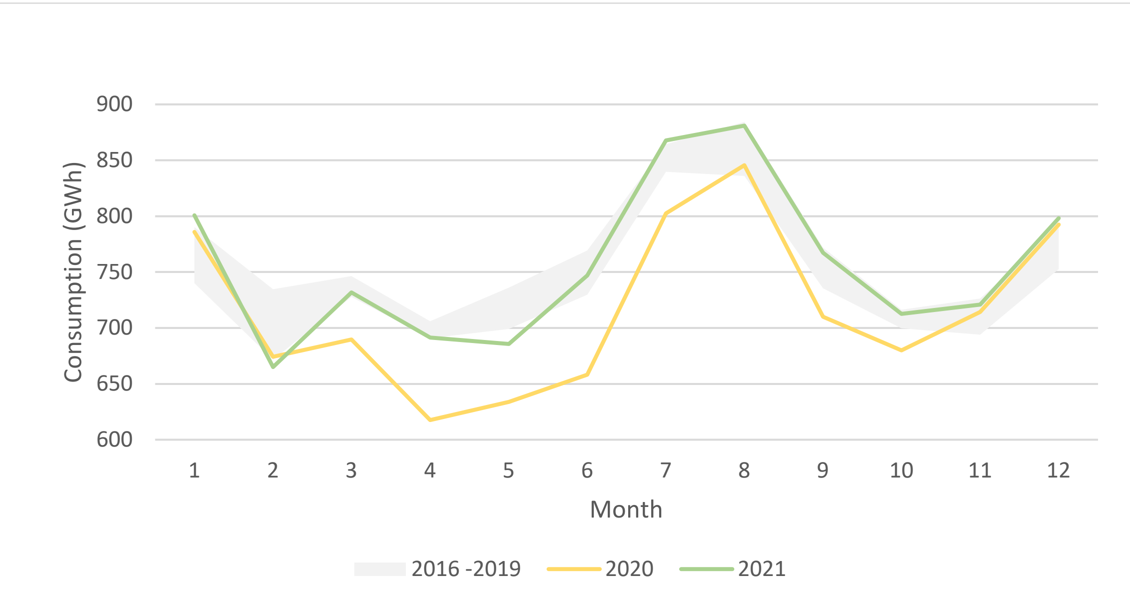


Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.5.3 Tourism and energy linkage in Sardinia

In Sardinia electricity consumption falls already from March 2020 and reaches its largest decrease, compared to 2019, in June 2020. However, this decrease is smaller compared to the previous locations, since it is around 14%. By June of the next year, 2021, this decrease will be recovered since consumption increases 13% compared to 2020. As shown in **Figure 26**, the electricity consumption in Sardinia recovers totally, and is actually on the higher bound of the values of the 2016-2019 period.

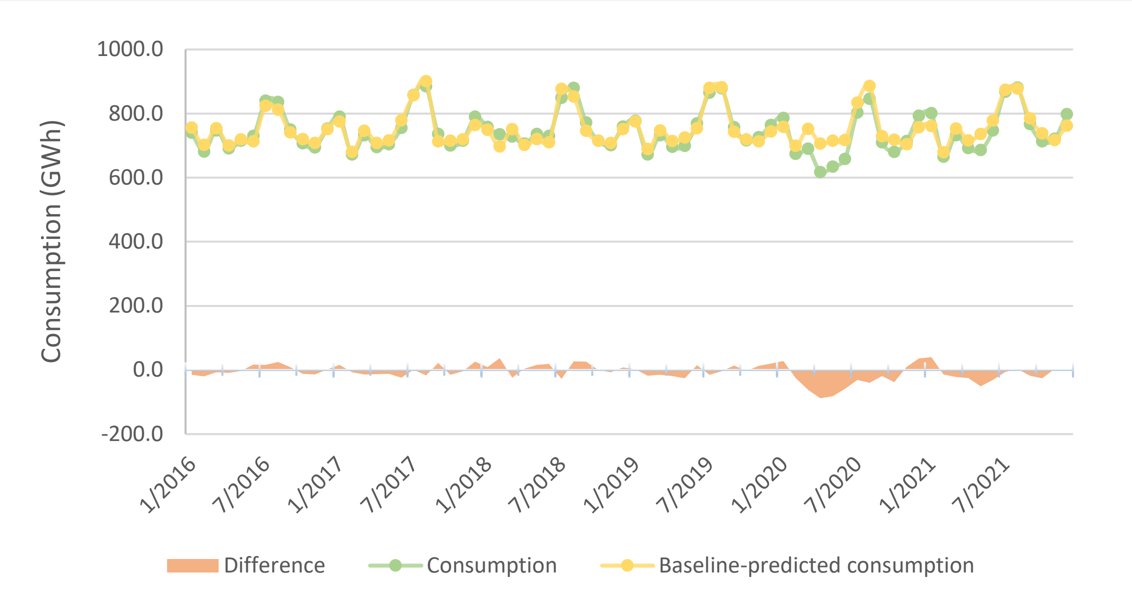
Figure 26. Electricity consumption in Sardinia for 2016-2021



Source: Author's elaboration on Terna Spa data

The impact of pandemic in the beginning of 2020 and the recovery of Sardinia electricity consumption in 2021 is obvious also when comparing the consumption data with the developed mathematical model that incorporates the weather events as shown in **Figure 27**.

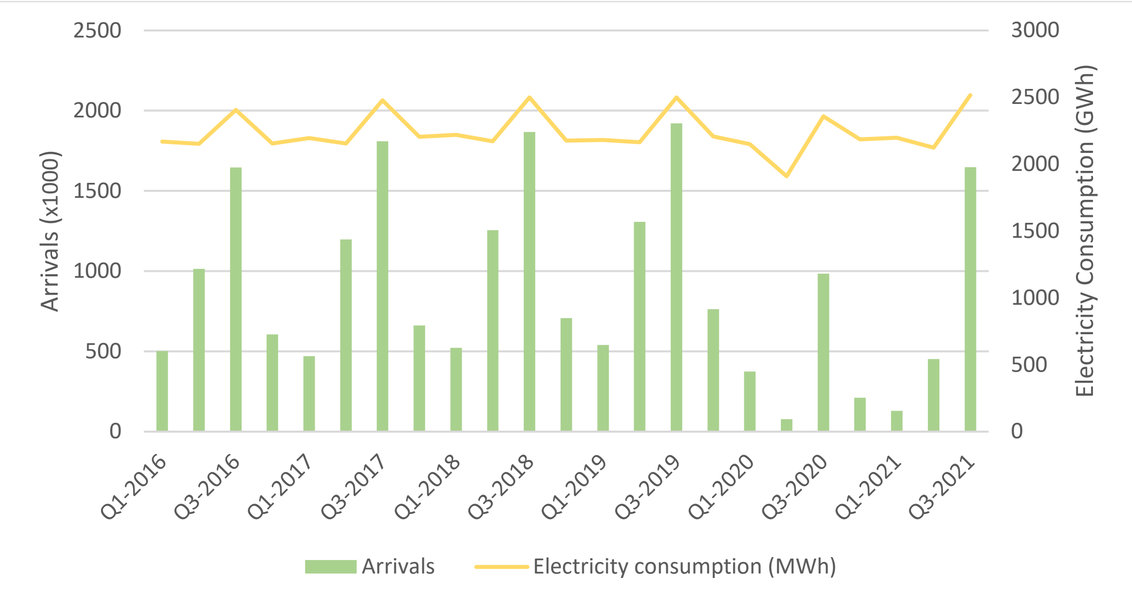
Figure 27. Baseline-predicted consumption and actual consumption for Sardinia 2016-2021. The change in electricity demand is shown in area graph



Source: Author's elaboration on Terna Spa data, Eurostat and degreedays.net

When combining the energy consumption data, we get the graph in **Figure 28**. Unfortunately, for Sardinia we only managed to get quarter arrival data thus the granularity is different. Despite that, the relationship between arrivals and electricity consumption is still obvious. In Sardinia there is seasonality in tourism, and that's why the arrival peaks, as well the electricity consumption highs, are in the 3rd quarter (July, August, and September).

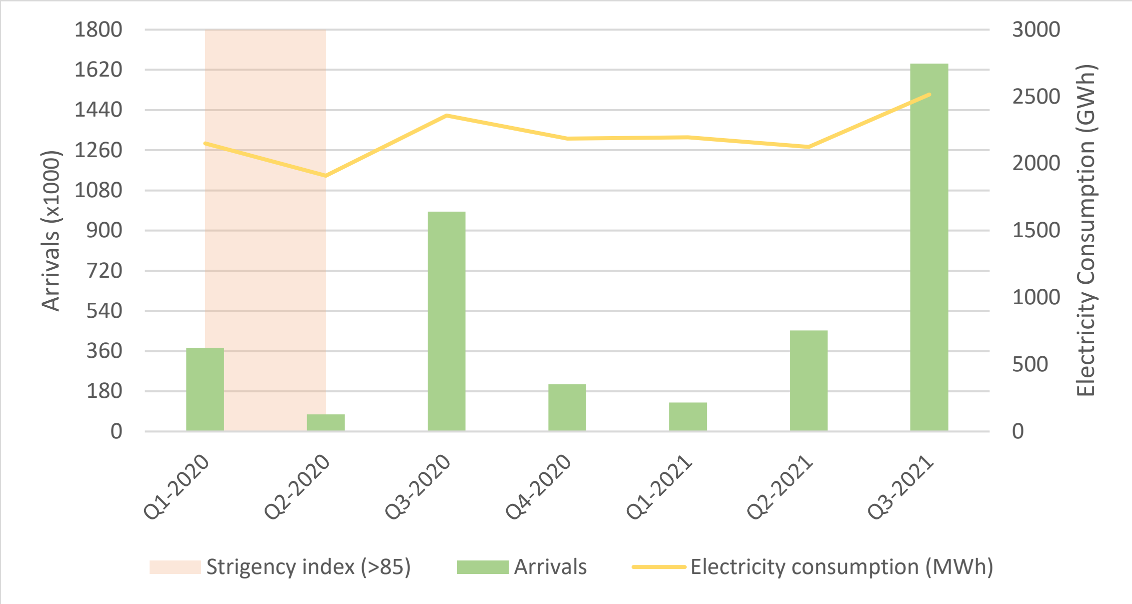
Figure 28. Arrivals and electricity consumption with stringency index Sardinia 2016-2021



Source: Author's elaboration on Terna Spa and IStat data

By getting a closer look at the pandemic period, with the highest numbers of stringency index being in March and April of 2020, the parallel path that arrivals and electricity consumption is following is evident; as arrivals decline due to travel restrictions so does the electricity consumption, and as arrivals increase in the summer period, when there is the tourism seasonality, so does the electricity consumption.

Figure 29. Arrivals and electricity consumption with stringency index for Sardinia 2020-2021



Source: Author's elaboration on Terna Spa, IStat & stringency index (Hale et al., 2021) data

4.6 Sicily (IT)

Sicily (Italian Sicilia), located at southern Italy, is the largest and one of the most densely populated islands in the Mediterranean Sea. Together with the Egadi, Lipari, Pelagie, and Panteleria islands, Sicily forms an autonomous region of Italy. It lies about 100 miles (160 km) northeast of Tunisia (northern Africa). The total area of Sicily is 25.711 km2 with a population of 4.969.147 (population density 190/km2).
The island has a typical Mediterranean climate along the coasts and on the smaller islands, with mild, moderately rainy winters and hot, sunny summers. In inland areas, on the other hand, the climate is slightly more continental where winters become moderately cold, and summers are still hot. The island is subject to a hot wind from Africa, called Sirocco, which can raise the temperature to around 20 °C or above in winter and 40 °C in summer. The average high temperature in July/August can reach 31oC - 32oC in coastal cities and 27oC in some inland cities. The average low temperature in January/February can range from 5oC to 10oC in the coastal cities and can go down to 2ºC in some inland cities.

In 2019 Sicily was visited by 3.96 million visitors, slightly more than half of which were Italians, who spent in total 11.85 million nights, with an average stay of 3 days[40]. In terms of total GDP Sicily is the eighth largest regional economy of Italy[41]. Although tourism in Sicily is regarded as an important economic activity and it is a source of wealth in the island, the sector faces development struggles attributed mainly to infrastructure issues (limited touristic capacity) and to the decrease in domestic demand. The contribution of the services related to tourism to the regional gross value added since 2016 is almost stable around 22%. Exactly as in Sardinia, in Sicily from 2016 the disposable income of households is minor[42]. Additionally, the last years, investments in the hospitality sector are slowly but steadily improving the hosting capabilities of the island.

The island of Sicily is interconnected with the Italian mainland and with Malta through underwater high voltage cables. With respect to Malta, Sicily is an exporter and covers a significant share of Malta's electricity needs. The local electricity generation is provided by thermal power plants, primarily on natural gas, hydro plants, biomass, solar PV and wind.

4.6.1 COVID-19 Restrictions

Applying also for Sicily the same methodology as before, in **Figure 30**, we observe the trends of mobility[43] in transportation, parks and recreation in comparison with the stringency covid index[44] of Italy. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was reduced on average for 31%, the mobility for visiting public places was reduced on average by 17%; and finally, mobility for recreation was reduced on average by 28%, which is the highest observed reduction for this period.

