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Energy Metabolism of the Balearic Islands (1986-2012)

Xavier Ginard-Bosch[a, *], Jesus Ramos-Martin[b]

[a]Camino Can Pastilla 86, A4, 07610 Palma de Mallorca, Islas Baleares, Spain

Email: xavier_ginard@hotmail.com

(*) Corresponding author

[b]Facultad Latinoamericana de Ciencias Sociales (FLACSO), La Pradera E7-174 and Av. Diego de Almagro, Quito, Ecuador.

Email: jramos@flacso.edu.ec

ABSTRACT

Researchers from multiple disciplines point to the link between fossil fuel consumption and socio-ecological deterioration. Studying the energy metabolism of the Balearic Islands (1986-2012) gives insights on the ecological, economic and social consequences of regional specialization in mass tourism. The methodology applied, Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), has been developed in the last decades to analyze societal metabolism from the perspective of complex systems. This study has allowed to see that since the entry of Spain in the European Economic Community in 1986, the real-state/tourism business model has been reinforced

giving place to a higher level of consumption of fossil fuels, an increase in work instability and a diminishing of labor productivity.

KEYWORDS: energy; social metabolism; multi-scale integrated analysis; economic crisis; sustainability; Balearic Islands.

1. INTRODUCTION

The great dependency shown by the world economy on fossil fuels and other non-renewable resources puts into question the future of current society, as we know it. There is no doubt that improvements in energy efficiency and development of renewable energy sources will help in reducing pressure upon mineral deposits and in reducing atmospheric pollution. However, unless significant changes in production systems occur, reverting current trends and therefore avoiding conflicts related to material and economic scarcity will be difficult (Giampietro et al., 2007; Klare, 2012).

The IEA (2014) foresees world energy demand will increase 37% between 2012 and 2040, with at least three quarters of it coming from fossil fuels. This growing trend in the consumption of resources goes hand in hand with a generalized process of environmental degradation (Chew, 2001; Moore, 2000).

Tourism has been one of the economic activities that has played an important role in the international division of labor (Fröbel, et al., 1981). Mass tourism was promoted in the West during the second half of the XX century because of the expansion of the consumer society and also a consequence to the development of the leisure industry. Since then, tourism has been part of the official agenda of institutions, governments and capital, as a strategy to increase currency and international capital and to escalate positions in the global economy (Hawkins and Mann, 2007; Pack, 2006).

The Balearic Islands in Spain (a situation map is provided in Annex II) are one of the main touristic destinations in the Mediterranean and, in fact, in 2013 received more than 11 million international tourists (IBESTAT, 2015), well above countries such as Croatia or Morocco (UNWTO, 2014). To put this figure into context, we need to take into account that the population of the Balearic Islands in 2012 (or the 1st of January 2013) was of 1,111,674 people (INE, 2015c). The same year, the population of Spain was of 46,727,890 people. Spain, with a surface area of 505,990 km^2 (INE, 2008) received 60.7 million tourists, being the third main destination in the world (UNWTO, 2014), while the Balearic Islands, with 4,992 km^2 (INE, 2008), or just 1% of the surface of Spain, received 18% of the tourists, or 11 million. The impact of such number of visitors to the Balearic Islands is considerably higher than in continental Spain. In fact, were the Balearic Islands considered as a country, they would have ranked as thirteenth destination in Europe.

Mass tourism and real state have been the main drivers of the economic development of the Balearic Islands. The massive entry of tourists has stressed resource consumption in the islands. The aim of this article is to identify internal and external constraints of that development model. This is done by analyzing the energy metabolism of the Balearic Islands, by using a well established methodology called Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) (Giampietro and Mayumi 2000a, 2000b; Giampietro 2003; Giampietro, et al., 2009), which is inspired by the work of Georgescu-Roegen (1971). A subsequent aim of the article is to provide some policy measures that could address some problems related with the development model based on more use of land and of resources, adding to the current debate on development models based on touristic activities.

There is some literature on the use of energy in the Balearic Islands (Manera, 2001; Pujalte, 1997; Rosselló-Batle et al., 2010; Sanyé-Mengual et al., 2014). However, none of them refers to the different scales, compartments and functions within the socioeconomic system.

One exception to this literature is Murray (2015) who, in his complete assessment of the tourist sector of Spain, analyzes, among other things, the environmental impacts of the activity by showing the physical trade balances of Spain and its relation to tourism. Another exception is found in Ginard and Murray (2015) who conducted a detailed metabolic analysis of the Balearic Islands with emphasis in material flows for the period 1996-2010, including also physical trade balances. Our contribution here pretends to add to that relevant work by analyzing the missing piece on previous analysis, the energy metabolism.

2. SOCIAL METABOLISM AND AN OVERVIEW OF MuSIASEM

The concept of societal metabolism, referred to the exchange of resources between nature and society, appeared for the first time in the XIX century, due to the awareness that capitalism has a tendency to generate ecological and socioeconomic crises (Foster, 2000). In the decade of the 1970s, both oil crises enhanced the interest on the biophysical costs of advanced societies and some literature started growing on the link between the evolution of economies and the use of resources, mainly energy and materials (Adriaanse et al., 1970; Herendeen, 1981; Kneese et al., 1970; Odum, 1971; Slesser, 1978). The popularization of these kind of studies implied that, since the end of the 1990s, new methodologies have appeared which, using different interpretations, try to standardize and systematize the analysis of societal metabolism (Fischer-Kowalski and Hüttler, 1998; González de Molina and Toledo, 2014).

2.1. Study Methods: Theoretical framework

The methodology used in this study is called Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), introduced by Giampietro and Mayumi (1997, 2000a, 2000b) and developed in Giampietro (2003). MuSIASEM is a methodological framework inspired in the flow-fund model of Georgescu-Roegen (1971, 1977) and the theory of complex systems of Maturana and Varela (1980), among others. The interested reader can refer to Georgescu-Roegen (1971) and Mayumi (1999) for a deeper understanding of the fund-flow model and to (Giampietro et al., 2009) for its applications within MuSIASEM.

Considering human society as a complex system implies accounting for its internal organization and its dependence with the surrounding environment. From this perspective, a social system is conceived as a set of human activities that are hierarchical, whose relationship with the environment have implications on its own structure and evolution. The way in which a society self-organizes is determined by technology, culture, historical processes and the political-economic system, among other things. Internal constraints are derived from them: a set of social transformations that are under human control. Moreover, the availability of resources and the sink capacity represent the external constraints; that is, those that are not under human control. Integrating both perspectives, internal and external, requires the application of parallel non-equivalent discourses (Giampietro, 2003).

In this sense, MuSIASEM is an accounting methodology that allows studying biophysical and socioeconomic issues in an integrated manner, both for the level of the society and for the different compartments of that society. This integration helps to identify external constraints related to the supply of resources and some internal constraints related to demography and the economy. Being a static analysis, measuring congruence between flows and funds over several scales, it also allows for tracking the evolution of the system over time.

One of the theoretical pillars of MuSIASEM is that the technological development of a society can be described in terms of an acceleration of energy and material consumption together with the dramatic reallocation of distribution of age classes, human time profile of activities and land use patterns in various sectors of modern economy, resulting in time and land saving in the energy and agricultural sectors (Mayumi, 1991).

In the Annex, We present a description of the main variables used in MuSIASEM as well as its calculation and what are they intended for.

