Strong versus weak sustainability indexes in a conurbation context. A case example in Spain

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Abstract

Urban sustainability studies have been traditionally divided in two groups based on weak and strong sustainability paradigms. Several indicators have been presented which can be assigned to one of those groups. In order to analyze their advantages and drawbacks, these two antagonistic schools of thought regarding sustainability studies are presented, as well as a revision of weak and strong indicators in the literature. Differences between these approaches are analyzed by using two concrete indicators: ISEW and Emergy, applying them to a real case of a sustainability study in the Spanish Costa del Sol.

Keywords: ISEW; Emergy; Strong Sustainability; Weak Sustainability

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1. Introduction

Sustainability is a global issue that needs to condense the best efforts of humankind to deal with the goals that it is imposing on our planet and on our societies. Sustainability is a global goal in a double sense. On the one hand, globalism stands for a geographical area that comprises the whole world. On the other hand, global means that it is not only affecting to certain societies which may be more exposed to unsustainable conditions, but it is affecting to the whole humankind, since the effects of socio-economic activity of a certain area over the whole planet has been widely proved to go further the strict region that supports it.

Nevertheless, although sustainability is a global issue, it must be studied at different scales, i.e. international, national, regional and local. All these studies are necessary in order to propose political actions that may improve the sustainable behavior of our societies. During the last forty years, huge efforts have been done in all these scales, but one of them has revealed as a priority: urban areas. In present, more than the half of people in earth lives in cities. Hence, sustainable studies of these special zones where people are concentrated is absolutely relevant.

When dealing with sustainability of urban areas, several approaches can be chosen [1] [2] [3]. Some of them are rooted on the weak sustainability paradigm and others on the strong sustainability one. Regarding the former, several aggregate strategies have been proposed. Since complete substitutability among different capitals, including natural capital, is accepted by this paradigm, aggregation of different measurements is possible. Hence, final figures are presented as condensed indicators, or *environmentally adjusted macro-aggregates* [4]. ISEW, an alternative to GDP developed by Daly and Cobb [5], is one of them.

Regarding the latter, since no perfect substitutability among different forms of capital is accepted by strong sustainability paradigm, a different quantifying method, in which different sources of capitals are taken into account separately, must be used. Emergy Accounting methods propose a solution. These methods provide a single unit of measurement that can account for all material, energy, and monetary flows between the urban system and its surrounding environment [6]. It is worth highlighting that, using this strong approach, aggregation of different capitals is being used as well. The difference between this aggregated approach and the weak sustainability one is in the starting point. While weak sustainability aggregated indicators are rooted on the transformation of every measurement into its monetary equivalent, emergetic ones are rooted on physical measurements of the ecosystem and on the transformation of other throughputs into their physical equivalent units.

Therefore, Emergy Accounting is a conceptual and operative strong approach to sustainable development. It focuses on the necessity to protect ecosystem services that support humans by providing materials, goods, and services. Thus, strong sustainability paradigm reveals the necessity of setting some limits to development which must be measured in physical terms.

However, assuring that these limits are not met does not achieve the sustainability goal by itself. Three poles of sustainability must be taken into account, and social one is not explicitly present in strong sustainability studies. Democracy, social justice, fair wealth distribution, etc, are social issues which absolutely have to do with sustainability in urban areas, but are not taken into consideration in Urban Metabolism studies. Hence, a complementary analysis, offering an insight into these matters must be presented if a complete sustainability framework is to be drawn.

In this paper, we attempt an ambitious objective: to offer a mixed strong and weak sustainability study for urban areas, applying it to a case study afterward: Costa del Sol conurbation in the south of Spain. Firstly, we provide a strong Urban Metabolism analysis based on an emergy study of Costa del Sol. From this study, a complete set of emergy-based indicators are presented in order to evaluate the pressure (Carrying Capacity) of human activity over the ecosystem that supports it. The study is centered on two different years: 2001 and 2007, in order to show the evolution of the indicators. Secondly, another (weak) indicator is calculated. Since emergy can be situated in a middle way between economic and ecological poles of sustainability, another approach was chosen that could cover the area situated between the economic and social poles. This area is better analyzed by weak sustainability approaches. Hence, ISEW method, a widely used and contrasted tool, was chosen.

Since the debate between weak and strong sustainability is in the roots of the present research, a concise introduction to this interesting disputation is presented next, before the description of the empirical study.

2. Strong versus weak sustainability

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [7]. This definition of sustainability, stated by the World Commission on Environment and Development in its Brundtland report of 1987, has become the classical definition for this complex concept, but it is not the only one. Among many other approaches, the sustainable development triangle proposed by Munasinghe at the 1992 Earth Summit in Rio de Janeiro [8], is another widely accepted definition. It encompasses three major perspectives: economic, social, and environmental. Each viewpoint corresponds to a domain that has its own distinct driving forces and objectives. However, although each viewpoint focuses on a certain area, they are closely related. Economic, social and environmental approaches to sustainability are complementary contributions which need each other in order to offer a complete insight.

Nevertheless, as many authors highlight, finding a suitable definition for sustainability is not the same thing as achieving it [9]. Obtaining a way to accurately measure sustainability will always be a necessity in order to propose the necessary political reforms. This is a very controversial issue, given that two antagonistic approaches regarding sustainability and its measurement, that is, strong and weak, have been traditionally proposed.

The weak sustainability paradigm was founded in the 1970s by extending the neoclassical theory of economic growth to account for non-renewable natural resources as a factor of production. The key question investigated in these pioneering studies was whether optimal growth was sustainable, i.e. if it allowed non-declining welfare in perpetuity. According to Hartwick and Neumayer [10], weak sustainability assumes that natural capital, that is, renewable and non-renewable natural resources that sustain our socio-economic activity, is similar to produced capital and, hence, can easily be substituted for it.

In turn, the strong sustainability paradigm argues that natural capital is to a greater or lesser extent non-substitutable. Since strong sustainability is a more diffuse paradigm than weak sustainability, a number of rules have been suggested that seek to operationalize it. Neumayer identifies two main schools of thought. One requires that the value of natural capital is preserved assuming, in principle, unlimited substitutability between forms of natural capital. The second school requires that a subset of total natural capital is preserved in physical terms so that its functions remain intact. This is the so-called Critical Natural Capital [11]. Overcoming it means surpassing the Carrying Capacity of the ecosystem under study [12] [13]. If it occurs, linearity of ecological behavior is completely broken and predictions about its consequences become extremely difficult to achieve, as well as frightening.