[40] Italian National Institute of Statistics.

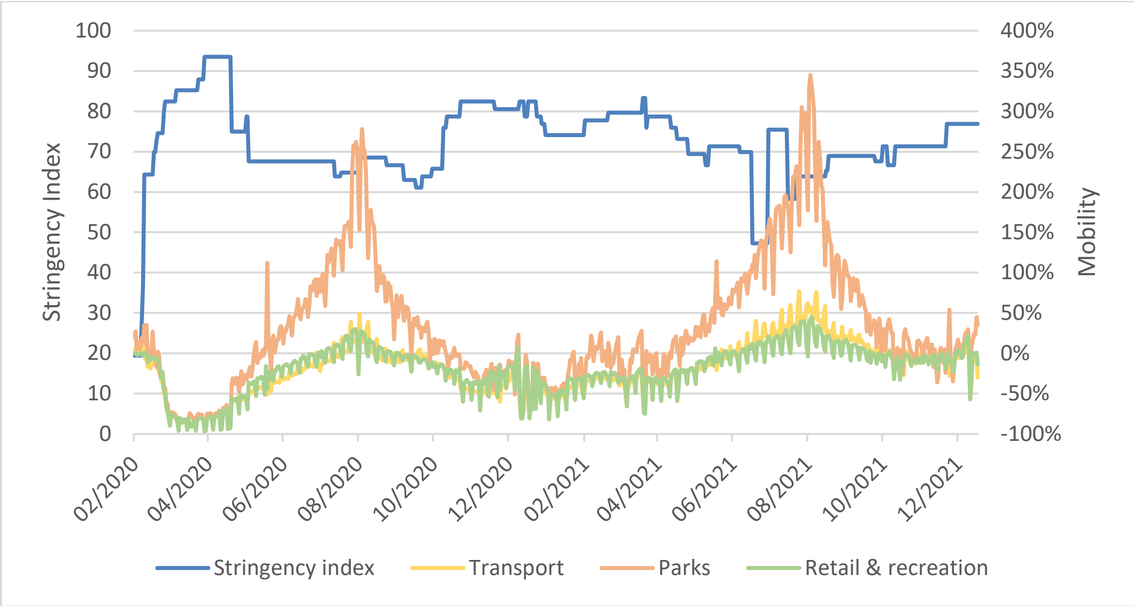
[41] https://en.wikipedia.org/wiki/List_of_Italian_regions_by_GDP

[42] Italian National Institute of Statistics

[43] Data retrieved from Community Mobility Reports of google available at: https://www.google.com/covid19/mobility/

[44] Stringency index available at: https://ourworldindata.org/grapher/covid-stringency-index

Figure 30. Stringency Index and Mobility for Sicily 2020-2021

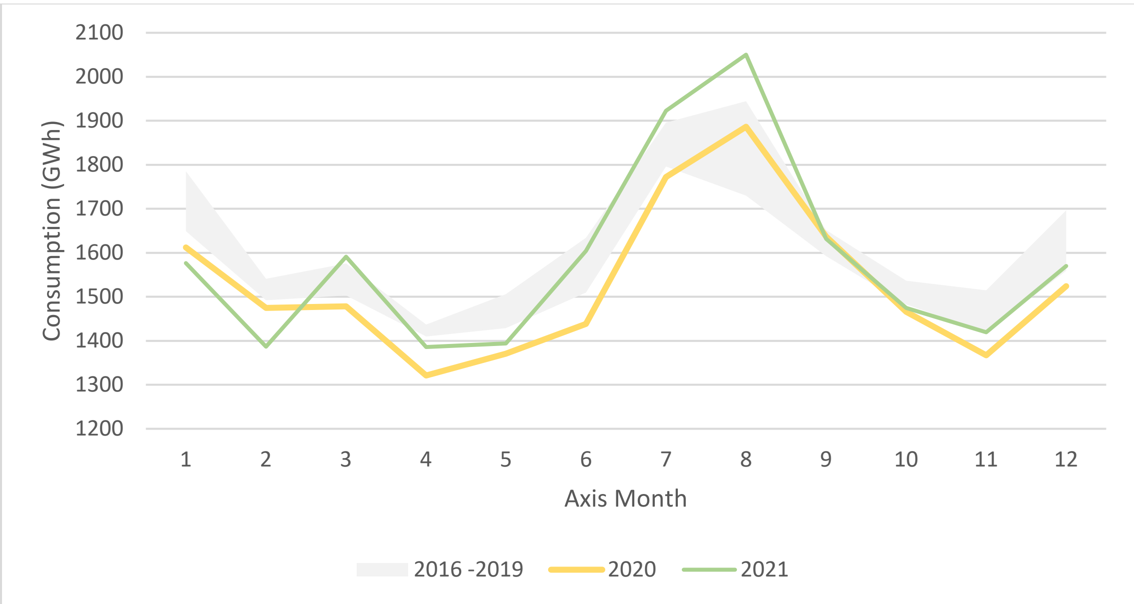


Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.6.2 Tourism and energy linkage in Sicily

Sicily presents the slightest impact on electricity consumption so far, since the largest decrease occurs in June 2020 and is approximately 10%. Although a slight decrease occurs already in April 2020, in general, during both years of the pandemic period, electricity consumption fluctuates closely to the historical values of the period 2016-2019. Even more, in August 2021 a large increase in electricity consumption occurs.

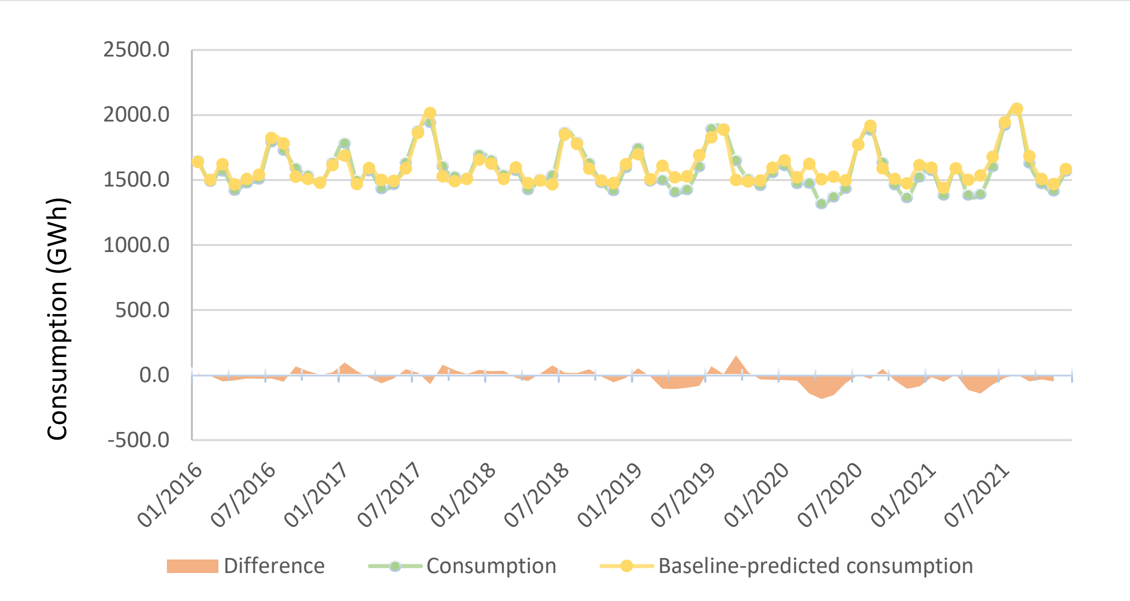
Figure 31. Electricity consumption in Sicily for 2016–2021



Source: Author's elaboration on Terna Spa data

The slight impact of pandemic in Sicily electricity consumption is clearly depicted at the following diagram where the actual consumption data are compared with the developed mathematical model. In 2020 pandemic influenced consumption especially until summer, but afterwards the impact is negligible or non-existent.

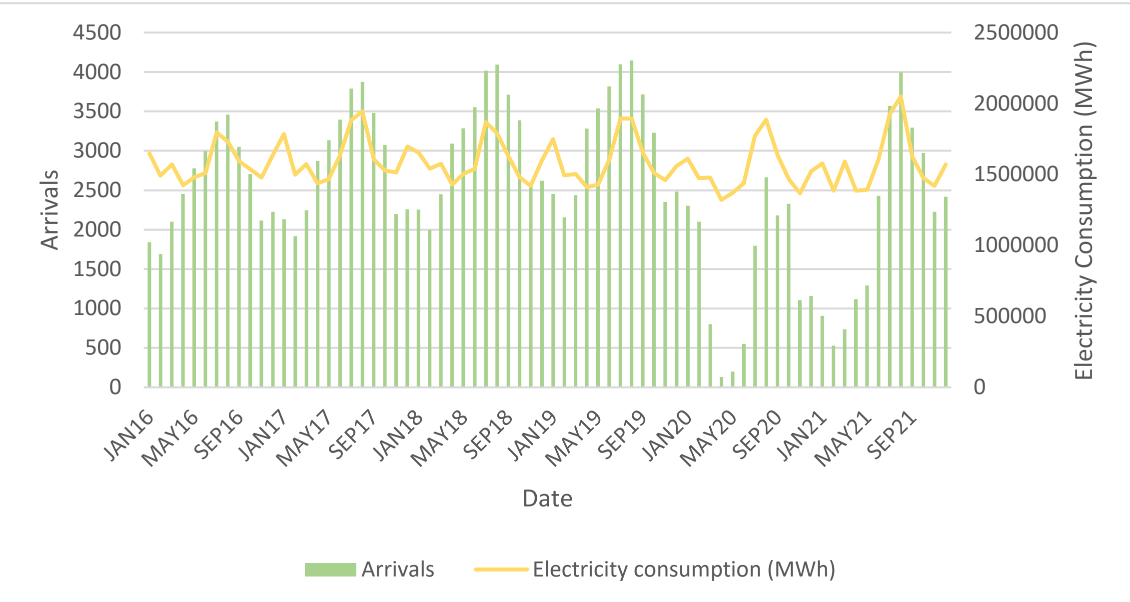
Figure 32. Baseline-predicted consumption and actual consumption for Sicily 2016-2021. The change in electricity demand is shown in the area graph



Source: Author's elaboration on Terna Spa data, Eurostat and degreedays.net

By combining arrivals data and electricity consumption data for Sicily, we see again the same patterns of electricity consumption and tourism. As in Sardinia, there is a seasonality in tourism periods when airport arrivals increase and so does the electricity consumption.

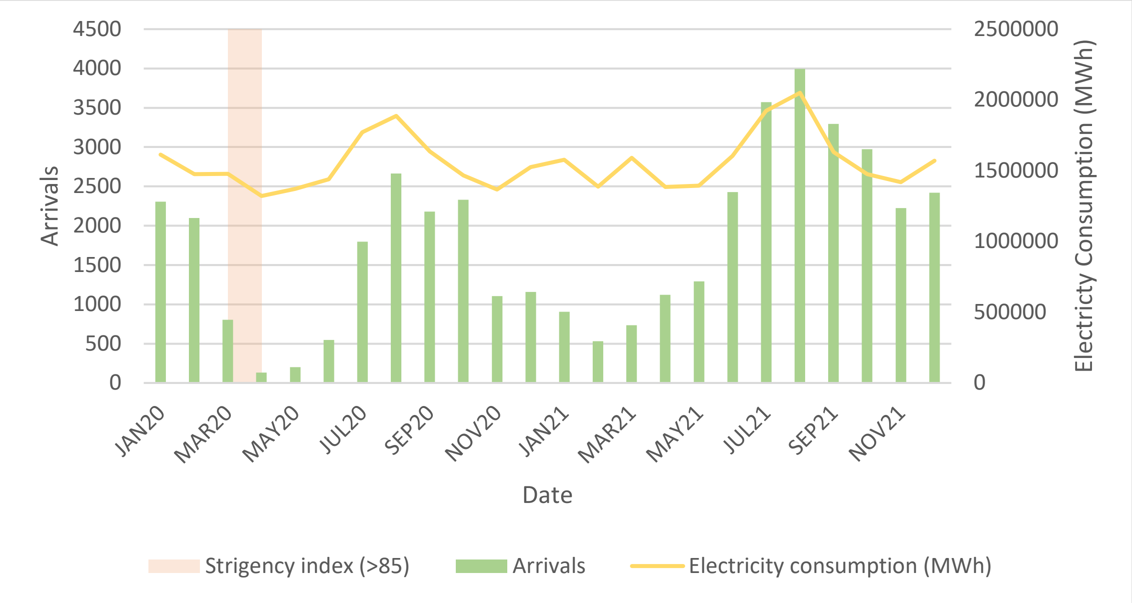
Figure 33. Arrivals and electricity consumption for Sicily from 2016-2021



Source: Author's elaboration on Terna Spa and EUROCONTROL data

The same pattern applies for the period of the pandemic, from 2020 till 2021. Indeed, when the Covid restrictions are tighter - for March and April of 2020 - we also have the lowest arrivals number as well as the lowest energy consumption.