One of the main limitations MuSIASEM has is that it offers a snapshot of a single moment. It represents a system in one particular moment and therefore is not dynamic. One could also say, it makes strong assumptions when it uses the level of consumption per hour of activity (the exosomatic metabolic rate) as a proxy for the level of capitalization of economic sectors or as a proxy for the *material* standard of living of households. Economic productivity of labor depends on the level of capitalization of an economy. Our hypothesis that the energy consumption per hour of work is a proxy for the level of capitalization builds on the work of Cleveland et al. (1984) and Hall et al. (1986) and has been tested in many of the applications of MuSIASEM such as Falconí (2001), Ramos-Martin (2001), Ramos-Martin et al. (2007), or Velasco et al. (2015).

2.2. *Practical Application of MuSIASEM*

In the last years MuSIASEM has been applied to different issues, among which the generation of integrated matrices of environmental impact can be stressed (Giampietro et al., 2014). There are also some studies on energy metabolism at national, regional and local scale (Arizpe et al., 2014; Eisenmerger et al., 2007; Falconi-Benítez, 2001; Ramos-Martin and Giampietro, 2005; Martínez-Iglesias et al., 2014; Ramos-Martín, 2009, 2001; Ramos-Martín et al., 2007; Recalde and Ramos-Martín, 2012; Velasco-Fernández et al., 2015).

In this investigation we have considered four levels of analysis:

i) level n refers to the whole Balearic society (or Societal Average, SA);

ii) level n-1 splits the overall system into two compartments, one in charge of production (or Paid Work sector, PW) and one in charge of consumption (or HouseHold sector, HH);

iii) level n-2 splits the paid work sector into different economic sectors: Agriculture (and the rest of primary sector, AG), industry, energy and construction (PS) and Services and Government (SG);

iv) and level n-3 which splits some sectors in different economic activities: total transport (T), air transportation (AT), private household transport (PT), maritime and land commercial transport (CT), electricity generation (EP), construction and manufactures (CM), services (without transport) (SS), residential sector (without transport) (RS) and agriculture, husbandry and forests (AG).

Levels n, n-1, n-2 have been analyzed using flow variables: energy consumption and value added; as well as through fund variables: hours of human activity. Flow-flow and flow-fund ratios have also been utilized. In the case of Level n-3 only data for energy consumption was used due to the lack of disaggregated information for both added value and time use.

2.3. Data used

GDP data for the Balearic Islands was obtained from Spanish National Statistical Institute (INE, 2015a), regional economic accounts. Energy data was obtained from the Energy Balances published by Dirección General de Industria y Energía of the Government of the Balearic Islands (DGIE, 2015). However, some adjustments were needed:

i) we have adapted the Energy Balances reported with the Partial Substitution Method (PSM), where net electricity is measured as thermal energy equivalent applying coefficients depending on the technology used. In this way, the different energy vectors used for electricity generation are treated equally in terms of the coefficients used (Giampietro et al., 2011; Giampietro et al., 2014) contrary to the data provided officially in the Energy Balances. In the latter, renewable energy sources contribution is always downplayed when translating into primary energy equivalents;

ii) the energy consumption of the household, primary and service and government sectors for the period 1986-1995 needed to be estimated due to lack of data;

iii) gasoline consumption of vehicles between 1986 and 1997 had to be subtracted from services and included in the transportation sector.

Following the MuSIASEM methodology (Giampietro et al., 2013) energy consumption in the transport sector was allocated to the household sector and the services and government sector. The share corresponding to the household sector was calculated according to:

i) cars and motorcycles of household use (total cars – (taxis + rental cars) + motorcycles) (CAMAT, 2006; DGT, 2015; INE, 2015b; La Caixa, 2015);

ii) average yearly distance: 13,423 Km for cars and 6,813 Km for motorcycles (Sanz et al. 2014); and

iii) average fuel consumption per Km by type of vehicle and fuel (DGCAL, 2001).

Total yearly hours of human activity was calculated from population statistics from INE (2015c), times 365 days per year times 24 hours per day:

$$THA_i = 365 \ days \times 24 \ hours \times Population$$

In order to allocate hours to the productive sector and the different economic sectors, the employment survey (INE, 2015d) was used, assuming 46 working weeks per year and 40 hours per week, following Ramos-Martín (2009). Therefore, 1,840 working hours per year corresponded to each employed person.

$$HA_{PWi} = 46 \ weeks \times 40 \ hours \ per \ week \times employed \ population$$

$$HA_{AG, PS, SGi} = 46 \text{ weeks} \times \text{hours per sector} \times \text{employed people per sector}$$

Finally, human activity in the household sector (including non-working time of employed people) was derived by subtracting hours dedicated to productive sectors from the total human time available to society:

$$HA_{HHi} = THA_i - HA_{PWi}$$

The Exosomatic Metabolic Rate (EMR_{ij}), measured in Mj/h, informs on energy consumption per hour of human activity allocated to a certain activity. Furthermore, the Economic Labor Productivity (ELP_{ij}), measured in €/h, provides information on the value added generated per hour of human activity. Studying both ratios jointly allows seeing those activities that could be encouraged in order to reduce the energy consumption and the generation of value added. There ratios are calculated with the following equations, where *i* refers to the year and *j* refers to the sector of economic activity:

$$EMR_{ij} = ET_{ij} / HA_{ij}$$

$$ELP_{ij} = GDP_{ij} / HA_{ij}$$

3. PRESENTATION AND INTERPRETATION OF RESULTS

The integration of Spain in the European Economic Community (EEC) in 1986 opened the Spanish economy to European capital, especially after the Maastricht Treaty was approved (1992) and the euro entered into circulation (2002). Investment in the Balearic Islands focused in tourism activities, infrastructure and the real state sector.

Consequently, the visitor's entry to the Balearic Islands increased from 5.81 to 12.56 million tourists per year between 1986 and 2012 (IBESTAT, 2015). The expansion of Palma de Majorca's airport (1994-1997) using European structural funds was key for increasing tourist flows. A large fraction of both domestic and foreign capital was invested in real state, increasing the number of dwellings being built and pushing up their price.

During this period, the Balearic Islands played a particular role within the European Union, receiving an excess in touristic-real estate investment while a process of technological de-capitalization of the economy occurred. Therefore, the increase of energy consumption was in parallel to a generalized loss of energy and labor productivity, as seen in Section 3.2.

3.1. Level n: The whole of the Balearic Islands

The Total Energy Throughput (TET) of the Balearic Islands grew 109.7% between 1986 and 2012, going from 52.94 PJ to 111.02 PJ (see Figure 1a). This trend was relatively constant in the period, with a compound annual growth rate of 2.89% (from now on all the annual growth rates are compound unless stated otherwise), except when major external shocks occurred: the Gulf War (1990-1991), the circulation of the euro (2002) or the real estate crisis (from 2008 onwards). Fossil fuels were largely used in those years (97.8% of TET), among which liquid petroleum products for transportation accounted for 43.25%, and coal for electricity generation another 25.7%. According to Giampietro et al. (2011), an increase in TET in a society is related to a larger consumption of materials and to a bigger waste production, that is, the Balearic Islands increased their environmental impact in the period under analysis, as shown by Ginard and Murray (2015).