Besides, classical approaches to sustainability, although accepting Munasinghe's division of sustainability in three poles (economic, social and environmental), usually tend to reduce indicators, whatever type they belong to, to their equivalent monetary values. This reductionism is strongly criticized by other authors. Once again, weak and strong sustainability paradigms collide. The former is represented by classical economics, while the latter is embedded into the Ecological Economics paradigm which presents an alternative to the classical one. As Martinez-Alier points out, ecological economists generally view the reliance on prices as primary expression of values with skepticism. They view economic activity as "taking place within a larger context of material flows, throughput or metabolism which originate in the environment, are processed in economic activity and released back into the environment as high entropy waste" [14]. In turn, for classic economists, the environment is a site of conflict between competing values and interests, and different groups and communities that represent them. Hence, the different dimensions of value can conflict with each other and within themselves, and any decision will distribute wealth and poverty across different groups both spatially and temporally.

The strong and weak sustainability debate extends its influence until nowadays. Nevertheless, if a position regarding their apparently antagonistic principles were to be adopted, most authors would agree nowadays with Daly and Ayres:"while there is plenty of room for substitution and some possibility of major breakthroughs, the pessimists (strong sustainability) appear to be closer to the truth than the optimists who believe in more or less unlimited substitution possibilities" [15]. Moreover, according to O'Hara,"it is not enough to ask how social and environmental functions can best be assigned monetary value so as to "correct" prices, what is needed instead is an understanding of the complex social, cultural, physical, biological and ecological system themselves. It demands relinquishing the centrality of the subsystem "monetary market exchange" and internalize economics into the material and non-material context of human lives and the environment. It requires a methodology that allows the complexities of all systems to be explicitly admitted to the valuation process rather than being implicitly considered in "corrected" market prices" [16]. O'Hara is defining in ethical terms what Odum proposed in physical terms with the Emergy paradigm, a scientific school of thought in which available and embedded solar joules instead of dollars lead the way towards sustainability. As mentioned in the Introduction, Emergy will be the strong sustainability technique chosen for our study.

Eventually, after defining these two extreme options, although strong position seems to be closer to the truth, searching for a kind of integration and cooperation between both paradigms seems the most coherent election. As mentioned in the Introduction, weak approaches are best able to deal with socio-economic aspects of sustainability, whereas strong approaches best deals with the ecological pole. As Neumayer does, we are persuaded that complementary efforts from different schools of thought are needed if global sustainability goals are to be achieved.

Many theoretical complementary approximations have been presented, but a few of them have been empirically verified. Thus, the question is still open for the debate: is it possible to offer a weak and strong complementary effort in order to achieve the common sustainability aim?

In order to propose an answer to the previous questions, the present research deepens into the roots of both paradigms through one of the most representative indicators of each tendency. These indicators will be tested in a real case example: a sustainability evaluation of the conurbation of Costa del Sol in Spain. The strong indicator will be required to condense the Carrying Capacity of the ecosystem under study, whereas the weak one will be requested to offer a figure representing the level of welfare in the society dwelling in that area. During the process, drawbacks and advantages of each indicator, that is, of each paradigm, will be highlighted.

In summary, the sustainable condition of the conurbation of Costa del Sol will be analyzed from a double but not excluding perspective based on strong and weak indicators. In the previous section, we disclosed that Emergy and ISEW were the chosen indicators for strong and weak paradigm, respectively. In the next ones, the reasons for this election are presented.

3. Index Review

In order to choose two representative sustainability indicators, a wide revision of the existing literature regarding this issue was done. Yet, before presenting the results, some reflections about the essence of indicators as measures of the sustainable condition of a region are presented.

Martinez-Alier [14] has highlighted several times and in several ways that sustainability indicators are primarily communication instruments which must offer new and useful information regarding their particular sustainable subject. Both conditions must be granted, that is, being a suitable instrument and offering useful information; otherwise, the indicator will be worthless. Moreover, he also emphasizes that adding new theoretical indicators to the vast list already accessible in the technical literature is worthless if we are not able to link them to a concrete sustainable issue, whatever at a local or at a global scale, present or future.

Deepening into Martinez-Alier [14] ideas, and according to a general consensus, every sustainability index must compile four main characteristics: *relevance*, that is, it must be centered on the main elements regarding the sustainability goal; *scientific soundness*; *real implementation capability* and

Table 1: Strong and weak indexes

Strong sustainability	Weak sustainability	Partially strong	Undefined
EF, HANPP, Emergy, EVI, LPI	CDI, ISEW, GPI, GS	EPI, FEEM	HDI

Table 2: Scope of the indicators

Original scope	Suitable for urban studies	Not suitable
National	EF, HANPP, GPI, ISEW, GS	EPI, HDI, EVI, FEMM
Regional or Local	CDI, Emergy	LPI

usefulness as a decision-making tool. Having these ideas clearly present in our mind, a revision of the literature regarding sustainability indicators was done and it revealed extremely vast. A summary of the results is presented next, adding some useful references where the reader interested in any of the particular indicators may obtain more information about them.

Ecological Footprint (EF) [17] [18]; Human Appropriation of Net Primary Production (HANPP) [19]; Emergy [6]; Environmental Performance Index (EPI) [20]; FEEM Sustainability Index (FEEM SI) [21]; City Development Index (CDI) [22]; Human Development Index (HDI) [23]; Environmental Vulnerability Index (EVI) [24]; Living Planet Index (LPI) [25]; Index of Sustainable Economic Welfare (ISEW) [26]; Genuine Progress Indicator (GPI) [27]; Genuine Savings (GS) [28].

A classification of these indexes according to their weak or strong sustainability condition is very useful for our purpose. Based on Mori's research [22], Table 1 distributes each index in its proper group. Mori's research scans the literature regarding sustainability indicators, trying to distill which ones are able to measure the three poles of sustainability, and which ones can measure the leakage effects[1]. In the analysis, he differentiates among weak indicators and strong ones, thus, Table 1, but also among indicators which are originally developed for national, regional or local areas, thus, Table 2.

Hence, since our case study is a sustainability analysis of an urban area, our focus will be centered on the second column of Table 2. In order to obtain this table, two criteria are used by Mori. First, the original unit of analysis, i.e if they were originally proposed as city sustainable indicators. Second, if they can be used to compare cities around the world, i.e if the measurements

[1]Effects of local unsustainable behaviour over ecosystems far from the area responsible of it.

used to compile them are significant in an urban context.

Attending at this Table 2, the normal weak sustainability election for our case study should have been the City Development Index, since it was the only one whose scope was focused on urban areas. Nevertheless, it is not the single index approach that we were looking for, but a set of indicators. Therefore, another election based on weak sustainability paradigm had to be done. No regional or local indexes were left in Table 2, but among the ones whose original scope was national, we could find the ISEW, an index that had also been succesfully applied to regional areas [29]. Therefore, it was are weak sustainable index election.