Figure 34. Arrivals and electricity consumption with stringency index Sicily 2020-2021



Source: Author's elaboration on Terna Spa, EUROCONTROL & stringency index (Hale et al., 2021) data

4.7 Bornholm (DK)

4.7.1 Overview

Bornholm (Bornholmsk Borrinjholm) is a Danish Island in the Baltic Sea, 169 km southeast of Copenhagen, 35 km southeast of Sweden, northeast of Germany and north of Poland. The northern two-thirds of the island is composed of granite with a rocky cliff coast and a high-lying wooded interior. The total area of Bornholm is 588.36 km2 (about 40km across at its widest point) with a population of 39,610 (population density 67/km2).

The climate of the island is oceanic. Because of its maritime and isolated position in the Baltic Sea, the summer never gets very hot and the winter too cold, providing, thus, a mild and constant climate with moderate temperature variations along the year. Due to the cold waters of the Baltic Sea, the spring reaches Bornholm later than any other place in Denmark. The warmest months are July and August, when the average high is around 20ºC, and the coldest months January and February when the average low temperature goes just below the freezing point, around -1ºC. Also, compared to the rest of Denmark in Bornholm there is less rain and more hours of sunshine annually.

In 2018, Bornolm received 32.8% of the total tourism in Denmark, and it is among the ten Danish municipalities with the largest turnover from the tourism sector (Karlsdóttir et al., 2021). Tourism is an important economic sector in the island, after agriculture. The gross value added of the economic activities related to tourism in 2019 contributed 17% to the total gross value added of all economic activities. The regional growth rate of GDP has been increasing since 2016, and in 2018 it reached a decade high of 3.5%, however, the increase is not steady and is characterised by great fluctuations. Since 2010, the number of visitors has been steadily increasing and, before COVID-19 the total number of visitors annually had surpassed 600 thousand with the total overnight stays reaching 1.68 million[45]. Bornholm is primarily visited by domestic tourists (Danish) representing a 58% in 2018, and the majority of the rest were Scandinavian, Polish and German. Only 13.4% of the visitors reach Bornholm by airplane, while the rest prefer sea travel by the neighboring Baltic ports. The sea transport includes also cruising and yachting[46]. A very common way for tourists to get around the island is by their own car brought by the ferry. Other ways to get around is by bus or by bicycle. Compared to most of the rest of the presented destinations, the majority of the people choose Bornholm for its nature and the majority of the activities are related to this type of tourism[47].

Bornholm is connected to the Scandinavian electrical grid, through a submarine power cable to Sweden, but is also capable of running the electric system off grid. It has a total energy demand of 900 GWh/year including power, heat, and transportation. All urban areas are supplied with district heating, and the heat is generated with biomass-boilers, using locally produced woodchips and straw as fuel. Electricity production integrates 37 MW wind turbines, 23 MW solar PV and 3 MW biogas which can cover the total consumption of the Island.

4.7.2 COVID-19 Restrictions

In **Figure 35** we observe the trends of mobility in transportation, parks and recreation of Bornholm, in comparison to the stringency Covid index of Denmark for the two years of the pandemic period. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was reduced on average for 5%, the mobility for visiting public places was reduced on average by 2%; and finally, mobility for recreation was reduced on average by 19%, which is the highest observed reduction for this period.

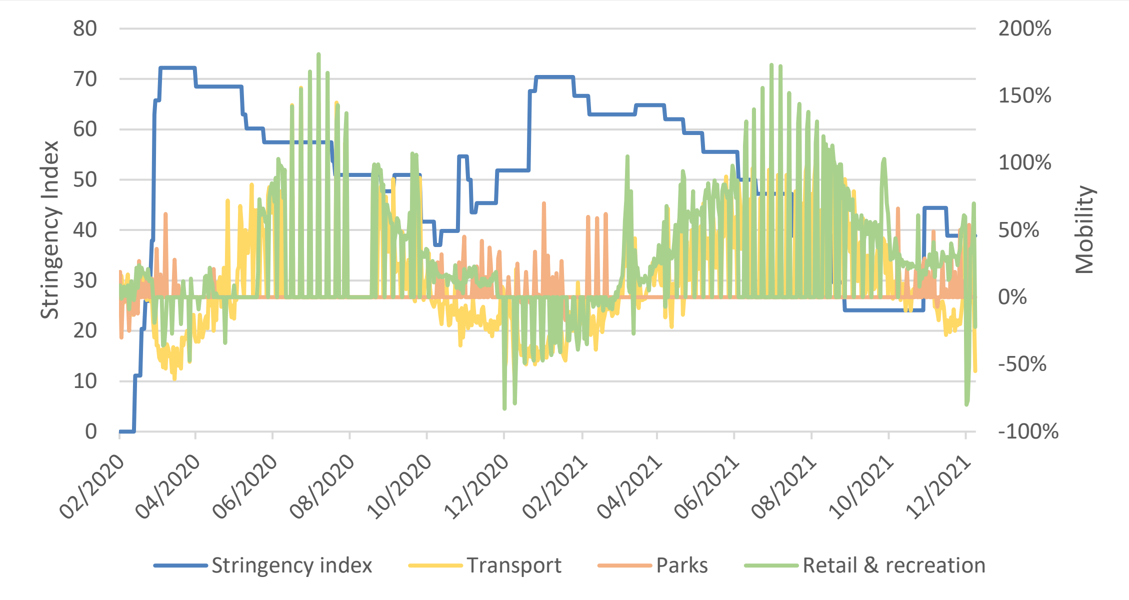
Bornholm has totally different levels of reduced mobility compared to previous islands as Denmark was one of the EU countries that had a relative low stringency index, along with an earlier reopening of human activities. However, as traveling was restricted in other EU countries, the mobility for recreation and retail, the indicator which we can assume is in greater link with tourism, has the greatest average value.

[45] Turismen i Danmark, VisitDenmark, 2020

[46] Aspects of tourism on Bornholm, Carl Henrik Marcussen, Centre for regional and tourism research, Bornholm, Denmark, 2019

[47] Destination Bornholm, Besoegsrapport 2018

Figure 35. Stringency Index and Mobility for Bornholm



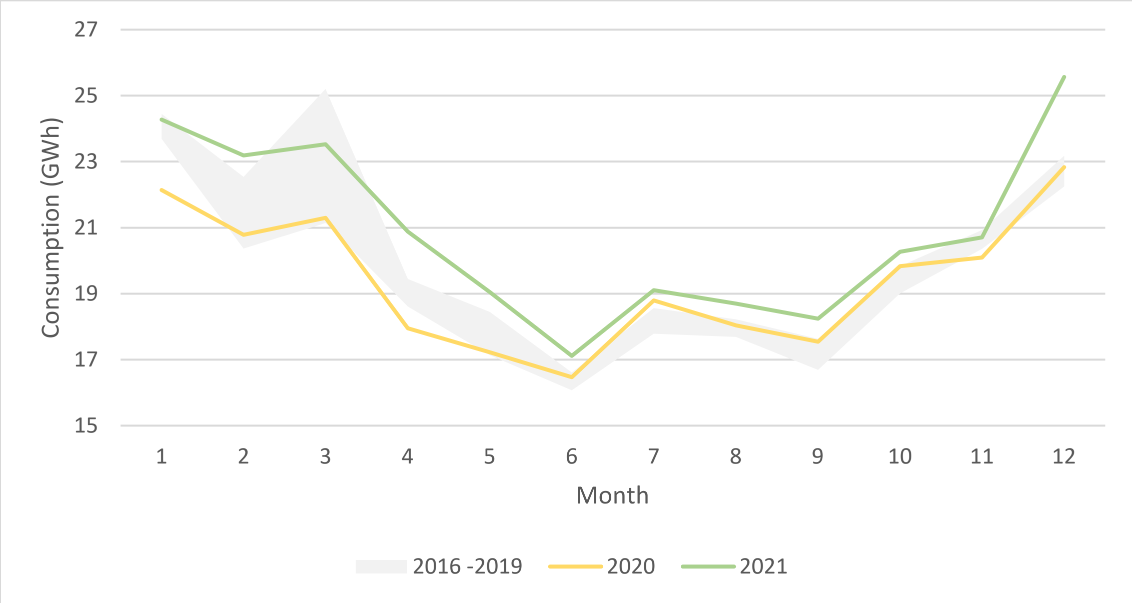
Source: Author's elaboration on Community Mobility Reports by Google & stringency index (Hale et al., 2021)

4.7.3 Tourism and energy linkage in Bornholm

As it is obvious from the data in **Figure 36** the electricity consumption in Bornholm seems to have not been affected by the pandemic. A small decrease in April 2020 can be identified (it is around 7%) but it can be hardly correlated with the COVID-19 outburst. On the contrary, 2021 shows a fluctuation over the historical levels of 2016-2019. It is interesting to note that Bornholm, compared to the rest of the selected locations, has an inverse consumption profile, according to which the energy consumed during winter is significantly higher compared to summer –the touristic season-, obviously due to the weather conditions and the activities of the local residents. These observations are also highlighted in **Figure 37** where the actual consumption data are presented along with the prediction of the consumption that was estimated using the mathematical model that takes into account both the actual weather events of the years 2020 and 2021 and the historical data of the previous years.

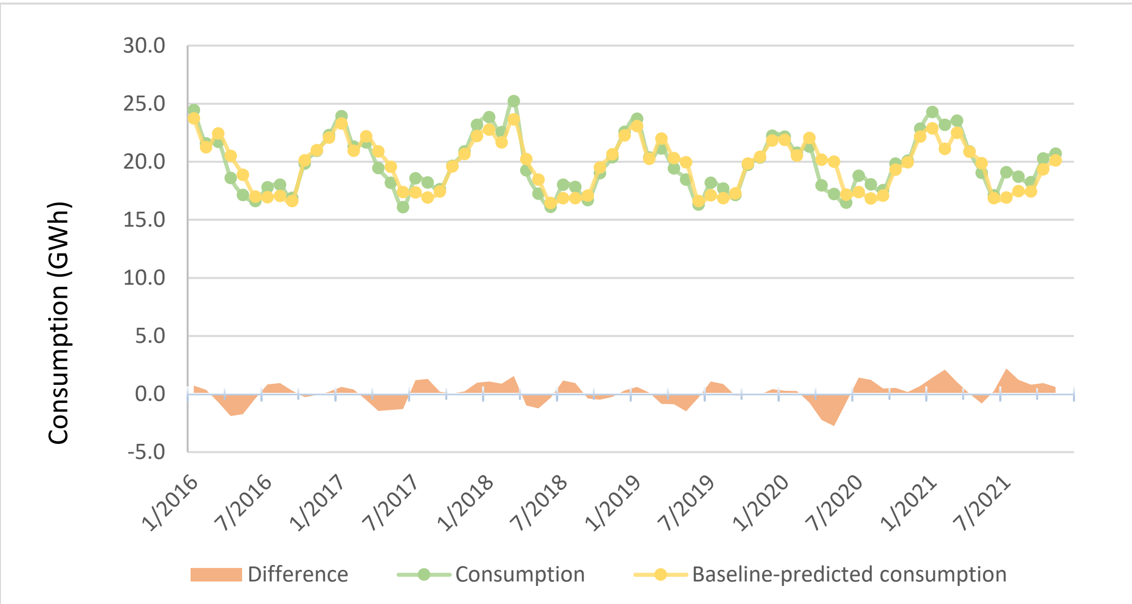
Bornholm, is a really interesting case regarding also the relationship between airport arrivals and energy consumption. Bornhom has patterns that do not apply in any other destination; despite the arrival peak in summer months, electricity consumption is at lower levels in summer than it is in summer. Additionally, the pandemic does not seem to have an impact on the arrivals so evident as in the other destinations we investigate. Even when the restrictions were more tight arrivals and energy consumption does not seem to be affected. Of course, at that point we have to stress out that in Denmark the stringency index was relatively much lower during the Covid crisis - no bigger than 74 -, even in the first wave of the disease. That's why, while in every other destination we have indicated the period when stringency index was bigger than 85, for Bornholm we indicated the period when the stringency index was bigger than 70.