During the same decades, GDP grew 93.27%, or 2.56% per year (Figure 1a). Until 1993, economic growth was driven by low oil prices, the increase in touristic beds and the development of touristic residential gated communities. From 1993 to 2002, tourist flows were encouraged by the devaluation of the local currency, peseta, the expansion of the airport in Palma de Majorca (1994-1997) and the take-off of rural tourism. Later on, the combination of residential tourism, real estate speculation and the construction of infrastructure and private homes was the main driver of economic activity in the period 2003-2007 (Pons and

Rullan, 2014; Pons et al., 2014). Finally, the international economic crisis and the bust of the real estate bubble made GDP decrease from 2008 to 2012 at a yearly rate of 1.25% (see Figure 1a).

The Economic Energy Intensity (EEI) of the economy accounts for energy consumed per unit of value added generated. The figure went from 4.45 MJ/€ in 1986 to 4.86 MJ/€ in 2012, with a peak of 5.49 MJ/€ in 2007 (Figure 1b). In comparative terms, the value for the Balearic Islands was lower than that for Spain: 7.51 MJ/€ in 1986 and 6.8 MJ/€ in 2011; and the European Union (EU-27): 15.71 MJ/€ in 1986 and 6.58 MJ/€ in 2011 (ECB, 2015; IEA, 2015; INE, 2015a; TWBG, 2015). This may have been the result of the economic structure and the lack of industrial activity in the islands, as most of consumer goods are manufactured abroad, therefore de-localizing energy requirements for their production (see Table 1). On the other hand, it is worth mentioning that EEI in the Balearic Islands increased in this period (Figure 1b), rendering the economy more inefficient over time.

Table 1. Share of sectoral Gross Added Value, Balearic Islands and Spain, 1995-2010

	1995	2000	2005	2010
Balearic Islands				
Agriculture	1.9%	1.8%	1.3%	1.1%
Energy	3.7%	1.8%	2.1%	2.4%
Industry	6.4%	5.9%	5.2%	3.9%
Construction	6.6%	8.8%	10.8%	9.0%
Services	81.3%	81.7%	80.6%	83.5%
Spain				
Agriculture	4.5%	4.4%	3.2%	2.7%
Energy	3.9%	2.8%	2.8%	3.1%
Industry	18.0%	18.1%	15.4%	12.6%

Construction	7.5%	8.3%	11.5%	10.1%
Services	66.1%	66.4%	67.1%	71.7%

Source: INE 2015a

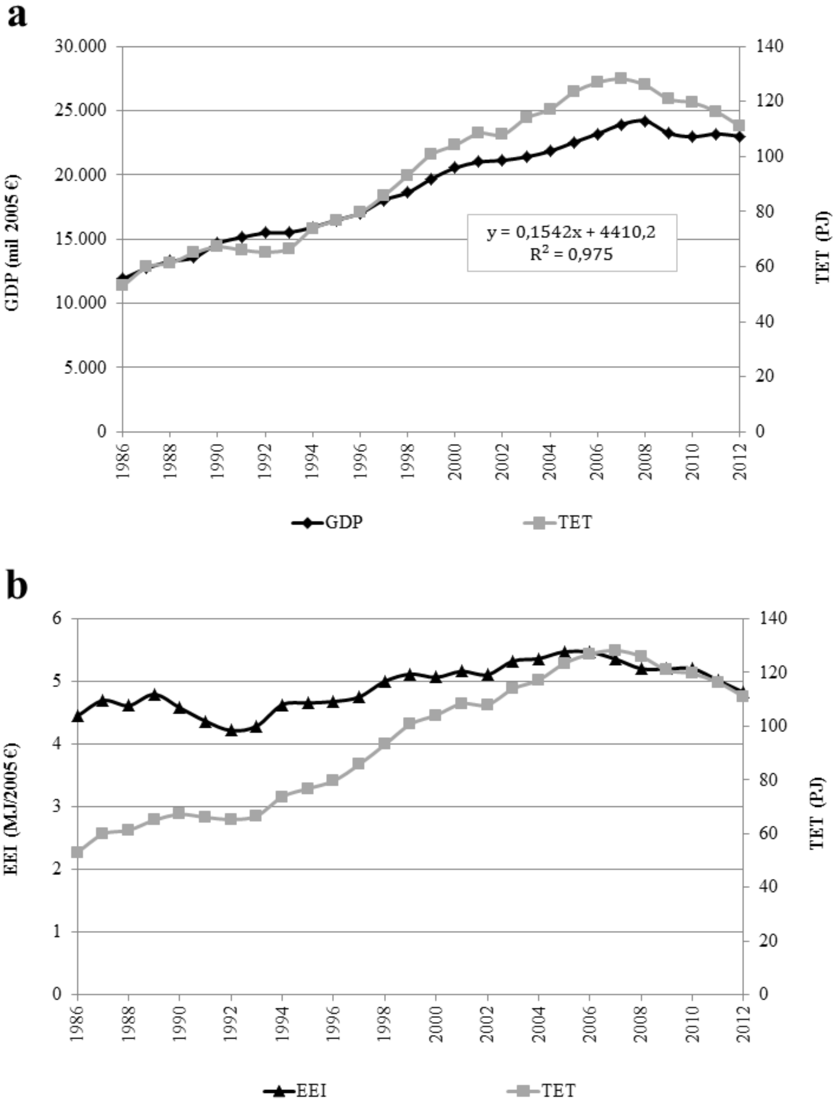


Figure 1. (a) Total Energy Throughput (TET) and Gross Domestic Product (GDP) of the Balearic Islands between 1986 and 2012. (b) TET and Economic Energy Intensity (EEI) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from DGIE (2015) and INE (2015a).

Population in the Balearic Islands grew at a much slower pace than energy consumption and GDP, a 60.57% in the period of 1986-2012, or 1.84% per year (Figure 2). This growth was, however, larger than that of Spain (20.95% in the period) or the EU-27 (9.99% in the period) (EUROSTAT, 2015; INE, 2015b). The main drivers for this distinct evolution of demographics in the Balearic Islands were, on the one hand the arrival of both immigrants from continental Spain and from developing countries in the decade of year 2000 (Miralles et al., 2009), and on the other hand, the settlements of residents from Northern Europe after the Schengen Agreement of 1985. In fact, foreign population grew from 6.8% of total population in 1998 to 22.8% in 2008 (Fundación BBVA 2009).

When looking at the energy performance of the Islands we see an increase in the Exosomatic Metabolic Rate (EMR_{SA}), which went from 8.82 MJ/h in 1986 to 11.51 MJ/h in 2012, with a peak of 14.98 MJ/h in 2005. Because energy consumption of the archipelago grew faster than its population, the society became more dependent on fossil fuels from abroad. Most of the growth in energy consumption came from the increased mobility needs, both by road or by plane (Sanyé-Mengual et al., 2014), new infrastructures and capitalization of households (air conditioning, heating, appliances, etc.).

At the same time, GDP per capita increased from 17,265 € in 1986 to a maximum of 25,287 € in 2001. After that year it decreased gradually during the construction boom (see Figure 2). In the 2000s much capital from the rest of Europe was invested in Spain in real estate, creating jobs and value added well above the productive capacity, especially in financial centers and along the touristic coastline (OSE, 2010). When the financial-real estate bubble busted, a large fraction of immigrant workers who arrived during the boom had already become residents in the Balearic Islands. Then, along with the reduction in absolute GDP a decrease came in GDP per capita, which in year 2012 reached 20,901 €, a similar value to that of 1990.