ISEW, GP and GS belong to the same group of indicators which try to correct GDP taking into account expenditures and incomes related to social, economic and ecological sustainability [30]. There are few differences among them. Moreover, the literature regarding ISEW studies is extensive. Several ISEW analyses can be found which have been used to correct GDP of Countries and regions all around the world [31]. Although the controversy regarding the drawbacks of this approach is also extensive, it is a consolidated weak approach worth of being analyzed, in special because of its social orientation based on inequality distribution issues.

Otherwise, choosing a strong sustainability index is more problematic. Attending at Table 1 and Table 2, there is only one option: Emergy. Why is it so difficult to find a proper strong sustainability index? There may be several answers to this question but we are persuaded that the main reason is rooted on the very essence of strong sustainability. Strong sustainability is a non reductionist paradigm. Assuming that non perfect substitutability is possible among capitals, we are suggested to use a different strategy than a single-figure one. Neumayer [10] and Martinez-Alier [32] propose Material Flow Analysis and Energetic Assessments as the two main strong tools for sustainability studies. Zhang and others [33] propose the Urban Metabolism paradigm. Emergy joins both propositions at the same time. Emergy is a thermodynamic measure of embodied emergy, but it is also the unit used in a kind of Material Flow Analysis or Metabolism called Emergetic Accounting. Thus, Emergy is not only an index but also a particular analysis which transforms economic and ecological flows into a single throughput.

Hence, Emergy is the strong index chosen, and ISEW is the weak one. Let us make a brief introduction to them.

4. ISEW

Over the last couple of decades, ecological economics have proposed several sustainability and welfare indexes as an alternative to Gross National and Domestic Product (GNP/GDP) which are not welfare indicators, although sometimes they have been wrongly used as it. According to Neumayer, there are four main critiques related to GNP/GDP [10]. First, it does not include household and volunteer labour. Second, it does not weight the effects on welfare of unfair income distribution. Third, it does not include effects of environmental degradation due to the economic activity. Four, it considers defensive expenditures wrongly as contributions to welfare. According to Daly and Cobb, "defensive means a defense against the unwanted side effects of other productions" [5]. Hence, these expenditures should not be considered as positive contributions to welfare, but as protections against side effects of the economic activity (i.e, illnesses due to pollution). In order to fix these problems, several indexes were proposed. The Index of Sustainable Economic Welfare (ISEW) is one of them [34].

The calculation process of ISEW was established by Daly and Cobb in 1989, but it has been modified by different authors in several studies. ISEW accounting starts with the Private Consumption (PC), which is a subcomponent of GDP. Afterwards, PC is adjusted according to an index of income distribution. Two options can be found in the literature regarding this index of income distribution, that is, Atkinson index and Gini index. Once the PC has been corrected by an income distribution index, all the Items defined in order to correct it are calculated and are assigned their sign, according to their positive (services) or negative (costs) contribution to welfare. Finally, all Items are added or subtracted to PC in order to obtain the final figure for the ISEW index. Therefore, the ISEW is simply the sum of weighted personal consumptions expenditures and all its corrections [26].

ISEW index, as Lawn points out [27], is rooted on Fisherian concept of income, in contrast to the traditional Hicksian definition which is the basis for GDP calculations. According to Fisher, "only the services rendered one year by non-durable consumer goods and durable producer and consumer goods manufactured in previous years are part of that present year's income". Hence, in Fisher's view, since the stock of human-made capital depreciates through use, its maintenance is a cost not a benefit. Therefore, it is necessary to produce a throughput of matter-energy by exploiting natural capital to sustain human-made capital intact. This is the idea under the inclusion of ecological Items in the calculation of the ISEW, i.e. long-term environmental damage, and the separation between "services" and "costs".

Different ISEW studies have been developed in regional and national scales during last twenty five years [31]. The one we are presenting here is an ISEW study for an urban area, which is quite an unexplored area.

Nevertheless, as mentioned before, ISEW is not lack of controversy [10] [35]. Three items condense the criticism to this indicator to the indicator that can be found in the literature. First, the lack of theoretical foundation of ISEW; second, the ambiguity of being presented sometimes as a sustainability indicator and others as a welfare indicator, third, the arbitrary election of Items used to correct GDP. We are persuaded that Daly and Cobb were not blind to the limitations of the index they had presented. In fact, as Daly himself stated: "ISEW is like putting a filter on a cigarette. It is better than nothing" [29].

The literature of ISEW studies is vast, but most of the studies have been developed over national territories [31]. Nevertheless, a quite recent research was done by Pulselli in 2007 for the region of Siena, in Italy [29]. Since the scope of Pulselli's analysis was closer to the present one, it was the main guide used for our own research. Pulselli, in his study of the ISEW for the province of Siena, used a particular division of the Items involved in ISEW analyses, assigning a letter to each one, following an alphabetical order. We also used that strategy. Next, each item is presented and explained, indicating the method used to calculate it along with the assumptions adopted in the present study.

Item A. Year: It stands for the year under study.

Item B. Private consumption: Similar to GDP, ISEW's basis is the total Private Consumption for the region under study in a year.

Item C. Index of income distribution: According to Daly and Cobb, Private Consumption (PC) does not indicate real economic and social welfare of society. One of the main reasons behind this fact is the unequal distribution of income. Thus, Daly and Cobb proposed to correct the PC figure using an index of income distribution. Two different approaches have been used in the ISEW studies. Some authors have used the Gini index while others have proposed to use the Atkinson index. According to Neumayer, the latter approximation should be preferred to the former, since it is able to reflect the estimation of society's aversion to inequality, through a parameter. Nevertheless, the calculation of this preference index is a controversial issue which lacks of enough data in most occasions.

Item D. Calculation of adjusted private consumption: This item is calculated through the next equation:

$$APC = PC/(1 + G) \tag{1}$$

where APC is the Adjusted Private Consumption (Item D), PC is the Personal Consumption (Item B), and G is the Gini coefficient.

According to Daly and Cobb, APC will be the basis on which all other positive and negative modifications will be applied. Nevertheless, as Neumayer highlights, this is a controversial step. Once the PC is weighted using this inequality index, no coherent comparison can be done with GDP, since both indexes are rooted on different bases. As Neumayer points out, APC is not a real value which can be compared with real data since it is an artificially weighted PC value. Furthermore, if this index is to be taken into account, Neumayer proposes not to apply it to the PC, but to the final ISEW index. Nevertheless, this proposal is also problematic since we are assuming that income distribution affects to ISEW as a whole which is not true. In our calculations we have used the three different strategies. In Appendix A results are presented including the complete results, although in the resumed information of Table 3, just the first apporach is shown.

Item E. Services - Domestic Labour and volunteer work: Since domestic and volunteer labours are not remunerated work, they are not accounted for within the GDP. However, there is no doubt that this labours contribute in a positive way to global welfare. Therefore, Daly and Cobb decided to include these labours in the correcting Items for the calculation of the ISEW. Depending on the available data, several methods have been used for this calculation.