Figure 36. Electricity consumption in Bornholm for 2016–2021



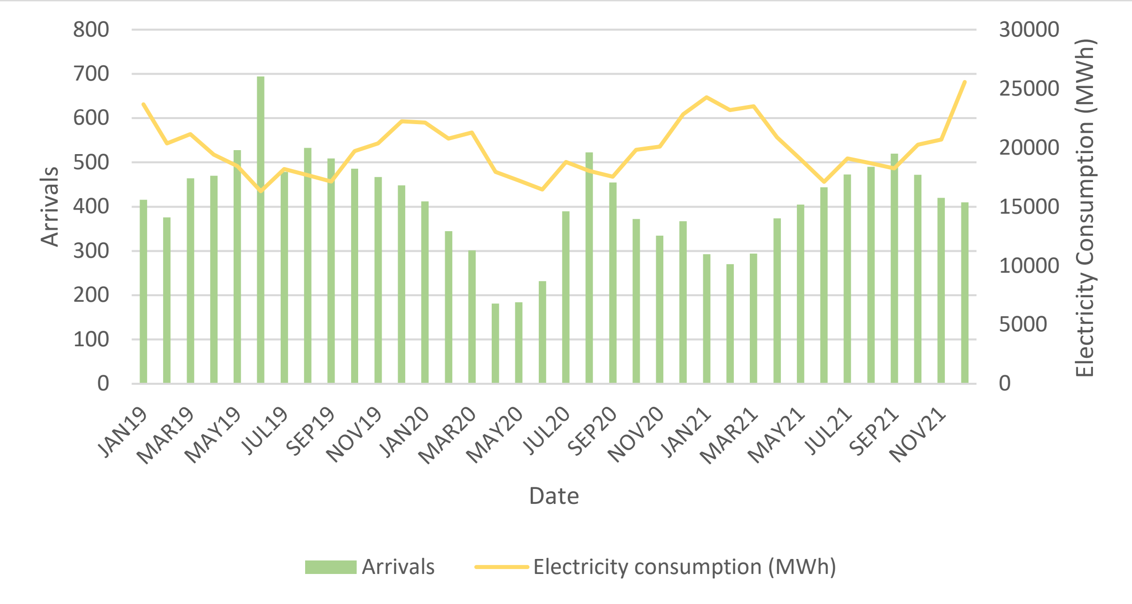
Source: Author's elaboration on Energi Data Service data

Figure 37. Baseline-predicted consumption and actual consumption for Bornholm 2016-2021. The change in electricity demand is shown in the area graph



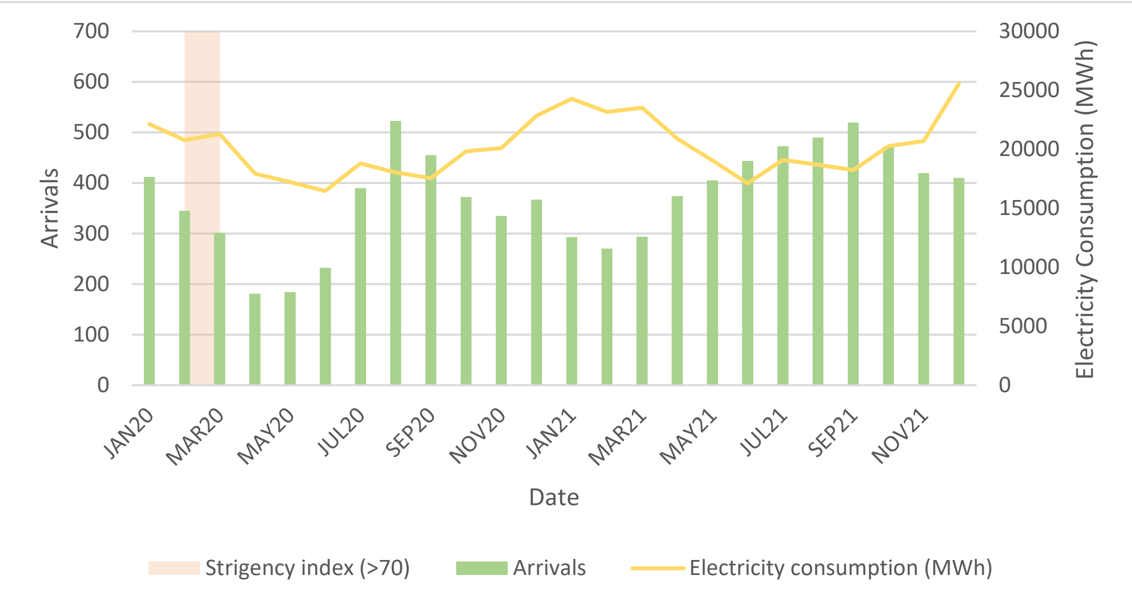
Source: Author's elaboration on Energi Data Service data, Eurostat and degreedays.net

Figure 38. Arrivals and electricity consumption for Bornholm from 2019-2021



Source: Author's elaboration on Energi Data Service and Eurostat data

Figure 39. Arrivals and electricity consumption with stringency index for Bornholm 2020-2021



Source: Author's elaboration on Energi Data Service, Eurostat & stringency index (Hale et al., 2021) data

4.8 Cyprus (CY)

4.8.1 Overview

Cyprus is the third largest and third most populous island in the Mediterranean after Sicily and Sardinia, located in the eastern Mediterranean Sea, south of Turkey, west of Syria and north of Egypt. The general pattern of its coastline is indented and rocky with long and sandy beaches while the inland is dominated by two mountain ranges and a central plain. Geopolitically, the island is divided into four main segments out of which only the Republic of Cyprus will be examined in this study. The total area of the island is 9.251 km^2 and the total number of residents in the Republic of Cyprus are around 1.2 million (population density 123.4/km^2)

Cyprus has an intense Mediterranean climate and one of the warmest climates in the Mediterranean part of the European Union with hot, dry summers and rainy winters which are separated by short autumn and spring seasons of rapid change. In July and August, on the coast, the average high temperature is around 33ºC and inland around 35ºC. In January and February, the average low temperature is 6-8ºC in coastal locations but on mountain Troodos temperature can reach below freezing temperatures and snowfall can be considerable.

Tourism in Cyprus has a dominant position in the island's state economic and cultural development. The tourist arrivals were relatively constant the period 2005 – 2014 but after that they had a considerable increase reaching around 4 million tourists in 2019 with total revenue estimated at 2.7 billion Euros and around 35.1 million night stays (around 8.8 days average length of stay), 95% of which were from non-residents, international tourists[48]. Over 80% of the visitors come from Northern, Western and Eastern Europe with the majority being from Great Britain, Russia, and Israel. The tourist industry relies primarily on the model of "sun and beach" and it is heavily seasonal with the touristic period being mainly between May and October in most places (76% in 2019). However, despite the seasonality, tourism plays a significant role in the country's economy: the gross value added of the activities related to tourism, in 2019, was 25% of the total gross value added; while the employment generated by tourism was 31% in 2019.

Cyprus has no interconnections with neighbouring countries and its electricity generation relies almost exclusively on three thermal power stations that use heavy fuel oil and gasoil and provide the 84% of the required electricity. The share of the renewable energy sources is 16% and comes from wind and solar[49].

4.8.2 Tourism and energy linkage in Cyprus

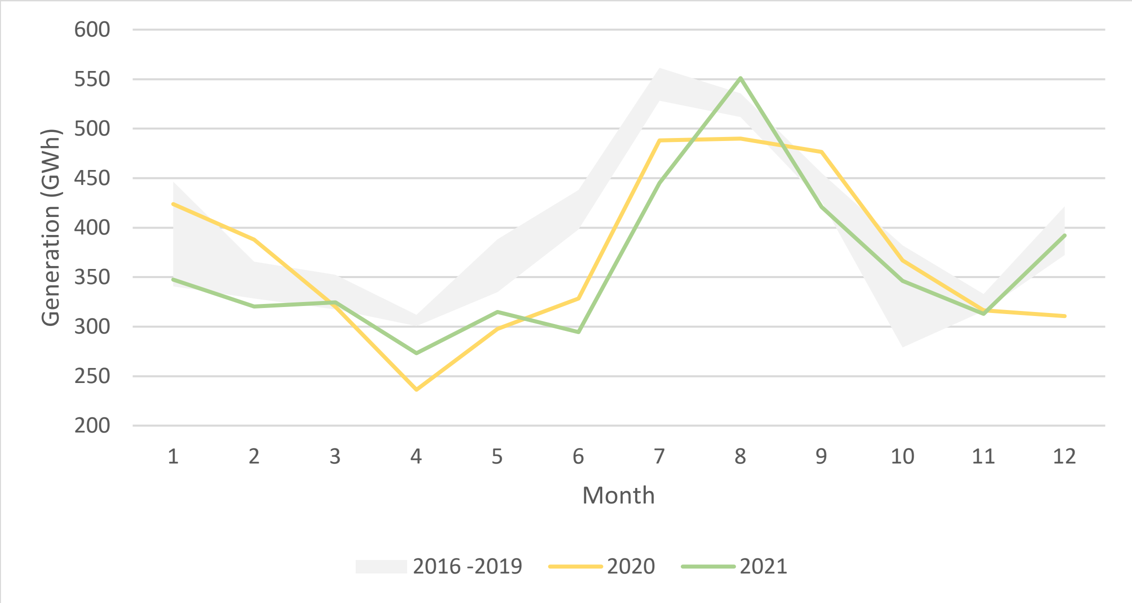
Electricity generation[50] in Cyprus was clearly affected by the pandemic during both examined years. From April up until July, both in 2020 and 2021 the restrictions imposed resulted to a maximum reduction of the electricity generation, compared to 2019, of 25% and 32% respectively, both in June. However, since August 2021 electricity generation seems to recover and stabilize around the historical trends of 2016-2019. These are also verified by the data in **Figure 40** which presents the actual consumption data and the prediction of the consumption that was estimated using the developed mathematical model.

[48] Tourism Market Overview, Axia chartered surveyors, 2020

[49] https://ourworldindata.org/energy/country/cyprus

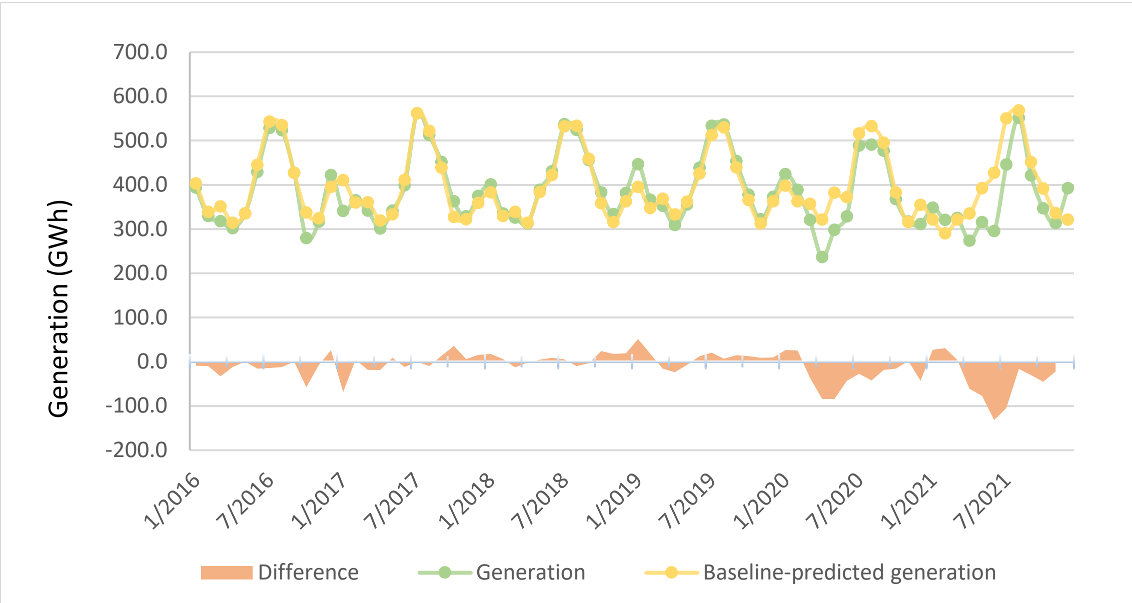
[50] In Cyprus only electricity generation data were available. The difference between the electricity generation and consumption is the technical and non-technical losses. In principle, the generation follows the consumption trends.

Figure 40. Electricity generation in Cyprus 2016–2021



Source Author's elaboration on Transmission System Operator of Cyprus data

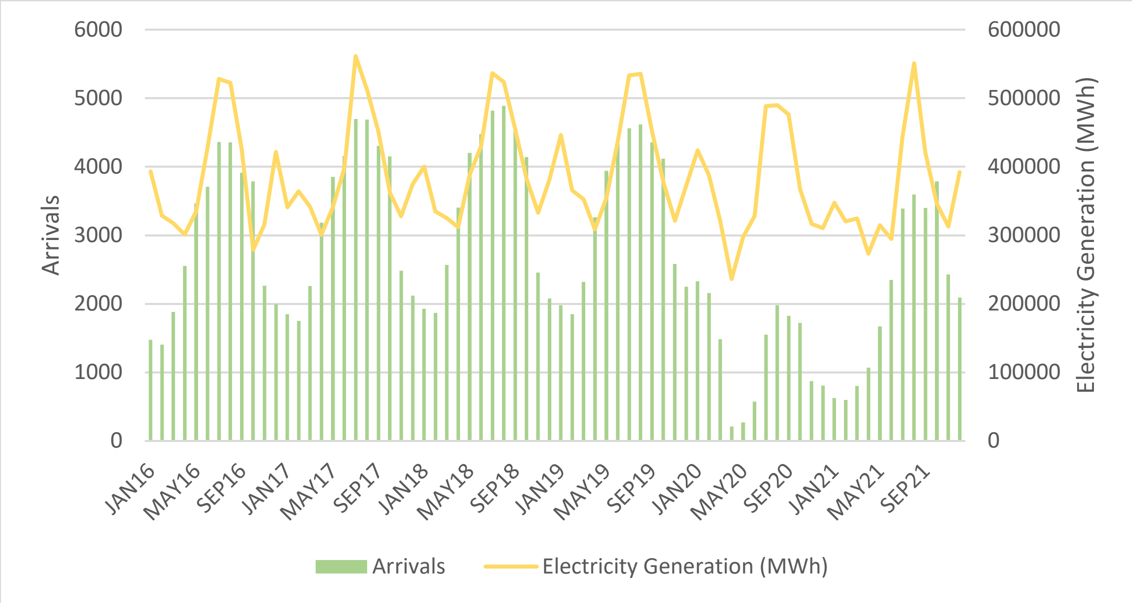
Figure 41. Baseline-predicted consumption and actual consumption for Cyprus 2016-2021. The change in electricity demand is shown in the area graph



Source Author's elaboration on Transmission System Operator of Cyprus data, Eurostat and degreedays.net

Cyprus is characterised by great summer seasonality in airport arrivals, and electricity consumption is following the same path for the examined years 2016-2019. The greater electricity consumption is observed when arrivals are at their peak.