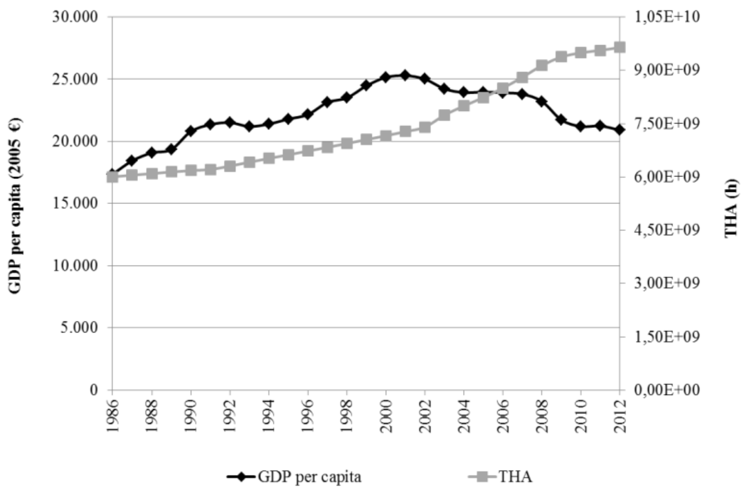


Figure 2. GDP per capita and Total Human Activity (THA) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from INE (2015a, 2015b).

3.2. *Level n-1: First split between productive and consumptive compartments of the economy*

Figure 3a shows the first split of TET between productive sectors (ET_{PW}) and the household or consumptive sector (ET_{HH}) in the islands between 1986 and 2012. The overall economy grew its consumption 97.95% in this period, whereas the household sector did increase it a larger 145.41%. This resulted in the share of ET_{HH} within TET going up from 25% in 1986 to 26% in 2005 and 29% in 2012. The interpretation of this fact is that the Balearic Islands are largely non-industrial (as seen in Table 1), which implies a much lower share of energy consumption dedicated to productive activities. Another explanation is that both private transportation and non-regulated residential tourism in the Balearic Islands are more relevant activities, driving up ET_{HH}. This last result can be seen as a weakness of the study presented here, since we have not estimated how much of that energy consumption takes place in non-regulated residential tourism. This is an exercise we expect to carry out in future research.

The distribution of human activity between the productive sectors (HA_{PW}) and households (HA_{HH}) is represented in Figure 3b. Employed population went from 214,460 people in 1986 to 471,825 in 2012, resulting in an increase in overall paid work time of 120%. Nevertheless, most of the jobs created were of low quality, temporary, low qualified and average wages lower than the average in the rest of Spain and Europe (OTIB, several years). In fact, the unemployment rate went from 6.5% in 2006 to a striking 23.26% in 2012, reflecting that most of the jobs created during the construction boom in the 2000s were precarious. On the other hand, even though working time grew faster (118.02%) than household time (56.59%), reducing the dependency rate of the society, the worsening of the working conditions leads us to suspect that the working hours needed to supply all the consumption needs of a household increased considerably.

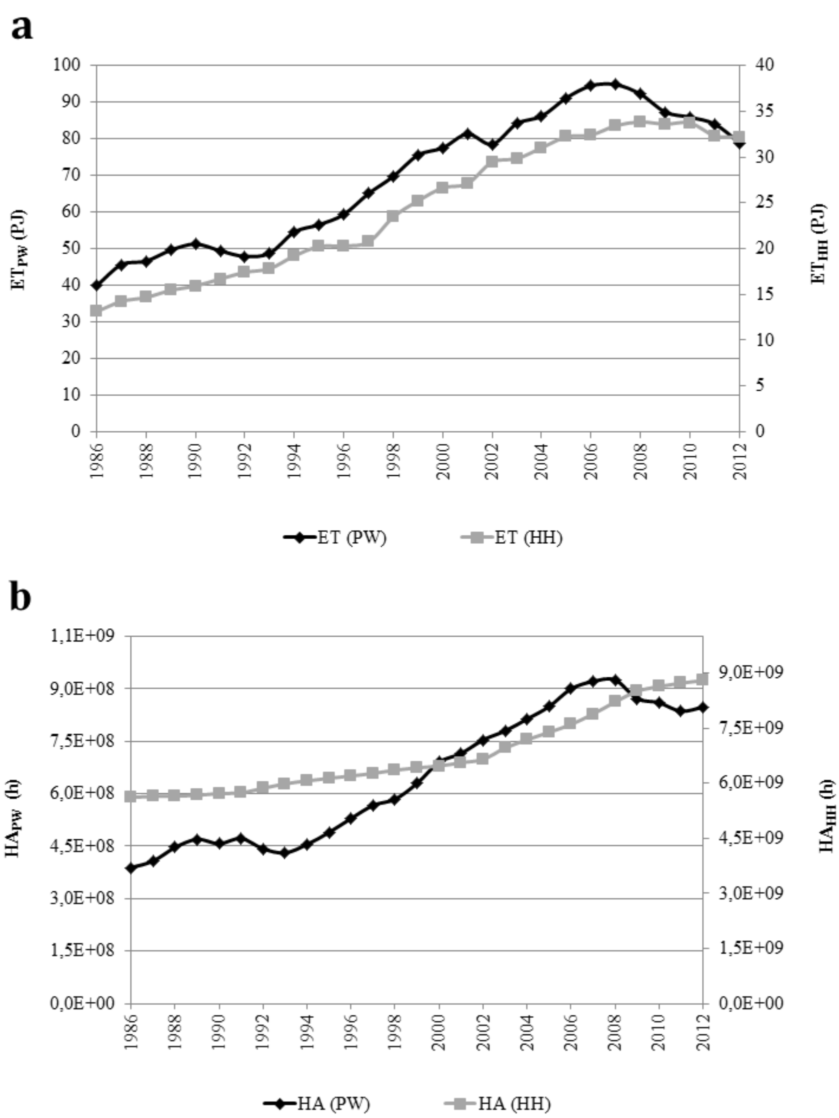


Figure 3. (a) Energy Throughput of the productive sectors (ET_{PW}) and of the households (ET_{HH}) of the Balearic Islands between 1986 and 2012. (b) Human Activity of the productive sectors (HA_{PW}) and of the households (HA_{HH}) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from DGIE (2015) and INE (2015b).

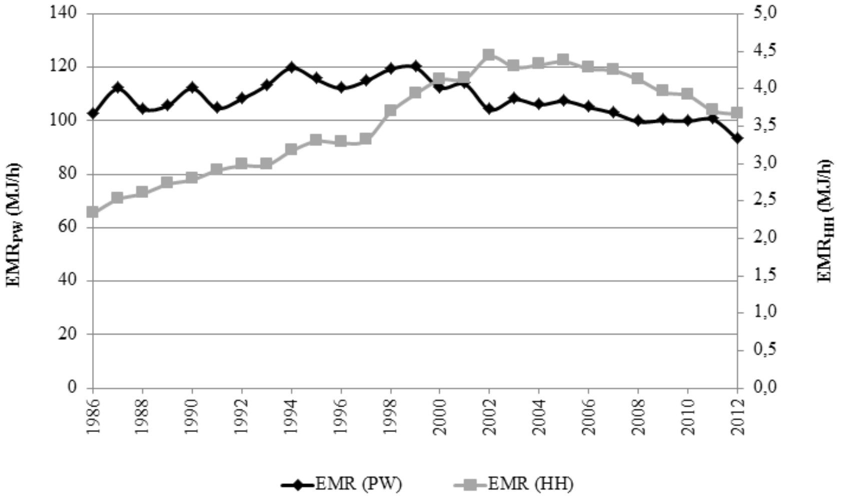
According to Velasco et al., (2015), following the discussion presented in Section 2.1, the Exosomatic Metabolic Rate of the productive sectors (EMR_{PW}) can be used as a proxy for the level of capitalization of the economy. On the other hand, the Exosomatic Metabolic Rate of the Households (EMR_{HH}) can be used as a proxy for the level of *material* standard of living of households. This assumption is based on the empirical study over 84 countries conducted by Giampietro et al., (2011) which, in Chapter 8, confirmed the relationship between higher energy consumption per hour and several traditional development indicators such as GDP per capita, share of labor force and value added in agriculture, infant mortality, life expectancy and the like.