Item F. Services - Consumer Durables: Daly and Cobb, following Fisherian concept of capital, proposed a double way of dealing with the contribution of consumer durables to welfare. First, services arising from the stock of consumer durables acquired during the accounting period should be considered a positive contribution, whereas costs of consumer durables acquired in the present year should be subtracted in order to avoid double counting (see Item I).

Item G. Services from public infrastructure: According to Daly and Cobb, services from public infrastructure, as well as health and education costs must be considered a component of economic welfare. They argue that growth of administration costs keeps economic welfare from declining.

Item H. Public Health Care and Education Costs: These public costs should be included in the ISEW calculation since they clearly affect welfare and sustainable development in a society. How to include it is, however, much more complex than it seems. According to the first revision of the ISEW calculation by Daly and Cobb (1994), 50% of this expenditure during the present year is a defensive cost, and should not be added. Thus, according to them, just 50% of global public expenditure in health and education would constitute a positive effect on welfare

Item I. Costs - Consumer Durables: As it was explained in Item F, Daly and Cobb considered that consumer durables expenditures during the present year of study should be subtracted from Personal Consumption given that its contribution to welfare would be taken into account during the next years.

Item J. Private Defensive Expenditure for Education and Health Care: In Item H, 50% of public health care and education expenditure was considered as a non defensive cost that increases economic welfare. In order to be consistent with this hypothesis, 50% of private consumption in health and Education will be considered as defensive costs as well, hence subtracted from Private Consumption.

Item K. Local advertising Costs: Local advertising contribution to ISEW in all the studies revised was found to be despicable. Moreover, accurate data regarding this issue for a local region are not normally available. Hence, we decided not to include this Item in the present research.

Item L. Costs of Commuting: Daly and Cobb estimated that 30% of the costs related to private cars and public means of transport were directly related to commuting costs. 30% of private and public maintenance of vehicles was also added to that figure.

Item M. Urbanization Costs: Following some authors that had excluded this Item from calculations of ISEW in different studies, we also decided not to include it. Lack of consensus on the right way of computing the equivalence between the level of urbanization and the welfare related to this fact, suggested us not to include such an arbitrary Item. Besides, its relative contribution was found to be less than 1% for most ISEW studies.

Item N. Costs of road accidents: This items comprised the total costs related to road accidents.

Item O. Cost of Water Pollution: Unfortunatelly, finding an accurate methodolgy for measuring this concept is extremely difficult. Nevertheless, an option was to be chosen, and Total costs for water purification was the one we selected, following Pulselli's proposal. An estimation of the total costs of purification of water supply were obtained from data on a standard purification plant. The cost has been corrected to 17,56€, applying a 3% cost increase per year, and it is referred to the equivalent inhabitants (E.I.) of the area.

Item P. Cost of Air Pollution: Daly and Cobb divided their estimation of this Item in six different categories: damage to agricultural production; material damage; cost of cleaning implement; damage caused by acid rain; urban degradation and damage to buildings and surroundings. Following Guenno and Tiezzi [36], we focused on external costs per ton of emissions devoted to different pollutants.

Item Q. Costs of Noise Pollution: It was not computed.

Item R. Loss of Wetlands: It was not computed.

Item S. Loss of agricultural land: Assigning a monetary value to the consequences of urban expansion and bad land management is a controversial task. An estimation of lost agricultural lands in Costa del Sol was done according to data from OSE report. Besides, a cost of 12.900€per hectare of lost agricultural land was chosen [29].

Item T. Depletion of non-renewable resources: Including the cost of non-renewable resources depletion into de ISEW calculation has been a controversial issue since the very proposal of Daly and Cobb in 1989. Two different methods have been used in the literature. The first one was the resource rents method, which aims to separate the sustainable from the non-sustainable income parts. The second one is the replacement cost method, which stems from the idea that the total amount of non-renewable resources must be replaced by renewable resources. Although the former method was used by Daly and Cobb in 1988, the latter was the chosen one for the revision they presented in 1994. In this study, each barrel of oil equivalent was valued as an anchored replacement cost of $75, with a 3% escalation per year from 1950 to 1990. This escalation factor is another controversial fact. Neumayer states that no escalation factor should be applied since renewable technologies improve every year and costs get cheaper and cheaper.

Item U. Long-term Environmental Damage: Including this Item, Daly and Cobb took a clear bias towards ecological economics positions. Valuing the long-term cost of environment degradation in a macroeconomic index is the clearest sign of it. Nevertheless, applying an accurate annual value to this issue is extremely difficult and controversial [37]. As Neumayer and Stochhammer point out, the main question regarding this subject is whether this value should be accumulated over time or not. According to Neumayer, to let this value accumulate over time is self-contradictory as it leads to multiple counting of the total future damage. Hence, he suggested to apply a marginal social cost to long-term environmental damage per ton of carbon, and to calculate the total amount in the region under study. Several values of this marginal social cost have been proposed in the literature. An exhaustive research regarding different values assigned to a ton of carbon emitted was developed by Tol [38]. In this study, he presented several statistical marginal damages costs for carbon emissions and suggested a value not higher than 50$/ton, which was the one used in the present research.

Item V. Net Capital Growth: In order to sustain long-term economic welfare, there should be an increasing or constant supply of capital per worker. Daly and Cobb proposed that ISEW took into account this net capital growth (NCG), which is calculated by, on the one hand, adding the stock of new capital and, on the other hand, by subtracting the capital requirement. Nevertheless, since the relative contribution of this value to the ISEW in a local urban area was found to be despicable, we decided not to include it in the final results.

Item W-X-Y-Z. ISEW and local GDP: Finally, these four Items include: the final ISEW calculation; the ISEW per capita; the GDP and the GDP per capita, respectively.