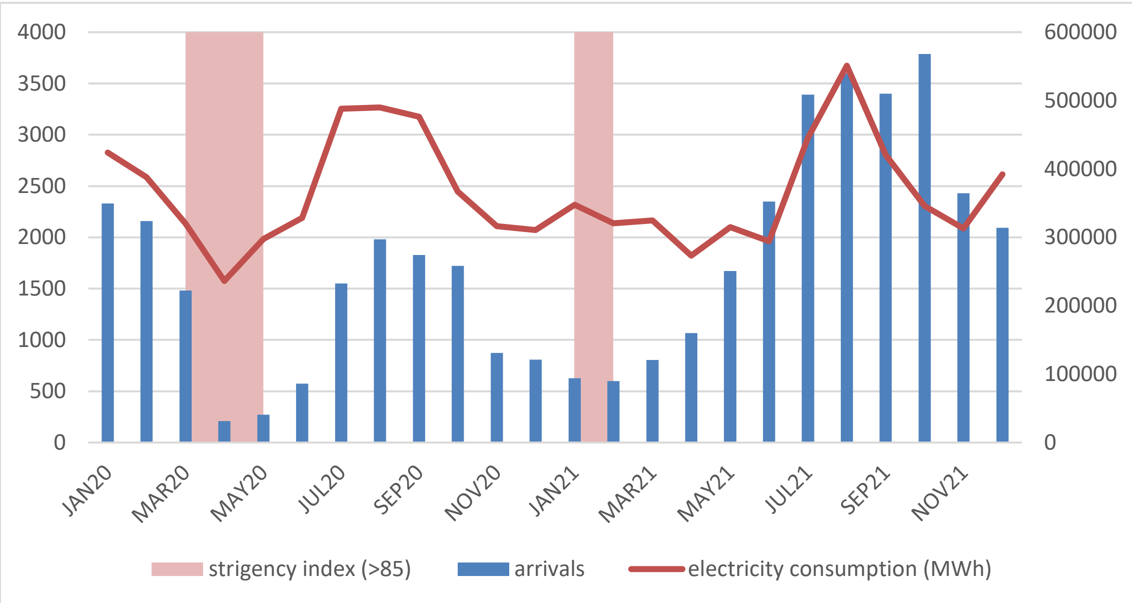
Figure 42. Arrivals and electricity generation for Cyprus from 2016-2021



Source: Author's elaboration on Transmission System Operator of Cyprus and EUROICONTROL data

However, when we examine the pandemic period (2020-2021), despite that the arrivals face a great decrease, the electricity consumption has a relatively lower peak but not as expected. Unfortunately, mobility data for Cyprus were not available.

Figure 43. Arrivals and electricity consumption with stringency index Cyprus 2020-2021



Source: Author's elaboration on Transmission System Operator of Cyprus, EUROCONTROL & stringency index (Hale et al., 2021) data

4.9 Crete (GR)

4.9.1 Overview

Crete (Greek Κρήτη) is a Greek island, located at the south of Greek mainland, at the southern border of Aegean Sea with the Sea of Crete to the north and the Libyan Sea to the south. It has an elongated shape with a mountainous range crossing from west to east. It is the largest island of Greece and the fifth largest in Mediterranean Sea, with a total area of 8,450 km2 and a population of 636,504 (with population density 75.3/km2).

As regards the climate, there are significant differences between the coastal zone and the mountainous areas, as well as between the west and east regions of Crete, due to Crete's geographical position and morphology. It has a primarily Mediterranean climate, with mild, rainy winters and hot, dry summers. The southern coast of Crete falls into the North African climatic zone, with significantly more sunny days and high temperatures throughout the year. The temperature might have significant differences between the coastal and high altitudes of the mountainous regions. At the north coast of Crete the maximum daily average temperature reaches the 29oC in July and August while the minimum the 9oC in January and February.

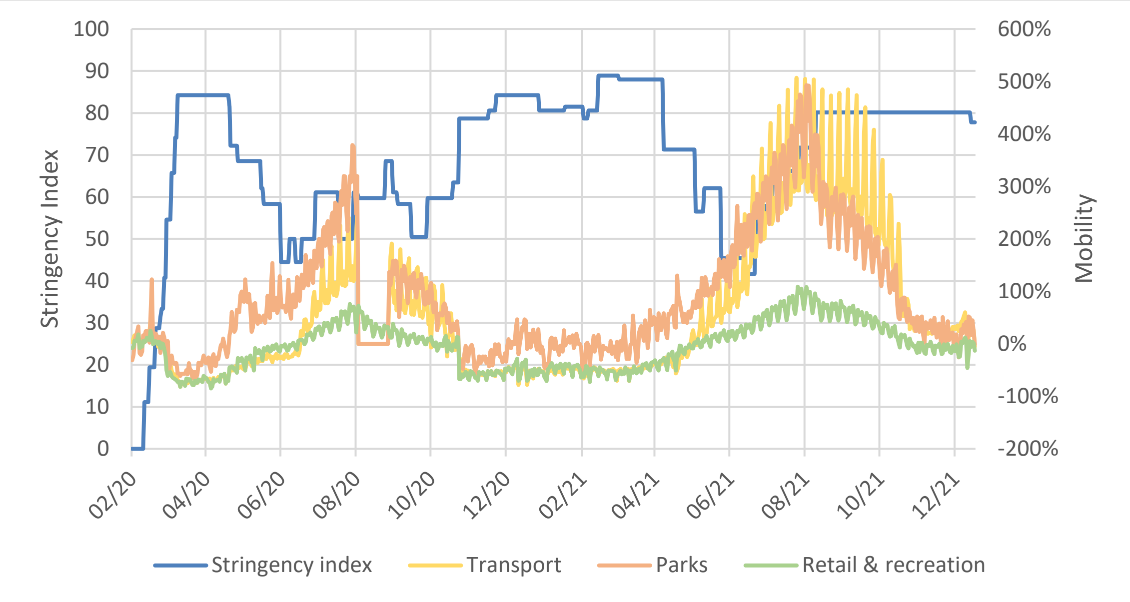
Crete is one of the main touristic destinations in Greece, receiving around 5.3 million visitors in 2019 (a 10% increase compared to 2017) that is a 14% of the total visitors of Greece the same year. The total overnight stays in 2019 was 43.3 million nights, a 7% increase compared to 2017, while the average number of nights spent was 8.2 days. Germans, British and French were the three nationalities with the biggest share of the stays. The total revenues from the touristic activity reached in 2019 4.8 billion euros representing a 36% share at the GDP of the Crete region (which in 2019 was 9.46 billion euros) while the 45% of the total jobs were in Accommodation and Hospitality.

In July 2021, Crete was interconnected with the mainland grid through a 150kV AC, 300 MW cable between Crete and Peloponnisos region. In 2023 a second interconnection between Crete and Attika region is expected through a 500kV DC, 1 GW cable. Currently, at the island there are around 820 MW of thermal power plants, 203MW of wind turbines, 78 MW of photovoltaics and a few small hydro plants, The share of RES in the total electricity generation in 2020 was around 20%.

4.9.2 COVID-19 Restrictions

In the diagram below, as before, we observe the trends of mobility for Crete, in comparison to the stringency Covid index of Greece. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was reduced on average for 3%, the mobility for visiting public places were increased on average by 53%; and finally, mobility for recreation was reduced on average by 15%, which is the highest observed reduction for this period.

Figure 44. Stringency Index and Mobility for Crete

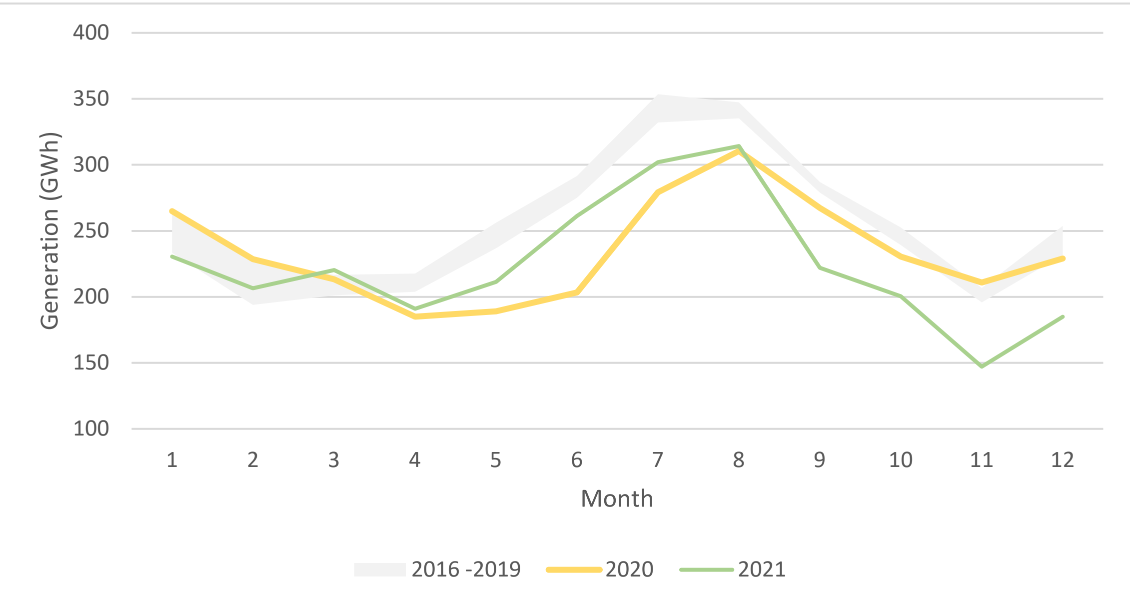


Source: Author's elaboration on Community Mobility Reports by Google & stringency index

4.9.3 Tourism and energy linkage in Crete

Electricity generation[51] in Crete (both local and imported by the interconnection after November 2021) was strongly affected by the pandemic after May 2020. In 2020 the largest decrease occurred in June and reached 30% compared to 2012, however after summer 2020 and the first half of 2021 electricity generation reaches the historical levels, as shown at **Figure 45**. For the rest of 2021 electricity is further affected during the touristic season and especially at the end of the 2021, where the decrease reaches almost 25%.

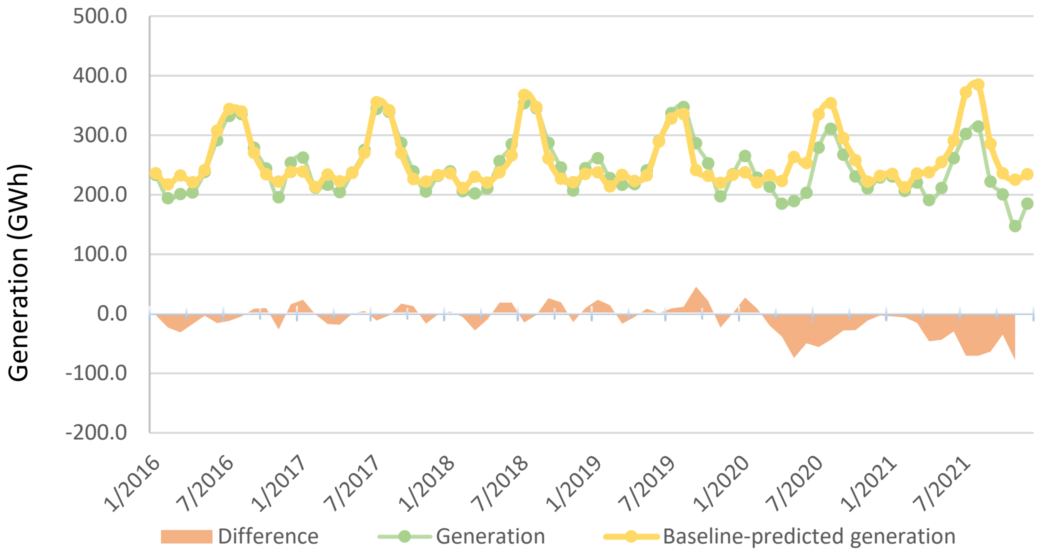
Figure 45. Electricity generation in Crete 2016 – 2021



Source: Author's elaboration on Hellenic Distribution Network Operator data

[51] In Greece only electricity generation data were available. The difference between the electricity generation and consumption is the technical and non-technical losses. In principle, the generation follows the consumption trends.