When looking at the data of the Balearic Islands, we see that productive investment diminished between 1986 and 2012, as EMR_{PW} went from 102.45 MJ/h to 93.02 MJ/h in the period. The economic structure of the Balearic Islands, biased towards tourism and real estate, makes it difficult to introduce machinery and technology and therefore boost productivity.

The metabolic pattern of households also changed. EMR_{HH} increased from 2.3 MJ/h in 1986 to 3.54 MJ/h in 2012, showing that most of the increase in energy consumption was directed to increasing material standard of living (see Figure 4a). The high value found can be related with the larger share of the private car (DGT, 2015; INE 2015b) and non-regulated residential tourism (CCM, 2006), but can also be hiding consumption made by non-regulated residential tourism.

Finally, Figure 4b shows the evolution of the Economic Labor Productivity (ELP_{PW}), which went from 30.62 €/h in 1986 to 27.14 €/h in 2012, going through a peak of 36.02 €/h in 1993. This confirms that a large fraction of the increase in energy consumption was not oriented to capitalize the productive sectors (and then to increase labor productivity) but was oriented to increasing consumption levels at households, fact that resulted in a decreased income per hour worked in productive sectors.

a



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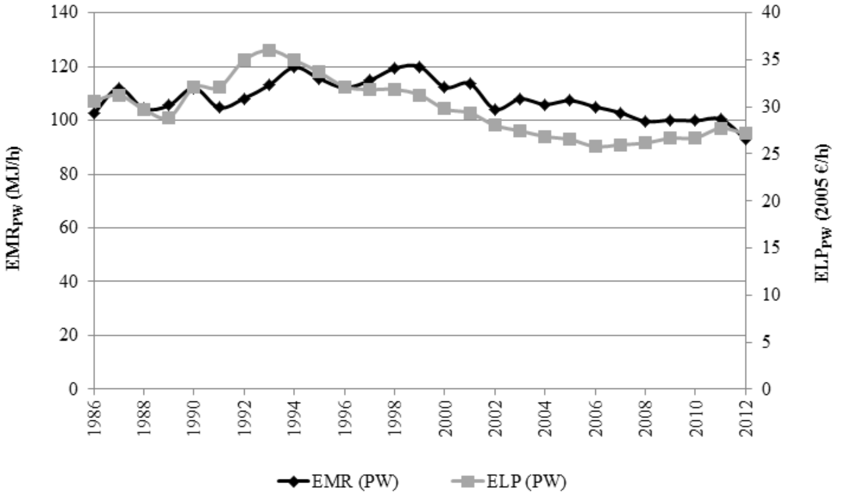

Figure 4. (a) Exosomatic Metabolic Rate of the productive sectors (EMR_{PW}) and of the households (EMR_{HH}) of the Balearic Islands between 1986 and 2012. (b) EMR_{PW} and Economic Labor Productivity of the productive sectors (ELP_{PW}) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from DGIE (2015) and INE (2015a, 2015b).

3.3. Level n-2: main productive sectors

Between 1986 and 2012, 50% of energy consumption in the Balearic economy was related to services (public, private and commercial transport), 46% with industry (electricity generation, construction and to a lower extends manufacturing) and only 4% with the primary sector (agriculture, stockbreeding and fishing). The increase of 95% in energy consumption observed in services responds to the increase in air traffic as well as to tourist visits. The growth of 107.9% seen in industry responds largely to the electricity generation sector, which was responding also to the huge increase in final energy demand in the hotel industry and in households. The increase of 32% detected in the primary sector can be explained by the introduction of machinery and irrigation systems in agricultural production and by the expansion of animal farms.

The massive entry of workers from the rest of Spain and from abroad was the consequence of deep structural changes in job distribution. In particular, the primary sector and the industry (without construction) lost 45.5% and 23.2% of occupation between 1986 and 2012 respectively. On the other hand, the construction and the services sectors attracted employment, raising 59% and 191% respectively. This resulted in a distribution of the labor force (HA_{PW}) very different from the rest of Spain. The services and government sector (HA_{SG}) implied 74% of occupation, industry (HA_{PS}, including construction) represented 24.31%, and the primary sector (HA_{AG}) was only the remaining 1.7% of employment. As said, construction played a key role within industry, from the 24.31% of HA_{PW} stated above, 13.3% was in the construction sector and only 10.9% in manufacturing.

When looking at intensive variables, one can see interesting results in terms of energy intensity and productivity of labor. Between 1986 and 2012, the exosomatic metabolic rate (EMR_i) shows big differences in the level of capitalization in the economic sectors: 238.9 MJ/h in the primary sector, 137.9 MJ/h in industry and 74 MJ/h in services (see Figure 5a). The growing trend in energy consumption per hour of activity in industry is explained by an increase in electricity generation (energy intensive), a loss in manufacturing occupation and the reduction in construction activity after year 2008. In the primary sector the main explanation for the huge increase in EMR_{AG} is the gradual and continuous loss in occupation, resulting in more capital per worker. Finally, the reduction in EMR_{SG} is explained by the enormous growth in working population in that sector, which is characterized by the low level of capitalization.

The economic labor productivity (in value added per hour of work) is represented in Figure 5b. At the beginning of the period, labor productivity was higher in the services' sector than in the rest of sectors. However, in 2012 it was slightly higher than in the primary sector, although lower than in industry (ELP_{AG} = 22.56 €/h, ELP_{PS} = 25.45 and ELP_{SG} = 23.11 €/h).

The reduction of 33.6% in ELP in the most important sector in the Balearic Islands (ELP_{SG}) denotes the loss of competitiveness of its economy and is consistent with the stagnation in the number of regularized touristic beds available. Otherwise, the higher values of ELP_{PS} at the beginning of the 1990s and after 2007 reflect the large unemployment registered in those periods. For instance, occupation in industry and construction went from 85,100 in 2007 to 35,678 in 2012 (OTIB, 2013, 2008). Finally, the evolution of ELP_{AG} is also explained by a large move of workers to the construction sector.