5. Emergy approach

Emergy research area is rooted in the Exergetic School [39] [40], a consolidated technical area which has centered their efforts during the last decades in trying to go further the mere quantification of energy, offering a thermodynamic way to measure its quality [41]. Based on the first and second thermodynamic principles embedded in the exergy concept, in 1960, Odum proposed Emergy as a new paradigm in ecological studies. Emergy, specifically Solar Emergy, is "the available solar energy used up directly and indirectly to make a service or product" [6]. "Emergy, spelled with an "m", is a universal measure of real wealth of the work of nature and society made on a common basis". Yet, Emergy is not only a measure of natural wealth; it is also an analytical method of ecological analysis. Emergy Analysis presents an energetic basis for quantification or valuation of ecosystems goods and services. According to Odum, valuation methods in environmental and ecological economics estimate the value of ecosystem inputs in terms that have been defined anthropocentrically, while emergy tries to capture the eco-centric value. It attempts to assign the "correct" value to ecological and economic products and services based on a theory of energy flow in systems ecology and its relation to systems survival. In order to do that, Emergy Analysis characterizes all products and services in equivalents of solar energy, i.e. solar embodied joules (sej). Hence, emergy can be considered as the memory of energy, that is, the cumulative solar energy embedded in a good or a service along the years [42]. According to Odum, Earth is a closed system with solar energy, deep earth heat and tidal energy as major constant energy inputs, where all living systems sustain one another by participating in a network of energy flow and converting lower quality energy into both higher quality energy and degraded heat energy. Since solar energy is the main energy input to the Earth, all other energies are scaled to solar equivalents to obtain common units. Moreover, other kinds of energy existing on the Earth can be derived from these three main sources, through a *transformation*, which is the main concept regarding Emergy Analysis. Transformity is "the solar emergy required to make one joule of a service or product". Hence, solar transformity of a product is equal to its solar emergy divided by its available energy (exergy), that is:

$$M = T * E \tag{2}$$

where M is emergy, T is transformity and E is available energy (exergy). The central idea offered by Odum is that "energy flows of the universe are organized in an energy transformation hierarchy". Thus, the position in the energy hierarchy is measured with transformities. Energy transformations generate hierarchies over production chains similarly to the food chain in ecosystems. In self-organization, items that require more energy would not be produced for long if they did not have a positive effect to the larger system. Thus, successful systems are those which develop structures that maximize useful resource production and consumption. Adaptive behavior rather than effectiveness is the key search for these systems. Taking this assertion into account is critical in order to understand the contribution of Emergy to sustainability analysis.

Once some basic concepts about emergy have been proposed, we are ready to analyze the advantages and disadvantages of Odum's contribution. According to Hau [43], among the most attractive characteristics of Emergy Analysis are the next: First, it provides a bridge that connects economic and ecological systems. Since emergy can be quantified for any system, their economic and ecological aspects can be compared on an objective basis that is independent of their monetary perception. Second, transformities compensate for the inability of money to value non-market inputs in an objective manner. Third, Emergy method is scientifically sound and shares the rigor of thermodynamic methods. Fourth, its common unit allows all resources to be compared on a fair basis. Emergy Analysis recognizes the different qualities of energy or abilities to do work (exergy) [44]. In summary, Emergy Analysis provides a more holistic alternative to many existing methods for environmentally conscious decision making. As Odum continuously emphasizes, “most existing methods ignore the crucial contribution of ecosystems to human well being” [6].

Although it is not the only ecological approach, these features of Emergy Analysis are particularly impressive since emergy was developed many decades before the more recent engineering and corporate interest in sustainability. Nevertheless, it has received a vast amount of critics, which are related to the next issues: first, the ambiguous relation between Emergy and economics; second, the combination of apparent disparate time scales;third, the inconsistent way Emergy Analysis represents global energy flows in solar equivalents, and, finally, the no-conservationism of emergy algebra. All these critics have been presented and answered by different authors in the past decades, and the debate is still open [45] [46].

As it has been highlighted above, a sustainability study based on an ecological approach like Emergy is not lacking of controversy. Some important drawbacks have been exposed and it would not be scientifically honest to underestimate them. Nevertheless, we may not forget that classic economic approaches are not absent of drawbacks, in special regarding the price assignment to eco-services outside the Market. Emergy sustainability studies can offer an alternative vision of the sustainable condition not only of a system but also of the ecosystem which is supporting that very system. That is the main feature that convinced us to choose this, in our point of view, underestimated strategy. Therefore, Emergy will be the strong sustainability indicator chosen, but, as it was mentioned before, it is more than a single figure, it is a complete evaluation method which has been adapted to a wide range of sustainability studies [47] [48].

Every emergetic analysis is divided in four steps:

1. To select the limits of the region under study.
2. To draw the model.
3. To calculate the emergetic table according to the area under study. In

order to do this, proper transformations must be chosen.

4. To obtain the indicators from the emergetic table.

In Section 7.2, this method will be applied to our case example: a conurbation sustainability assessment in Costa del Sol, Spain.

In summary, embedded into exergetic tools for sustainable analysis, Emergy goes a step forward, since it opens a new paradigm in which solar embedded joules accumulated in every commodity will be the units to be accounted for in an Emergetic Flow Analysis. Finding some emergetic figures directly related to the Critical Natural Capital and the Carrying Capacity of the ecosystem under study will be the final aim of this strong sustainability approach in the present research.

6. Case example: Emergy Evaluation of Costa del Sol

The Costa del Sol is a coastal region located in the Province of Malaga, one of the eight provinces that comprise the autonomous community of Andalusia, southern Spain.

Costa del Sol is divided in three physical areas: Eastern Costa del Sol, Malaga (capital city of the province) and West Costa del Sol. It is a popular tourist region that emerged as an international travel destination in the second half of the twentieth century. Although before this date it was made up only of a several small villages devoted to fishery and local agriculture, the region has been completely transformed during the latter part of the previous century.

Costa del Sol extends from the cliffs at Maro in the East, to Punto Chullera in the west, along 161 coastal kilometers of conurbation. It comprises a total area of 1.700 Km^2, a 23,28% of the extension of the province. Besides, the population of the Costa del Sol in 2001 was 1 million inhabitants, the 77,91% of the total population of the Province, whereas this figure increased to 1,21 million inhabitants and a share of 79,48% in 2007. Moreover, on the one hand, according to local estimations, around 600.000 people are settled in the Costa del Sol but have not been registered; and, on the other hand, around 2 million tourists visit the Costa del Sol and stay there for a mean value of 8 days [49]. The present research has been based on data according to registered inhabitants; nevertheless, some figures are included which offer an estimation of the impact of this heavy touristic activity. A future sustainability research focused on the touristic influence on the Costa del Sol will be a very interesting complement to the present investigation.

Since offering a double weak and strong sustainability research over an urban area was the aim of the present investigation, the authors chose Costa del Sol as the area under study because it offered very interesting characteristics. That is, from the point of view of the distribution of the population, the high concentration of inhabitants in the area is significant, which is a recurrent tendency in modern urban areas. Moreover, regarding the economic activity and its relation with the environment, Costa del Sol is situated in a privileged area in terms of renewable capabilities, i.e. hours of direct solar irradiation, wind and sea energetic possibilities. Nevertheless, its dependence on fossil fuels is very high. Besides, the fast urban development that Costa del Sol has experienced during the last sixty years provides an excellent opportunity to investigate how such a quick urban development has influenced the ecosystem which is supporting it.