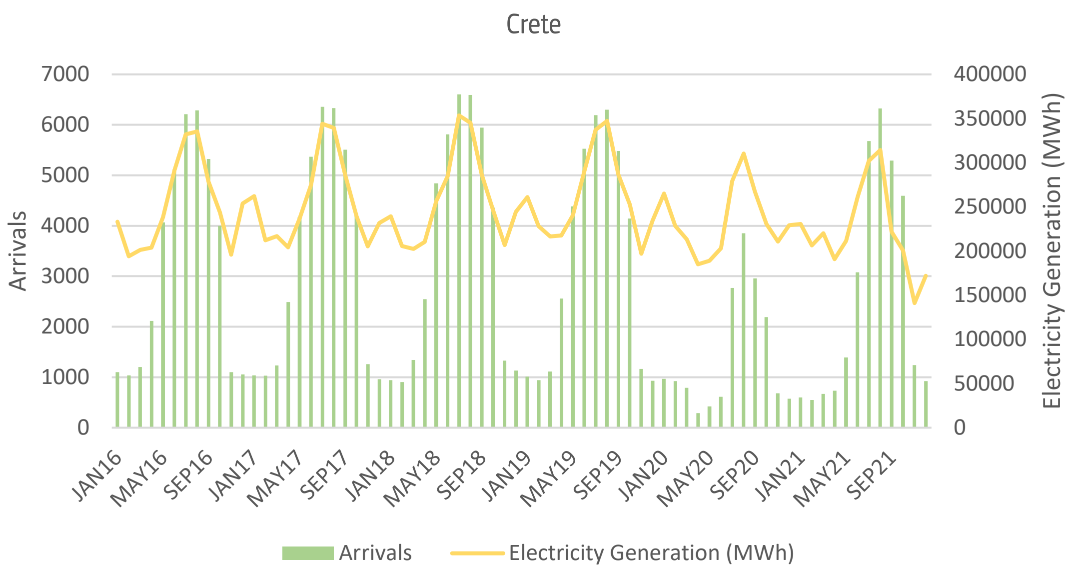
Figure 46. Baseline-predicted consumption and actual consumption for Crete 2016-2021. The change in electricity demand is shown in the area graph



Source: Author's elaboration on Hellenic Distribution Network Operator data, Eurostat and degreedays.net

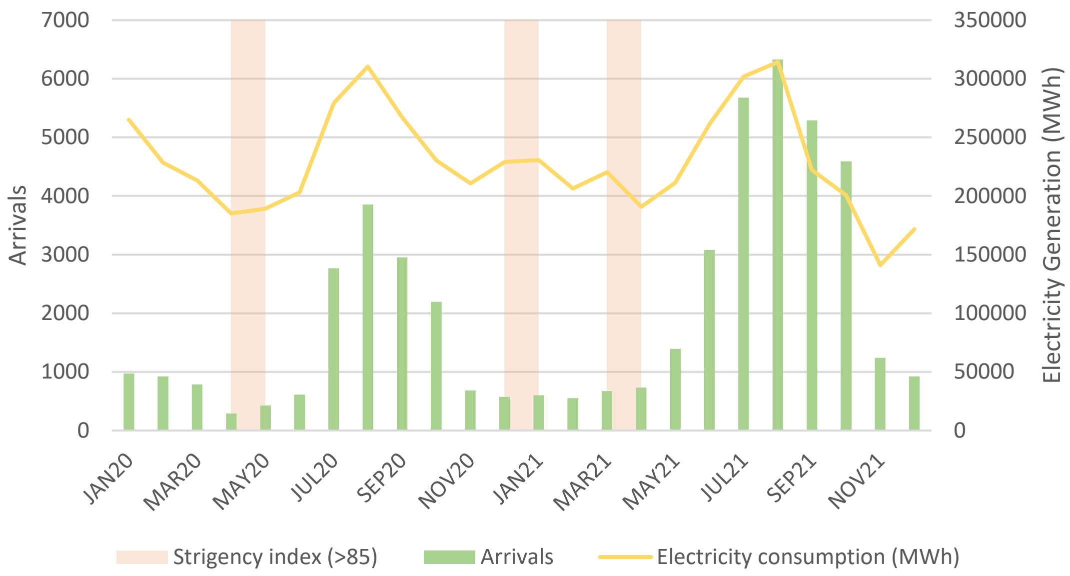
Greek islands appear to have great tourism seasonality. Starting with Crete in summer months the airport arrivals increase tremendously, and this increase is followed by an increase in electricity consumption. If we focus on the pandemic period (2020-2021) the parallel path of arrivals and electricity consumption is repeating. Greece was a country with a really high stringency index, and many tight restrictions during many different periods between 2020-2021 as indicated in **Figure 48**. During those periods arrivals are at their lower number and electricity consumption is also low compared to the rest periods of investigation.

Figure 47. Arrivals and electricity generation for Crete 2016-2021



Source: Author's elaboration on Hellenic Distribution Network Operator and EUROCONTROL data

Figure 48. Arrivals and electricity consumption with stringency index Crete 2020-2021



Source: Author's elaboration on HEDNO, EUROCONTROL & stringency index data (Hale et al., 2021)

4.10 Rhodes (GR)

4.10.1 Overview

Rhodes (Greek Ρόδος) is a Greek island located at the Southeastern part of the Aegean Sea and is the largest of the Dodecanese group of islands. The principal town of the islands and seat of the municipality is Rhodes, located at the northern tip. It has a mountainous and sparsely inhabited interior part, covered with forests, and rocky shores. The total population of the island is 115,490 and a total area of 1,400 km^2 (population density 82/km^2).

The climate of Rhodes Island is hot Mediterranean, with mild winters and hot summers. The Southern part of the islands experiences a significantly warmer climate, one of the warmest in Greece. The average high temperature occurs in August and is 30.7oC while in February the average low reaches 9.1oC.

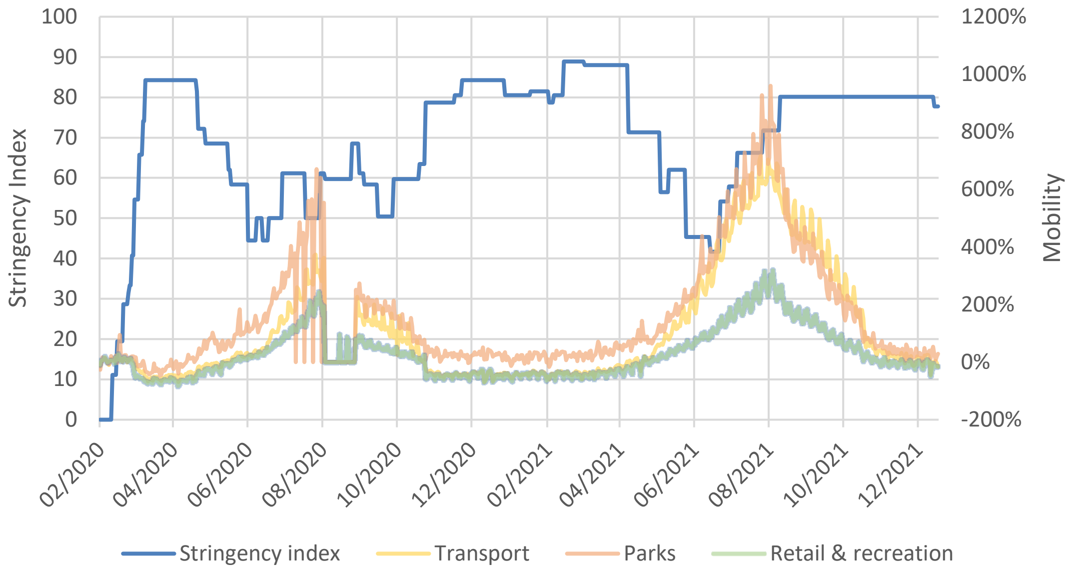
Rhodes is one of the most popular destinations in Greece, along with Crete, and tourism is a fundamental part of the local economy, which is generally tourist oriented. In 2019 Rhodes is estimated that it was visited by more than 3.5 million tourists, less than 10% of which were cruise passengers, with the total nights spent exceeding 18.5 million nights. In 2019, the tourism sector's share of regional GDP was 43.31% while 53% of the total jobs were in Accommodation and Hospitality. Additionally, the share of tourism in regional GVA was 47%.

The electrical system of Rhodes is autonomous, since the island is not interconnected with the mainland system. The majority of the energy is produced by the two oil-fuelled thermal power plants of total capacity 350 MW while the rest from renewable generation, solar and wind, the share of which in 2019 reached 12.6%.

4.10.2 COVID-19 Restrictions

Figure 49 shows the trends of mobility for Rhodes, in comparison to the stringency Covid index of Greece. For the period from 15/02/2020 until 31/12/2020 (Hale et al., 2021) the mobility for public transportation was increased on average for 39%, the mobility for visiting public places was increased on average by 99% and for recreation was increased on average by 8%.

Figure 49. Stringency Index and Mobility for Rhodes

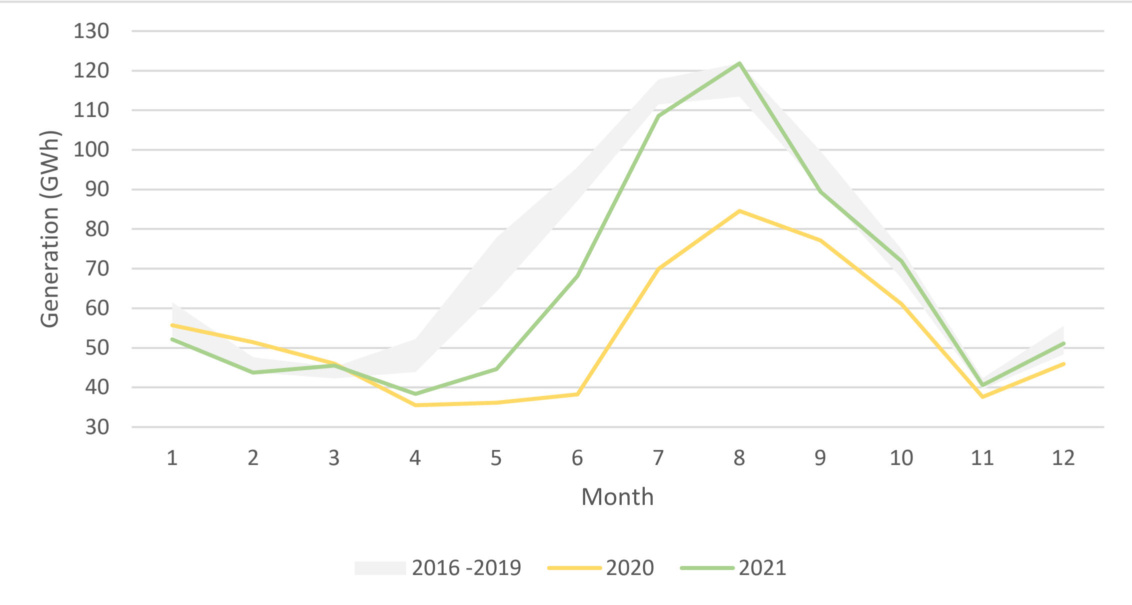


Source: Author's elaboration on Community Mobility Reports by Google & stringency index

4.10.3 Tourism and energy linkage in Rhodes

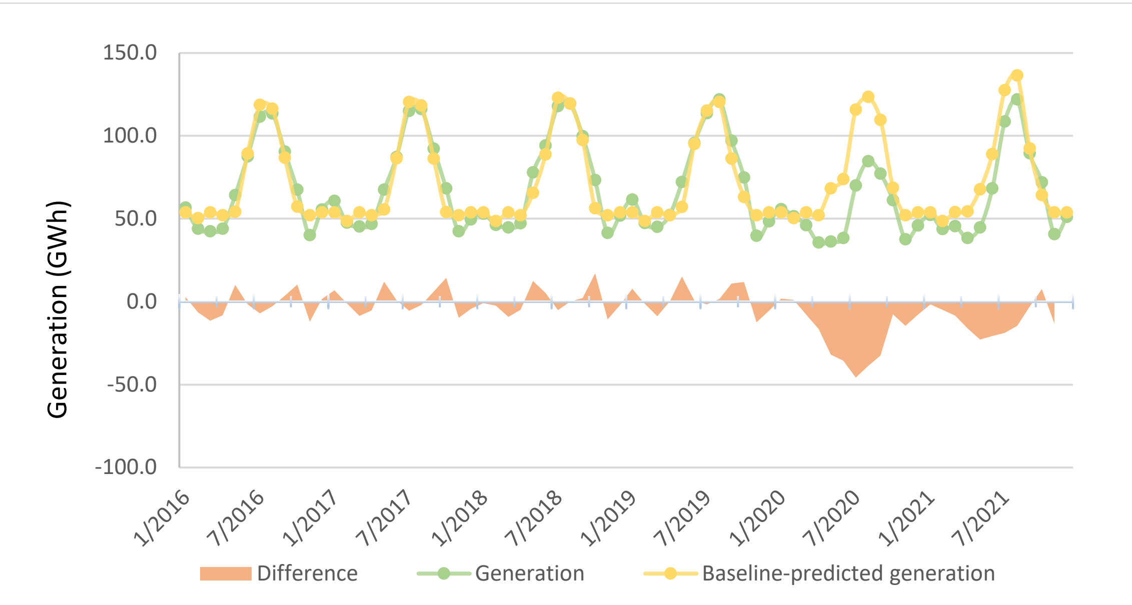
In 2020 electricity generation in Rhodes followed a similar trend with the Crete and all the selected locations highly dependent on tourism, but the influence of the pandemic was much stronger, as **Figure 50** shows. In June 2020 a decrease of 60% compared to 2019 was the largest of the year, while for 2021 the largest decrease occurred in May and was 38%. By the end of the years 2020 and 2021 values fluctuated around the historical levels of 2016-2019 indicating the strong impact of tourism in local economy.