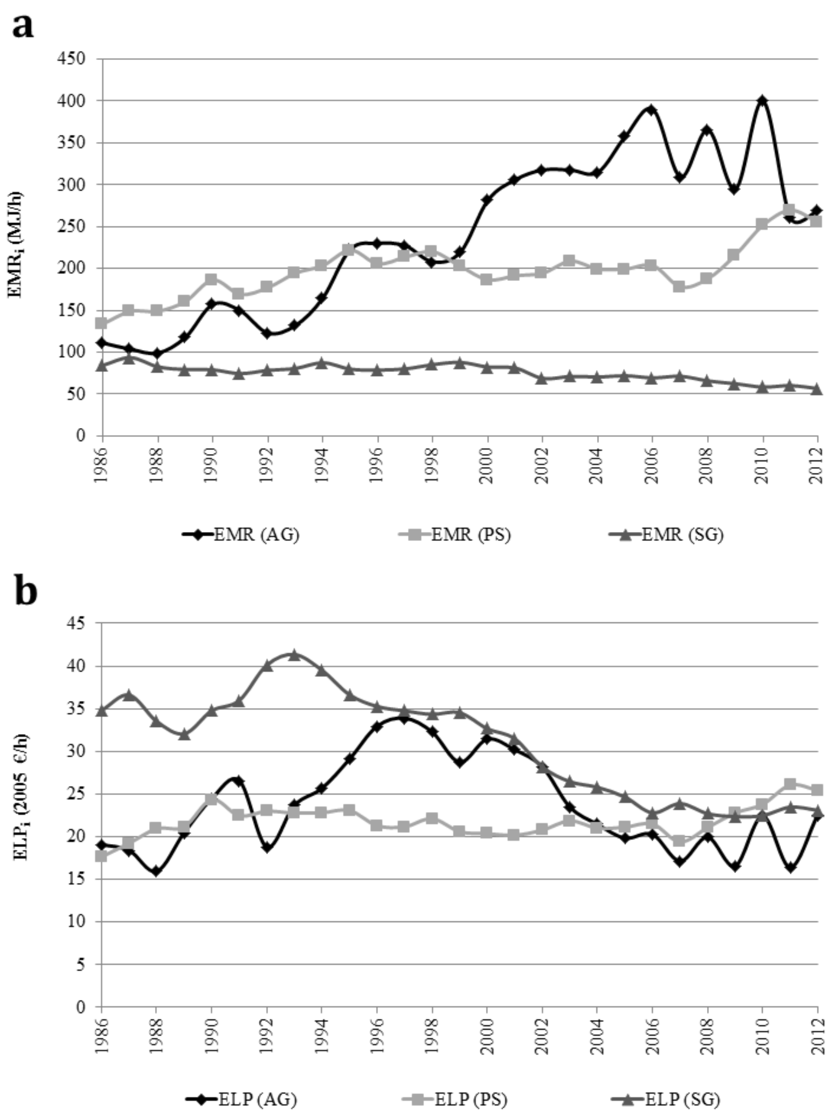

Figure 5. (a) Exosomatic Metabolic Rate per economic sector (EMR_{AG}, EMR_{PS} and EMR_{SG}) of the Balearic Islands between 1986 and 2012. (b) Economic Labor Productivity per economic sector (ELP_{AG}, ELP_{PS} and ELP_{SG}) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from DGIE (2015) and INE (2015a, 2015b).

3.4. Level n-3: energy consumption per economic activity

When we split energy consumption by economic activity (Figure 6a), we observe that the transport sector was responsible of 42.7% of TET. In the period analyzed, it grew 102.1%, or 2.74% per year, as a consequence of the arrival of more tourists thanks to the new ‘low-cost’ companies that started operating, as well as the liberalization of the air space (Bauzà, 2009). Another reason was the increase in road transport that came along the huge investment in infrastructure the archipelago experienced (Sanz et al., 2014).

Electricity generation was the second activity with higher consumption, with a 28.6% of TET. It grew 143.3% in the period (or 3.48% per year). The reason for this huge increase is that electricity is mainly generated with coal, which is very inefficient in the conversion; therefore, increases in electricity consumption imply larger increases in primary energy in the form of coal. In fact, in 2012, 50.9% of electricity was generated with coal, while oil products (fuel-oil and diesel) represented 23.68%, natural gas only 17.42%, incineration 7.2% and renewable sources (wind and solar) a marginal 0.8%.

The services sector (without transport) represented 11.21% of TET, growing at a 2.53% per year or 91.7% in the period. The household sector, although representing only 9.1% of TET, was the sector, which grew more rapidly, at a 4.9% per year or 247% in the period. The main explanations for this behavior were both the increase in the use of the private car and the growth of residential, non-regulated, tourism. In the case of the industry and construction sectors, decreased their contribution to TET to just a 19.5% because of the economic downturn after 2007.

Lastly, the transport sector (Figure 6b) was the largest consumer of energy. Air transportation consumed 18.5% of TET. Road transportation represented 17%, while maritime transportation reached 7.1% of TET. All of them grew between 40-50% in the period analyzed, although, as happened in other sectors, the economic crisis, which started in 2007 in Spain, implied a shift in the trend.

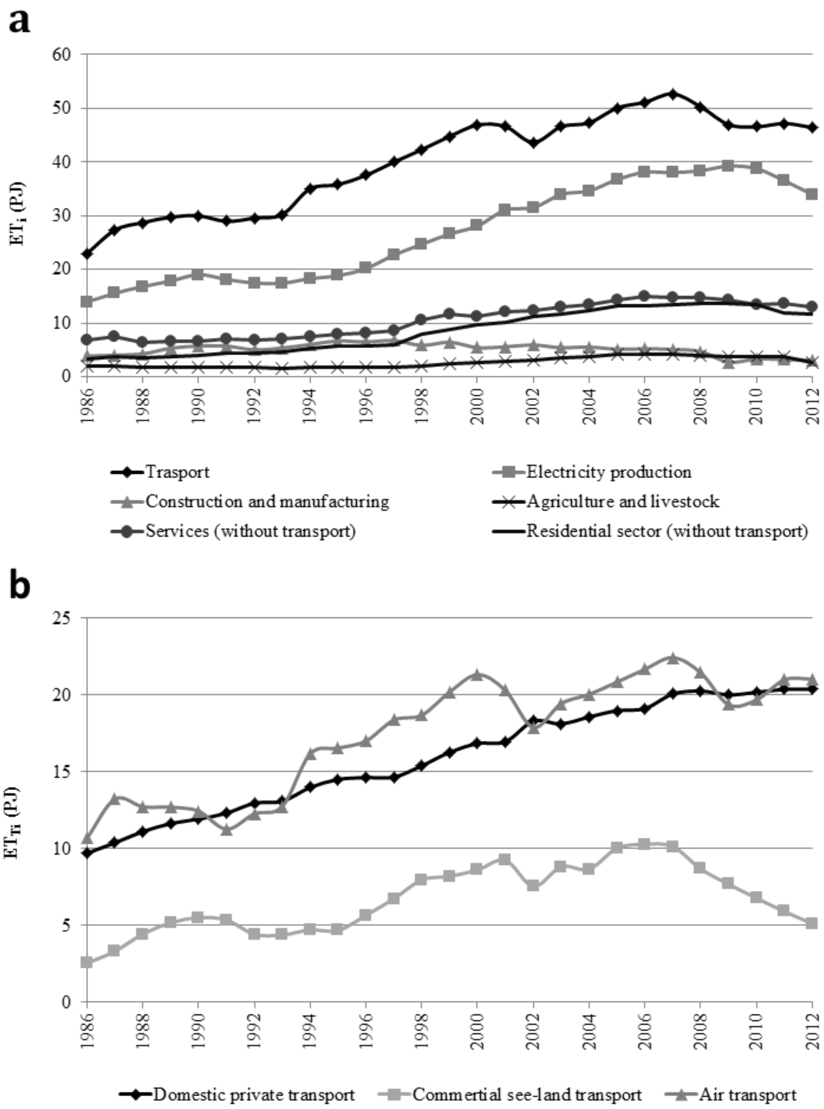

Figure 6. (a) Energy Throughput per economic activity (ET_i) of the Balearic Islands between 1986 and 2012. (b) Energy Throughput per transport typology (ET_{Ti}) of the Balearic Islands between 1986 and 2012.