Eventually, in Section 7.1, the ISEW calculations for Costa del Sol in 2001 and 2007 are presented, according to the methodology exposed in the previous section. Afterwards, in Section 7.2, the Emergy Accounting process developed for this very conurbation is presented. Since a huge amount of calculations have been done to achieve the final results, in order to make it easier for the reader to follow the study, most of the partial results have been confined into Appendix A and Appendix B.

Table 3: ISEW comparison Costa del Sol 2001 - 2007

A	Year	2001	2007	Reference	Data
B	Personal_consumption_expenditure	10.567.742.967,47	17.100.621.488,27	[50] [51]	Regional
C	Index_of_distribution_inequality	0,347	0,323	[52]	National
D	Weighted_personal_consumption_expenditure	7.845.391.958,03	12.925.639.824,85	[50] [51]	Regional
E+	Services_of_household_labour	3.024.219.388,80	3.582.070.244,45	[53]	Regional
F+	Consumer_durables_services	559.386.179,02	833.279.728,43	[50] [51]	Regional
G+	Services_from_public_infrastructure	668.052.704,68	1.116.623.806,23	[54]	Local
H+	Public_expenditure_on_health_and_education	703.640.745,61	1.178.055.855,34	[50] [51]	Regional
I-	Expenditure_on_consumer_durables	554.456.639,71	814.186.224,79	[50] [51]	Regional
J-	Defensive_private_expenditure_on_health_and_education	712.841.166,65	1.060.103.442,99	[50] [51]	Regional
K-	Local_advertising_expenditure	Not available	Not available		
L-	Cost_of_commuting	338.350.520,97	523.936.829,47	[50] [51]	Regional
M-	Cost_of_urbanisation	Not computed	Not computed		
N-	Cost_of_car_accidents	366.600.938,29	303.194.531,06	[55]	National
O-	Cost_of_water_pollution	14.568.608,39	20.926.247,81	[53]	Local
P-	Cost_of_air_pollution	402.537.004,35	520.948.826,78	[56]	National
Q-	Cost_of_noise_pollution	Not computed	Not computed		
R+	Loss_of_wetlands	Not computed	Not computed		
S-	Loss_of_agricultural_land	46.236.553,18	46.236.553,18	[53]	Regional
T-	Exhaustible_resources_depreciation	508.191.347,11	686.483.662,16	[53]	Regional
U-	Long-term_environmental_damage	65.270.925,62	72.369.908,23	[53]	Regional
V+	Net_capital_growth	Not computed	Not computed		
W	ISEW=sum_of_all_positive_and_negative_items	10.223.509.135,78	15.962.847.672,12		
X	ISEW_per_capita	10.196,42	13.234,51		
Y	GDP	11.383.553.034,50	21.678.429.099,60		
Z	GDP_per_capita	11.353,39	17.973,20		

Table 4: Emergy Indicators. Costa del Sol. 2001-2007

No	Flow/Index	Expression	2001	2007	Units
1	Renewable sources used	R	**1,57E+21**	**1,57E+21**	Sej/year
2	Non-renewable indigenous sources	N	8,64E+17	5,40E+17	Sej/year
	Rural Use	N0	8,64E+17	5,40E+17	Sej/year
	Urban Use	N1	0,00E+00	0,00E+00	Sej/year
3	Imported emergy	IMP	**2,25E+22**	2,44E+22	Sej/year
	Fuels and electricity	F1	4,82E+21	6,84E+21	Sej/year
	Minerals	M1	6,58E+21	1,13E+22	Sej/year
	Goods	G1	9,21E+21	2,86E+21	Sej/year
	Services	SS1	1,87E+21	3,41E+21	Sej/year
4	Exported emergy	EXP	**1,93E+22**	2,10E+22	Sej/year
	Minerals	M2	1,99E+21	2,45E+21	Sej/year
	Goods	G2	6,58E+21	2,61E+21	Sej/year
	Services	SS2	1,08E+22	1,59E+22	Sej/year
5	Total emergy available	U=R+N+IMP	**2,41E+22**	**2,59E+22**	Sej/year
6	Economic component of emergy used	U-R	2,25E+22	2,44E+22	Sej/year
7	Fraction of use derived from indigenous sources	(R+N)/U	6,54E-02	6,06E-02	
8	Fraction of use that is renewable	R/U	**0,070**	**0,064**	
9	Fraction of use that is free	(R+N0)/U	6,54E-02	6,06E-02	
10	Fraction of use that is imported	IMP/U	9,35E-01	9,39E-01	
11	Imports minus exports	IMP-EXP	3,16E+21	3,40E+21	Sej/year
12	Imports/exports	IMP/EXP	1,16E+00	1,16E+00	
13	Ratio of concentrated to rural	(U-R-N0)/(R+N0)	1,43E+01	1,55E+01	
14	Emergy use per capita	U/population	2,40E+16	2,15E+16	Sej/people/year
15	Fraction of use that is electrical	Electrical Emergy/U	1,75E-02	2,45E-02	
16	Fuels per capita	Fuels/population	4,39E+15	5,14E+15	Sej/people/year
17	Population	people	1,00E+06	1,21E+06	people
18	Empower density	U/Area	1,41E+13	1,53E+13	Sej/m2/year
19	Non-renewable empower density	(IMP+N)/Area	1,32E+13	1,43E+13	Sej/m2/year
20	Emergy investment ratio (EIR)	IMP/(R+N)	1,43E+01	1,55E+01	
21	Emergy yield ratio (EYR)	1+1/EIR	1,07E+00	1,06E+00	
22	Environmental loading ratio (ELR)	(U-R)/R	1,43E+01	1,55E+01	
23	Emergy sustainability index (ESI)	EYR/ELR	7,48E-02	6,86E-02	
24	Emergy exchange ratio (EER)	EMRg/EMR	8,58E-01	2,02E+00	
25	Gross domestic product at market prices (GDP)	GDP	1,12E+10	2,83E+10	$
26	Emergy to money ratio (EMR)	P1=U/GDP	2,16E+12	9,17E+11	Sej/$
27	Global emergy to money ratio (EMRg)	P2=Ug/GDPg	1,85E+12	1,85E+12	Sej/$
28	Renewable carrying capacity	(R/U) x population	**6,55E+04**	**7,31E+04**	People
29	Developed carrying capacity at European standard of living (ESL)	ESL x (R/U) x population	1,57E+06	1,76E+06	People
30	Developed carrying capacity at Mediterranean standard of living (MSL)	MSL x (R/U) x population	8,81E+05	9,82E+05	People
31	Renewable Empower Density (RempDr)	R/Area	9,24E+11	9,24E+11	Sej/m2/year
32	Renewable Empower Density (European Countries) (E_REmpDr	Re/Area_e	2,02E+11	2,02E+11	Sej/m2/year
33	Renewable Empower Density (Mediterranean basin Countries) (M_REmpDr)	Rm/Area_m	1,53E+11	1,53E+11	Sej/m2/year
34	Renewable support area European countries (SA(e))	(Ue-Re)/E_RempDr	3,24E+13	3,24E+13	m2
35	Renewable support area Mediterranean basin countries (SA(m))	(Um-Rm)/M_RempDr	3,06E+13	3,06E+13	m2
36	Renewable emergy needed to lower European ELR (R*e)	(IMP+N)/ELRe	9,57E+20	1,04E+21	Sej/year
37	Renewable emergy needed to lower MEditerranean ELR (R*m)	(IMP+N)/ELRm	1,71E+21	1,86E+21	Sej/year
38	Renewable support area (SA(r))	(IMP+N)/RempDr	**2,43E+10**	**2,64E+10**	m2
39	Synchronal support area at European standard of living (SSAe)	R*e/E_REmpDr	4,73E+09	5,13E+09	m2
40	Synchronal support area at Mediterranean standard of living (SSAm)	R*m/M_REmpDr	1,12E+10	1,21E+10	m2