Figure 50. Electricity generation in Rhodes 2016 – 2021



Source: Author's elaboration on Hellenic Distribution Network Operator data

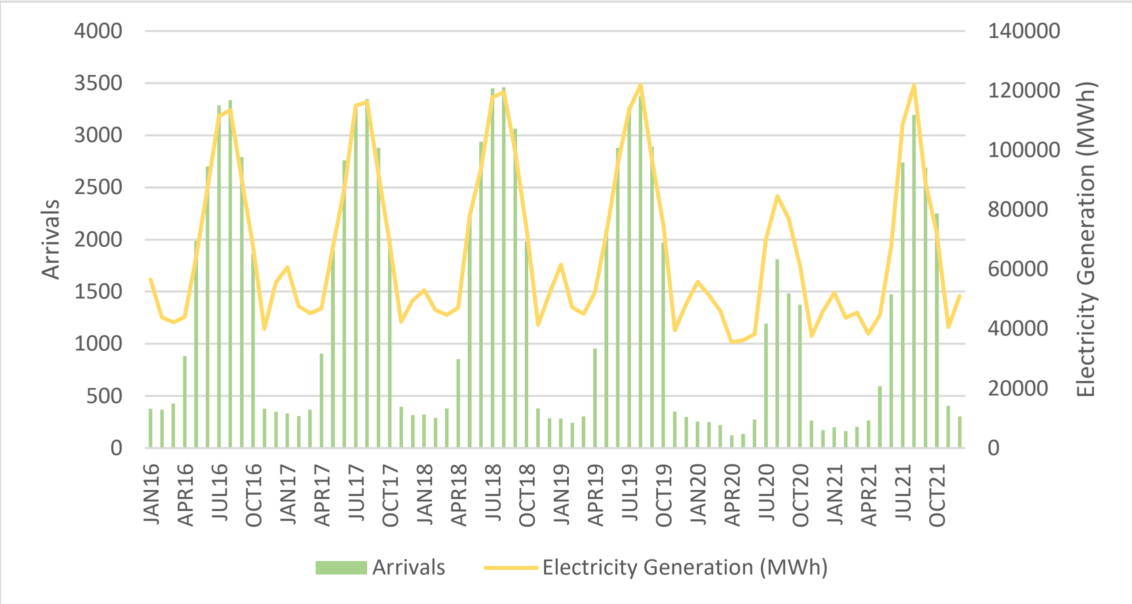
Figure 51. Baseline-predicted consumption and actual consumption for Rhodes 2016 – 2021 - The change in electricity demand is shown in the area graph



Source: Author's elaboration on Hellenic Distribution Network Operator data, Eurostat and degreedays.net

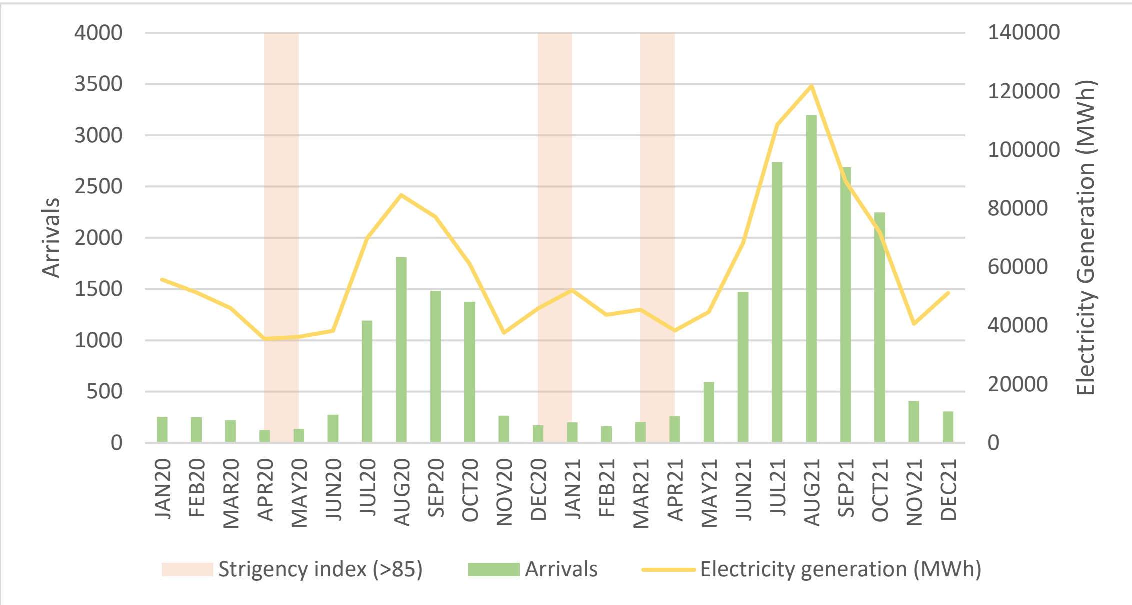
Rhodes has in every period of investigation the same characteristics as Crete: high tourism seasonality, reflected in airport arrivals, with energy consumption following the fluctuations.

Figure 52. Arrivals and electricity generation for Rhodes from 2016 to 2021



Source: Author's elaboration on Hellenic Distribution Network Operator and EUROCONTROL data

Figure 53. Arrivals and electricity consumption with stringency index Rhodes 2020-2021



Source: Author's elaboration on Hellenic Distribution Network Operator, EUROCONTROL & stringency index (Hale et al., 2021)

5 Analysis of the case studies

5.1.1 Mobility

The restrictions applied in the selected locations to prevent the virus from spreading were the same nation-wide. To indicate the effects of the restrictions on societies, we used the available mobility data for the period from 15/02/2020 until 31/12/2021, for all locations except Cyprus, where the data were not available. In **Table 2** we present the average mobility fluctuations for each location.

Table 2. Average mobility fluctuations from 15/02/2020 until 31/12/2020

	Transport	**Parks-Public places**	**Retail & Recreation**
Balearic Islands	-28%	-27%	-29%
Canary Islands	-41%	-32%	-42%
Madeira	*No available data*	*No available data*	-32%
Sardinia	-20%	-63%	-22%
Sicily	-31%	-17%	-28%
Bornholm	-5%	-2%	-19%
Cyprus	*No available data*	*No available data*	*No available data*
Crete	-3%	+53%	-15%
Rhodes	+39%	+99%	+8%

Source: (Hale et al., 2021).

In general, the average observed mobility was expected to have decreased because of the restrictions. The island of Sardinia had the greatest average reduction in mobility for public places, while the Canary Islands had noticeable reductions in all three mobility indicators. However, Greece followed a different pattern: Crete and Rhodes saw a tremendous increase in mobility in public places.

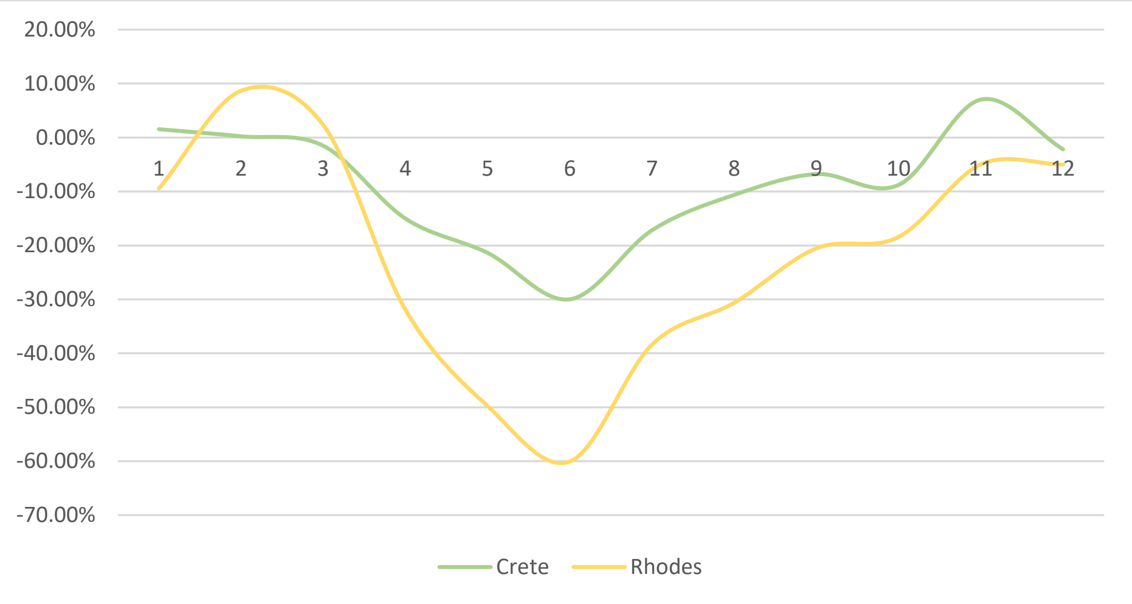
5.1.2 Impact on energy

In order to examine the impact of the COVID-19 pandemic on the electricity consumption of the selected touristic islands, we retrieved and processed data from local energy authorities. Elaboration on the monthly electricity consumption for the period from 2016 to 2021 highlighted various patterns and responses in electricity demand as a result of the restrictions imposed. To further ensure that the observed impact was not due to specific weather events and meteorological conditions during the two pandemic years, a linear machine learning model was trained, per case study, using the historical electricity demand and degree day data for the period from 2016 to 2019. The model was then used to predict the energy demand for the period from 2020 to 2021, which represents the energy consumption you would expect to have if it operated as it did in the 2016-2019 period. In that way, we were able to make a direct comparison with the actual energy consumption, having removed the influence of weather events.

Overall, the data showed that among the selected regions, the most significant impact was made on the electricity consumption of Rhodes, which reached a 60% decrease in June 2020. The lowest impact was seen in Bornholm, which was affected slightly at the beginning of the pandemic but quickly recovered. Sicily – the largest Mediterranean island – was visibly affected, but not strongly. The other Italian island, Sardinia, followed a similar pattern to Sicily but the impact was slightly stronger. In general, Bornholm and the two Italian islands were the least affected compared to the rest of the selected regions.

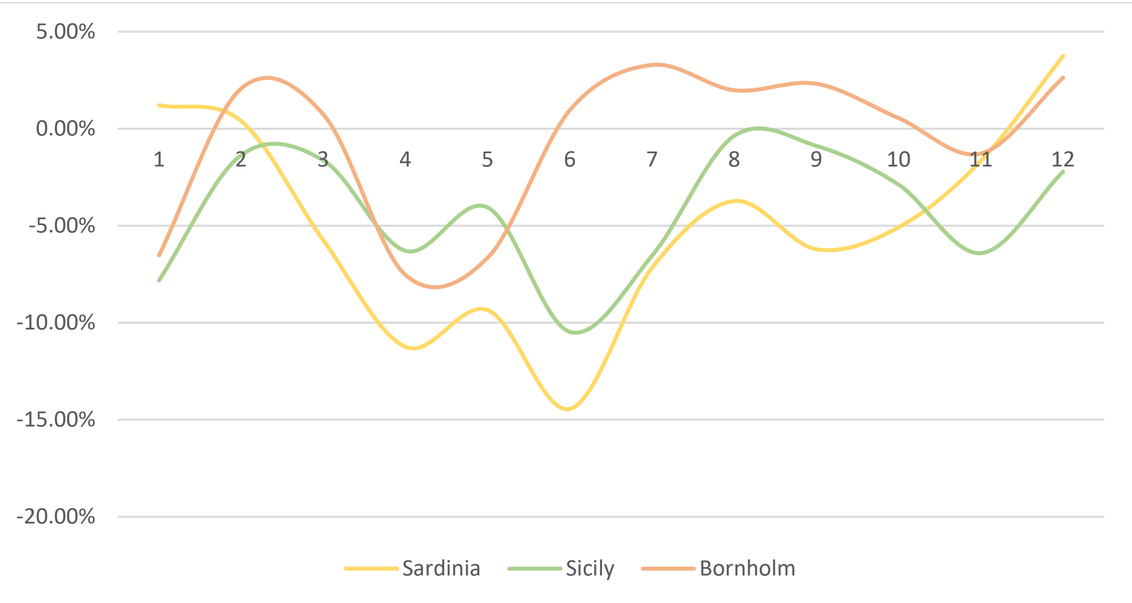
The second largest impact is observed in the Balearic Islands, followed closely by Crete. The Canary Islands and Cyprus experienced a similar reduction in their electricity demand. However Madeira, despite its similar touristic offering, is affected less, with a decrease of only 17%. In general, the electricity consumption of the Greek and Spanish islands, along with Cyprus, was strongly affected by pandemic restrictions. Aside from the scale of the impact, it is the Greek and Italian islands whose trends in electricity consumption match most closely, as seen in **Figure 54** and **Figure 55**. A recovery is observed by the end of 2020 and during 2021 in all selected locations, although some fluctuations still occur.