Source: Own elaboration from DGIE (2015) and INE (2015a, 2015b).

4. DISCUSSION AND POLICY RECOMMENDATIONS

The energy system of the Balearic Islands is heavily dependent on fossil fuels from abroad. This trend continues in time as energy use increases and there is no structural change in the energy mix, apart from the interconnection between Majorca and continental Spain that entered into operation in August 2012, which represents between 20-40% of electricity supply depending on the time of the day[1].

Energy consumption grew faster than GDP or population in the period, increasing energy intensity and making the Balearic economy more inefficient over time.

The fact that the economy is so dependent on tourism and construction activities, both pro-cyclical, made the crisis of 2008 to be felt more heavily than in continental Spain.

Most of the energy consumption increase took place in the household sector, not in productive sectors. The implication was a lower capitalization level (per worker) at the end of the period. An explanation for this behavior of the household sector is the increase in the level of capitalization (household equipment) and the increased relevance of non-regulated residential tourism that would pose some doubts on official figures. An outcome of that is the need to investigate the resource consumption by those tourists using non-regulated residential units in the future, so that their consumption is allocated to the services sector instead than to the household sector.

Within productive sectors, the transport sector alone accounted for 42% of energy consumption, followed by the energy sector. Since most of the energy consumption in the transport sector and a large fraction of the energy sector belongs to tourists, this result, badly urges for conducting an analysis of the tourism sector alone, in which the consumption of tourists can be calculated, by typology of tourist. We expect this to be part of our future research.

In economic terms, active population grew faster than total population, showing an entrance of migrants attracted by opportunities in the tourism sector. The fact that working population grew very fast and that most of the increase in energy consumption occurred in

[1] https://demanda.ree.es/movil/baleares/mallorca/total

the household sector, resulted in a decrease of the economic labor productivity in the period, which, in turn, implied precarious jobs in the tourism sector.

Breaking with this spiral of energy consumption and socio-economic instability in the Balearic Islands will require combining measures of energy efficiency and conservation, with the encouragement of renewable sources, as well as incentivizing stable and qualified employment. Next, we present some policy recommendations that could address some of the points raised here.

Emphasis should be given to improving quality tourism instead of just quantity, so that tourists have lower mobility demands and longer stays. Other services not so attached to fossil fuels, such as research, education, health and culture among others, could also be encouraged.

Regarding the transport sector, private mobility by road needs to be re-thought, encouraging effective collective (and/or public) transportation systems. For instance, in the case of the largest island, Majorca, a combination of penalizing the use of private transport plus recovering abandoned commuting rail tracks between the capital and the surroundings could be implemented.

When looking at the energy sector, coal-fired power plants could be replaced with solar and wind distributed generation projects, especially if small co-operatives run by producers/users bring supply closer to where demand takes place, very much in the line of the *energiewende* in Germany, or to the model represented by small companies such as Som Energia in Spain.

A large fraction of the energy consumption is derived also from the spatial planning adopted in a territory. Therefore, urban development should be limited, along with an increase in the number of protected areas. This would avoid speculative investment as the one occurring in the last years. Urban areas should tend to be more compact, caring for aesthetics and functionality, always adjusted to demographic needs of population. Linked to that is the need for conducting an inventory of underutilized infrastructure. This could help in focusing on re-habilitation of spaces instead of new construction, with the consequent reduction in resources use. Finally, the introduction of renewable energy in buildings and recyclable materials along with passive measures for reducing energy consumption is necessary, especially in an archipelago that depends on foreign primary energy for satisfying their needs.

5. CONCLUSIONS

The main conclusions reached in our analysis are the following:

- With only 1% of the territory of Spain, the Balearic Islands welcome more than 18% of tourists, pushing up pressure for the consumption of natural resources and therefore environmental impact.

- Energy consumption grew faster (at 2.89% per year) than GDP (2.56% per year) making the economy less efficient as energy intensity increased from 4.45 MJ/€ to 4.86 MJ/€ in the period.

- Population grew at 1.84% per year, resulting in an increase of energy consumption per capita as well. Most of the increase occurred in working population (i.e. immigration), however, the exosomatic metabolic rate of productive sectors (EMR_{PW}) decreased in the period, as most of the energy increase occurred in the household sector (with energy consumption growing at 4.9% per year, including consumption by non-regulated residential tourism). The outcome was a decrease in the economic productivity of labor.

- Finally, the transport sector accounted for 42.7% of total energy throughput (growing at 2.74% per year) and the energy sector accounted for 28.6% (3.48% of growth per year). Along with the residential sector, accounting for 9.1 % of total energy throughput and the referred 4.9% growth per year, these increases are not only accountable to the increase in the capitalization of households, but very likely linked to the increase in the number of tourists (more transport and electricity needs) and non-regulated residential tourism.

Because of these results, one can conclude that not only the development model of the Balearic Islands is unsustainable, but also it is increasingly unsustainable, as it is based in massive entrance of tourists that imply massive precarious job generation and consumption of energy with low labor productivity.

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Annex I: Description of the variables used and its calculation

Acronym	Fund/Flow /Intensive	Name of the Variable	Description	How is calculated?
TET	Flow	Total energy throughput	Total primary energy used in an economy in one year, measured in Joules (J)	Statistical sources
THA	Fund	Total human activity	Total human time a society has available for conducting different activities, measured in hours (h)	Population times 8760 h
GDP	Flow	Gross domestic product	Added value generated by an economy in one year, measured in euros or dollars (h) (or $)	Statistical sources
ET_i	Flow	Energy Throughput in activity i	Primary energy used in activity i, in one year, measured in Joules (J)	Statistical sources
HA_i	Fund	Human Activity in activity i	Human time a society has allocated to activity i, measured in hours (h)	Working population in sector i x 46 working weeks x average working hours per week
GDP_{hour}	Flow/fund indicator	GDP per hour in the society	GDP/THA or GDPp.c/8760	GDP per hour of human activity in the society
EMR_{SA}	Flow/fund indicator	Exosomatic metabolic rate, average of the society (MJ/h)	TET/THA	Energy consumptio n per hour of human time available to the society
EMR_i	Flow/fund indicator	Exosomatic metabolic rate (MJ/h)	ET_i/HA_i	Energy consumptio n per working

								hour in sector i
ELPi		Flow/fund indicator		Economic labour productivity (h/h)		GDP_i/HA_i		Added value per hour of working time in sector i
EEI_i		Flow/flow indicator		Economic Energy Intensity (MJ/€)		TET/GDP		Energy consumptio n per unit of added value

Annex II: Exploitation of the data and calculation of the variables

Figure A.1.: Situational map of the Balearic Islands and political and administrative division of Spain

Source: Martorell (https://commons.wikimedia.org/wiki/User:Martorell) license under Creative Commons.

Main data used in this research comes from official regional statistics (see section 2.3. Data used), however, the following estimations were needed to calculate the variables[2].