7. Result Analysis

7.1. ISEW Results

In Table 3 a summary of data regarding the ISEW calculation for Costa del Sol in 2001 and 2007 is presented. Besides, in Figures 1 2 3 and 4, percentage of positive and negative contributions to ISEW for both years are shown. Some indications about the particular methodology used to calculate several Items of ISEW along with two Tables, A.5 and A.6, containing detailed ISEW calculations for each year, i.e. 2001 and 2007, can be found in Appendix A.

Several items can be highlighted in an ISEW analysis. Nevertheless, we will focus on three particular issues per year, that is, the relation between ISEA and GDP, the influence of Gini index and the main relative contributions of positive and negative items. Afterwards, we will describe the evolution from 2001 to 2007.

First, attending at Tables A.5 and A.6, we realize that ISEW for Costa del Sol in 2007 is 27,43% lower than GDP if the inequality correction is applied to the Private Consumption; whereas it is 31,04% if it is applied to the final ISEW. Besides, if no inequality correction is made, the difference between both indicators is just 7,11%. It means that ISEW's contribution is highly dependent on the application or not of an inequality weighting factor. Moreover, in 2001, if no inequality correction is applied, ISEW surpass GDP, what is a really surprising result. Besides, attending to Figures 1 and 3, we observe that the sum of costs related to exhaustible resource depletion and to long-term environmental damage, constitutes the third most negative contribution to welfare. Moreover, these Items have been calculated using moderate instead of pessimistic assumptions. If Jackson proposal would have been used [29], this contribution had increased over the 50% of total negative ones in ISEW. Besides, only direct private energetic consumption has been taken into account to make the calculations. If public and indirect private energetic consumption would have been included, we could be over 90% of contribution of these two elements together. Hence, we can state that the main negative contributions to welfare in Costa del Sol are related to its unsustainable consumption off fossil fuels, along with its high defensive expenditures on health and education.

Nevertheless, the most interesting result of ISEW study for Costa del Sol emerges when we compare both years. Attending at Table 3 and to Figure 5, it is worth noticing that ISEW has increased a 35%, whereas the GDP has