Figure 54. Changes in electricity demand for Crete and Rhodes during 2020



Source: Author's elaboration Hellenic Distribution Network Operator data

Figure 55. Changes in electricity demand for Sardinia, Sicily and Bornholm during 2020



Source: Author's elaboration on Terna Spa data and Energi Data Service data

5.1.3 Arrivals and energy use

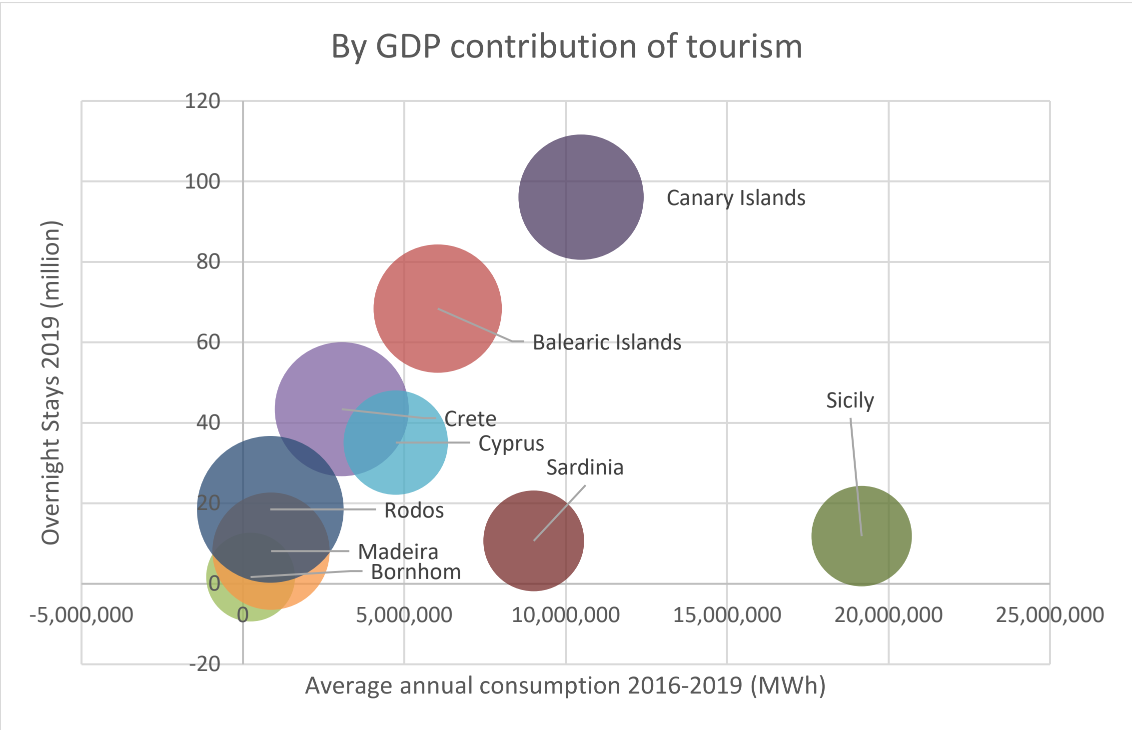
To explore the link between tourism and energy usage in the selected sites we used EUROCONTROL airport traffic data as a strong indicator of tourism presence. For the majority of the tourism destinations we selected – Balearic Islands, Sardinia, Sicily, Cyprus, Crete, and Rhodes – there is a seasonal increase in airport arrivals during the summer months because of increased tourism movement. Consequently, the patterns regarding the relationship between electricity consumption and tourism are the same. From 2016 to 2019, as airport arrivals start to rise around May, electricity consumption starts to rise as well, while the months with the most airport arrivals and electricity consumption are July and August, in every year of our study. On the other hand, off-season months are characterised by significantly lower energy usage with no noteworthy fluctuations. The pandemic impact is observed in 2020 and 2021; as a result of reduced tourism, electricity consumption does not approach the high levels of previous years at any point, while the peaks and electricity variations follow parallel courses with arrivals as the years before. However, on Madeira and the Canary Islands, there is less significant tourism seasonality though still observe a correlation between arrivals and electricity use for all the analysed periods. In the years 2020-2021, with the travel restrictions, the arrivals and electricity consumption continue to follow parallel paths. In every aforementioned location, when the stringency index is at its highest level, electricity consumption and arrivals are at their lowest level.

Bornholm is the place where none of the above is true. Despite the arrival surge in the summer months, electricity consumption is lower than it is in winter. Furthermore, unlike the other places we analyse, the pandemic does not appear to have had a significant influence on arrivals. Arrivals and electricity use do not appear to be influenced, even when restrictions are tighter.

5.1.4 GDP and impact on energy

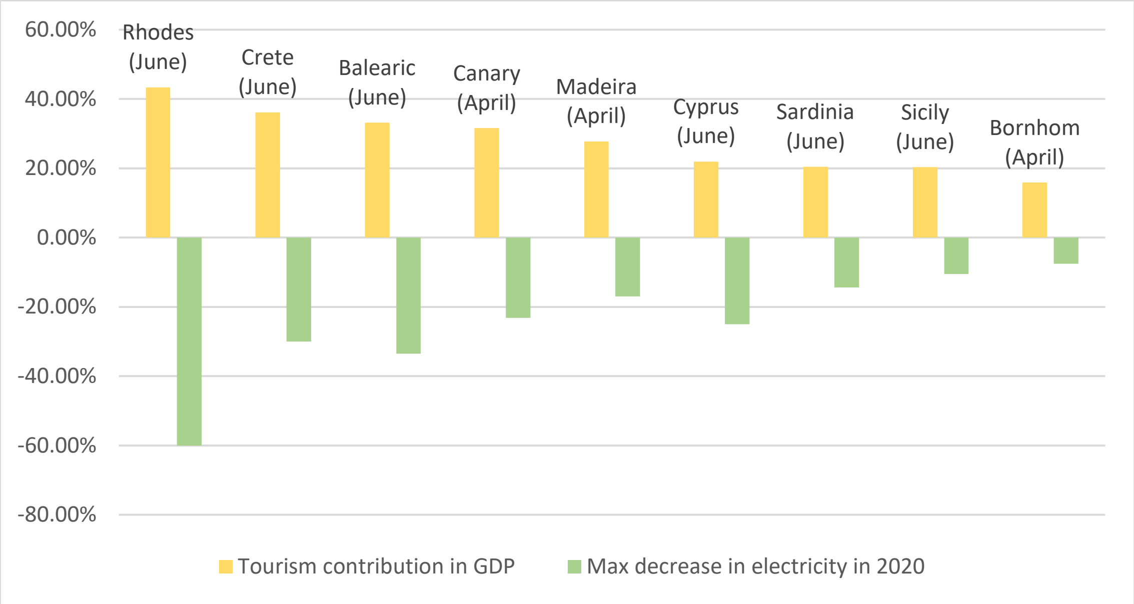
Figure 56, which is based on the 2019 data, confirms a shared trend already identified during the literature review, between overnight stays and electricity consumption. It seems that at the selected locations where tourist activity represents an important part of the regional GDP, electricity consumption raises as the number of overnight stays increases. In larger islands, such as Sicily and Sardinia where their economies can be considered more complex, we do not observe the same trend. Energy consumption seems to be affected by other factors; thus, a deeper socio-economic analysis for those locations is needed. We examined the maximum impact of the pandemic on electricity consumption, considering the contribution of tourism to GDP, at each of the selected locations. As **Figure 57** indicates, locations with a lower dependence on tourism, like Bornholm and the Italian islands, experienced a less severe impact compared to regions more dependent on tourism like Rhodes, Crete and the Balearic Islands. At each location, in the brackets, we indicate the month where the maximum decrease in energy consumption occurs. We see that June and April are the months showing the most extreme difference, with June being the most common month.

Figure 56. Average annual consumption and overnight stays by GDP contribution of tourism for the selected locations



Source: Author's elaboration on previously presented data

Figure 57. Comparison of selected location with respect to tourism contribution to GDP and maximum decrease in electricity in 2020



Source: Author's elaboration on previously presented data

6 Summary and lessons learned

As the need for sustainable and circular touristic economies becomes more critical this study can stimulate the discussion over the energy component of local sustainable tourism plans. Islands as semi isolated spatial entities are unique environments for the testing of circular and climate friendly touristic development plans. In regards to energy, by investing in local renewable projects, tourist areas experiencing high seasonal demand can increase circularity, energy security and generate secondary income year-round. Our analysis highlights the linkages between touristic activities and energy consumption, it provides clear evidence of the energy intensity of the sector and provides a proxy over the order of magnitude of tourism's sector impact on local energy systems in the specific islands.

In this report, we analysed the linkages between electricity consumption patterns and tourism, and fluctuations as a result of the pandemic. To study this impact we selected a group of European islands, known, to a lesser or greater extent, as tourist destinations. These include the Balearic and Canary Islands in Spain and Madeira in Portugal, which are among the top beach holiday destinations in the world. From Greece, we selected Rhodes and Crete, two of the biggest and most famous Greek islands. From Italy, we selected Sicily and Sardinia since they are the biggest islands in the country, although not exclusively touristic. The last Mediterranean island in the study is Cyprus, a country with a significant tourist industry. Finally, we included Bornholm, a touristic island in Denmark with a different model from its southern counterparts – with its tourism more focused on nature activities.

The case studies were examined using, at first, the stringency and mobility indices as proxies to represent the impact of the pandemic and its associated restrictions on the mobility of the people. After that, the impact of the restrictions on the energy sector were presented, specifically on the electricity consumption during the pandemic years of 2020 and 2021, as opposed to the historical data of 2016 to 2019. To decouple the influence of regional weather conditions from electricity consumption, regression analysis with heating and cooling degree days was performed via a developed model. The specific link between electricity demand and tourism was derived for each location by comparing flight arrivals of visitors and electrical consumption during the period 2016 and 2021. We chose flight arrivals as a proxy indicator to capture the tourist trends and monthly fluctuations for each region.

Similarly to the literature we confirm that **the periods of high tourism movement are accompanied by increased electricity consumption**. For most of the tourist destinations we selected – the Balearic Islands, Sardinia, Sicily, Cyprus, Crete and Rhodes – there is a seasonal increase in airport arrivals during the summer months as a result of increased tourism movement. From 2016 to 2019, as airport arrivals start to rise around May, electricity consumption starts to rise as well, while the months with the most airport arrivals and electricity consumption are July and August, in every year of our study. On the other hand, **off-season months are characterised by significantly lower and relatively stable levels of energy usage**. Similar patterns can be found in Madeira and the Canary Islands, with no times of great tourism seasonality and with a correlation between arrivals and electricity use for all the analysed periods. Those patterns are obvious during the pre-pandemic era, while they become even more evident during the movement restriction periods of the pandemic.

The data analysis from the studied locations highlighted the **correlation between reported lockdowns, drops in electricity consumption and decrease in tourism arrivals**. We examine the relationship between demand reduction and quarantine severity. The evidence suggests that the reduction in electricity demand is strongly related to confinement measures as they are represented by the stringency index and reflected in the mobility data. The lockdowns, along with the travelling restrictions, caused great mobility reductions, resulting in reduced electricity needs.

Additionally, our analysis showed that among the selected case studies, the **islands with a higher economic dependence on tourism experienced a greater decrease of energy use** (measured as a percentage share of regional GDP). Data showed that of the selected regions, Rhodes experienced the most severe impact on electricity consumption, reaching a 60% decrease in June 2020. At the other extreme, Bornholm recovered quickly after being affected only slightly at the beginning of the pandemic. In Rhodes, tourism contributes more than 40% to regional GDP, while in Bornholm it contributes less than 20%. The second largest impact was observed in the Balearic Islands, followed closely by Crete, the Canary Islands and Cyprus. Sardinia and Sicily, the largest Mediterranean islands, were not strongly affected, although the impact is noticeable. Although the two Italian islands are popular tourist destinations, the sector's contribution to GDP is around 20%.

Retrieving and analysing data for the purpose of this report was a complex task. Data for electricity consumption, tourism and Covid are available at country level, but when focusing on specific regions, data are not always available in one database or in a useable form. In addition, although the investigation of energy consumption in the tourism sector is a subject of academic and market research, there is a lack of data combining the two, let alone at regional level. However, as discourse grows around the sustainability of economic and touristic activities, it is expected that this data gap will be eliminated.

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List of abbreviations and definitions

CDD	Cooling Degree Days
CHP	Cooling Degree Days
EEA	European Environment Agency
EU	European Union
GDP	Gross Domestic Product
GVA	Gross Value Added
GHG	Greenhouse Gas
HDD	Heating Degree Days
IATA	International Air Transport Association
SME	Small and Medium-sized Enterprises
NO2	Nitrogen Dioxide
UNWTO	United Nations World Tourism Organization

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