About energy

i) As we have explained in the paper, energy official statistics have been transformed to Partial Substitution Method (PSM) to obtain Total Energy Throughput (TET). However, in the Balearic case, the effects of this change have been limited due to the low production of renewable energy,

ii) The Balearic Islands imported electricity from the rest of Spain in 2011 and 2012, so Energy Throughput per sector (ET_i) of these years has been calculated distributing the imported electricity[3] between the different economic sectors and using the percentage of locally produced electricity that they consume in the same years.

iii) Energy official statistics between 1986 and 1995 do not disaggregate the residential sector, the services and the primary sector, so they needed to be estimated. The estimation has been done applying the share of energy consumed by each of these sectors in 1996 to

[2] The main reasons for these estimations are the lack of data, the errors in the sources, the methodology changes in the sources, and some improvements that we have considered appropriate to introduce.

[3] This energy has also been transformed to the PSM using the substitution factor of Spain in 2003 (Giampietro et al., 2013).

their sum. To calculate backwards evolution, average rates of annual growth between 1996 and 2012 were used.

iv) After estimating primary energy consumption, we noticed that services and residential sector were overestimated for the period 1986-1995, compared to 1996 onwards. The same happened with service sector in 1996 and in 1997 compared with subsequent values. Hence, we found that between 1986 and 1997 official statistics accounted consumption of motor gasoline in the services sector and not in the transport sector during these years, probably because it was using another accounting methodology. Therefore, we proceeded to subtract this energy from services and include it within terrestrial transport.

v) According to the energy official statistics of 1987 no economic sector consumed electricity; this has been considered a statistical error, so these values were estimated from the average consumption between 1986 and 1988.

vi) The energy consumption of transport from the official statistics has been distributed between the different sectors according to the following criteria:

a. Separating the consumption of aviation from terrestrial transportation looking at the consumption of fuels: aviation (100LL avgas, jet A1 and B) and land transportation (gasoline and diesel A).
b. The consumption of aviation has been allocated to the services sector.
c. The official statistics only discriminate energy consumption of the merchant navy for the period 1987-1997, so it was considered part of the services.
d. Part of land transport corresponding to services has been estimated from the fuel consumption of taxis, rental cars, buses and commercial vehicles, using the year of 2004 as reference as it is the most recent year with reliable data:

Data	Source
Nº of taxis	Taxi statistics (1994-2012). Retrieved November 13, 2014, from INE Web site: http://www.ine.es/jaxi/tabla.do?path=/t10/p109/l0/&file=00001.px&type=pcaxis&L=0
Km/per year (taxis)	Estimation from the information directly provided by Asociación de Taxis de las Islas Baleares. [Balearic Islands Taxi Association]. http://www.taxisbaleares.es/
Kind of fuel (taxis)	Idem than above.
Nº of rental cars	Plan Director Sectorial de Transporte de las Islas Baleares (2006). [Director Sectorial Plan of Transportation of the Balearic Islands]. Retrieved November 13, 2014, from INE Web site: http://www.caib.es/conselleries/opubliques/dgtransp/esdev/pla/pladirector.html
Km/ per year (rental cars)	Estimation from the information directly provided by: Agrupación Empresarial de Vehículos de Alquiler con y sin Conductor de Baleares. [Association of Rental Vehicles Business with and without Driver of Balearics]. Retrieved

	November 13, 2014, from INE Web site: http://www.aevab.com/
Kind of fuel (rental vehicles)	Estimation from: Anuario 2004 del Ministerio de Fomento. [Yearbook of the Ministry of Development]. Retrieved November 13, 2014, from INE Web site: http://www.fomento.gob.es/NR/rdonlyres/FB82761B-2236-4414-BE62-5CA040186687/110391/anuar2004.pdf
Nº of buses	Idem than above.
Km/ per year (buses)	Estimation from: Balance de Emisiones de GEI en las Islas Baleares (2001). [Balance of GHG emissions in the Balearic Islands (2001)].
Kind of fuel (buses)	Idem than above.
Nº of delivery vans	Estimation from: Balance of GHG emissions in the Balearic Islands (2001) and the Yearbook of the Ministry of Development.
Km/ per year (delivery vans)	Balance of GHG emissions in the Balearic Islands (2001)
Nº of trucks	Estimation from: Balance of GHG emissions in the Balearic Islands (2001) and the Yearbook of the Ministry of Development.
Km/ per year (trucks)	Balance of GHG emissions in the Balearic Islands (2001)
Kind of fuel (trucks)	Idem than above.

About human activity

To calculate the hours of activity devoted to productive sectors, the following points were taken into account:

i) 4 weeks' vacation, 12 days holiday and an average of two days off have been subtracted to the 52 weeks available per year.

ii) The number of employers in each sector comes from INE (2015d).

ii) The average number of hours spent at work by economic sector was obtained from the Census of Population and Housing 2001, retrieved November 13, 2014, from INE Web site: http://www.ine.es/censo/es/inicio.jsp, extrapolating this data to all the period. Neither the 1991 Census nor the 2011 provide that information, neither the CCAA level EPA for provinces. However, there may not be many variations between years, since working hours are governed by collective agreements and are usually 40 hours per week.

Average number of hours worked

Sector	Hours
Primary sector	41,84

Industry	40,29
Industry without construction	39,78
Construction	40,8
Servicices	38,77

About GDP

i) The INE presents the GVA at market prices Base 1986 (1986-1996) (including taxes and excluding subsidies). Consequently, GVA at basic prices Base 1986 (1986-1996) was estimated: GVA basic prices = market price - taxes + subsidies (ESA-95).

ii) The sum of GVA at basic prices Base 1986 and the production taxes does not match with the GDP at current prices Base 1986 provided directly by the INE. The error is assumed as irrelevant and inevitable due to the methodology change of the source.

iii) The GDP at current prices and constant prices Base 1986 (1986-1995) were obtained directly from the INE series Base 1986 (not the GVA at basic prices, as explained above).

iv) To ensure that the data for the entire period (1986-2012) were homogeneous, we made a change of base to the series GDP at current prices Base 1986 (1986-1995) with the GDP series at current prices Base 2000 (1995-2010). Thus, GDP and its components at current prices Base 2000 (1986-2010) was obtained[4].

v) The transformation of the GDP series at current prices Base 2000 (1986-2010) to constant prices Base 2000 could not be performed through the chained volume indices Base 2000 (they only go up to 1995). Consequently, GDP components at constant prices Base 2000 for the period 1986-1994 were estimated, following the next steps:

a. Calculating GDP and its components at constant prices Base 2000 (1995-2010).
b. Splicing the aggregate GDP at constant prices Base 1986 (1986-1994) to Base 2000.
c. Calculating the components of GDP at constant prices Base 2000 (1986-1994). In this case, we have used the percentages representing each relative to GDP at current prices Base 2000.
d. To achieve greater coherence between the aggregate GDP and its components Base 2000 (1986-2010), after the distortions caused by the splices and the transformation to constant prices, GVA at basic prices was calculated as the sum of the sectoral GVA; and GDP at market prices as the sum of GVA at basic prices plus net taxes on production, as it is indicated by the ESA-95.

vi) Finally, the series of GDP at constant prices Base 2000 (1986-2010) was spliced to the GDP at constant prices Base 2005 (2000-2013), getting the series as current as possible[5].

[4] All the splices of series have been made by the variation rate or retropolation method.
[5] In this case, it has also corrected the splices distortions and the transformation to constant prices.