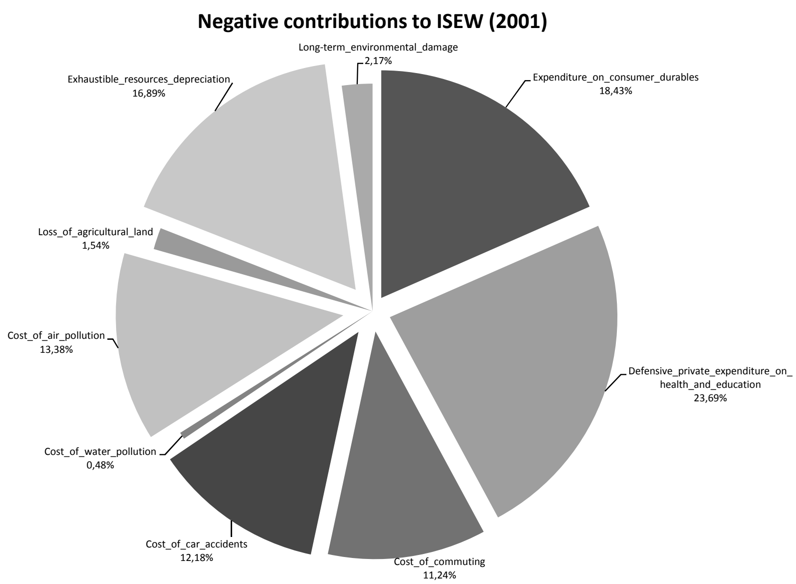

Figure 1: Negative contributions to ISEW in 2001

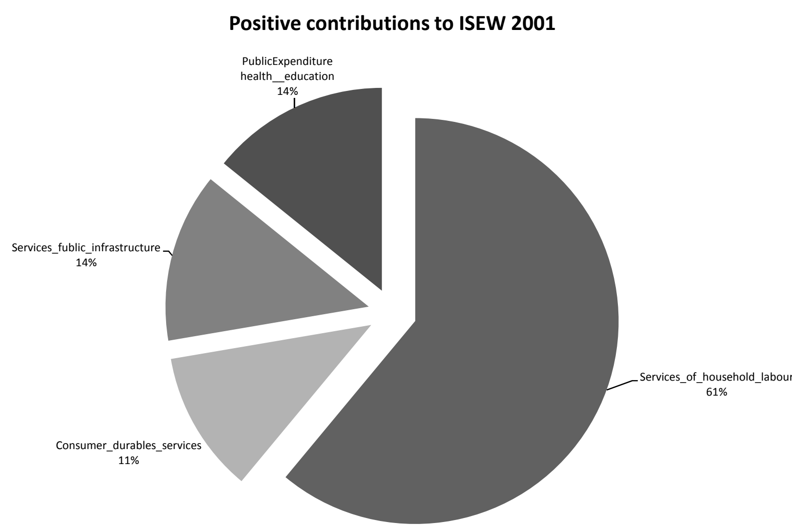

Figure 2: Positive contributions to ISEW in 2001

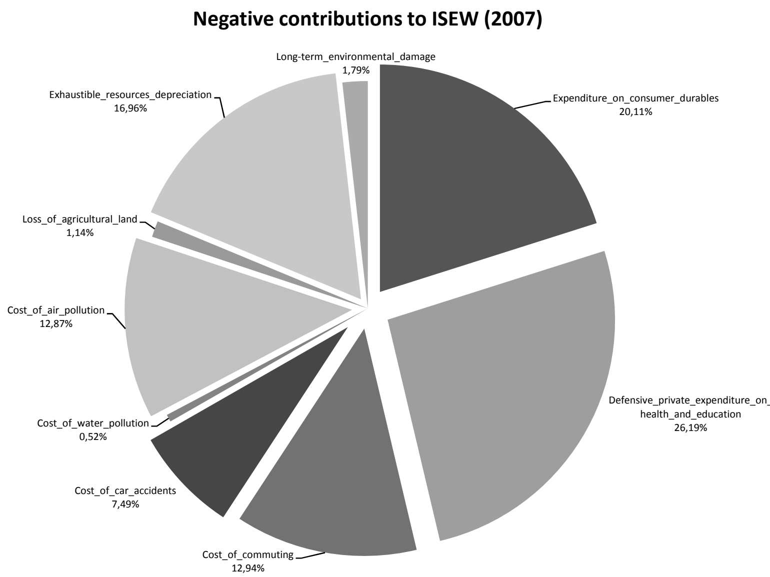

Figure 3: Negative contributions to ISEW in 2007

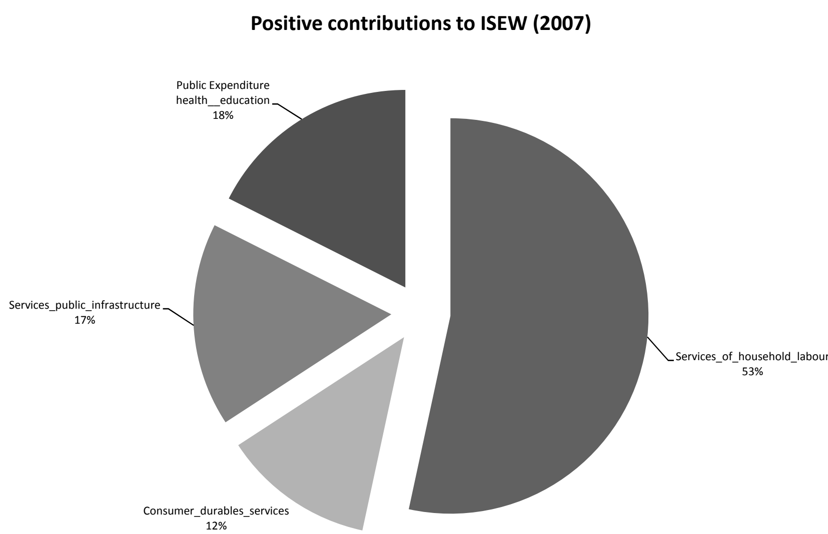

Figure 4: Positive contributions to ISEW in 2007

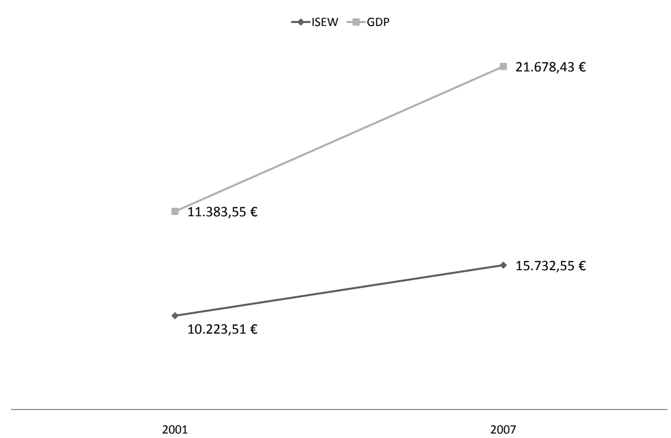

Figure 5: ISEW and GDP evolution from 2001 to 2007

done a 47%. It means that economic development has not been accompanied by an equivalent social one, thereby stating that the impressive development of Costa del Sol in the period from 2001 to 2007 in terms of GDP was not acompanied by an equivalent increase in ISEW. That is, welfare did not grew at the same rate as economy.

7.2. Emergy Results

As it was mentioned in Section 5, an Emergetic Analysis is divided in four steps, and that distribution was applied to the present research: First, the limits of the area under study were fixed to the conurbation of Costa del Sol comprising the three physical divisions: East, center and west. Second, the model was drawn, Fig 6 represents it. Third, the emergetic table was calculated. Appendix B includes all the rest of tables and the calculation methods used. Finally, the indicators were obtained from emergetic tables. Table 4 contains all the Emergy indicators obtained by the present research for Costa del Sol in 2001 and 2007, respectively.

Table 4 summarizes not only the emergetic indexes, but also the main emergetic inputs, outputs and some compound indexes of our case example in Costa del Sol. Lomas' Emergetic Analysis of Spain during the last two decades has been an invaluable guide for the present research [57]. Each row

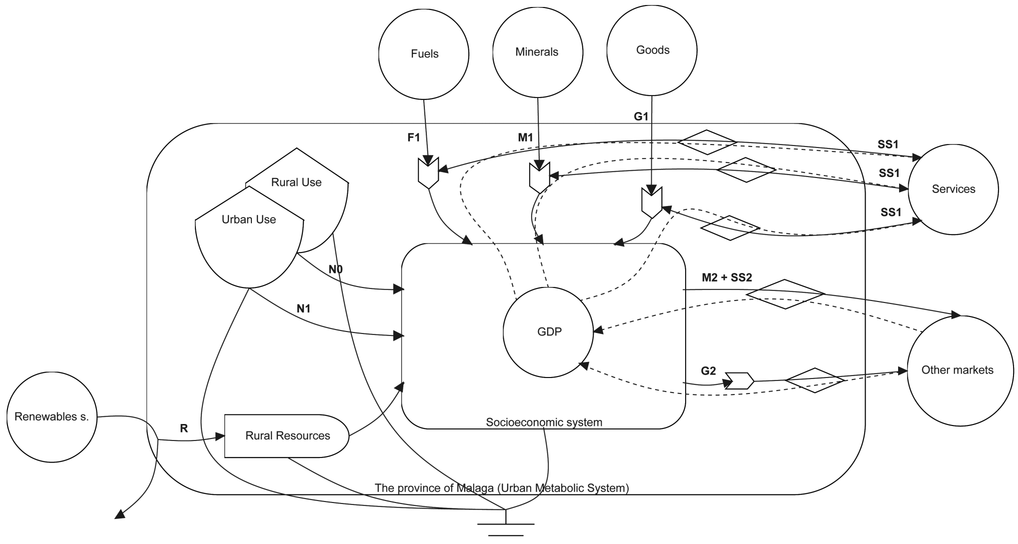

Figure 6: Emergy Model

is assigned one number in Table 4, unless rows 2, 3 and 4 which condense several items regarding the emergetic component they represent. Hence, rows 1 to 4 contain the emergetic inputs and outputs of the system. From rows 5 to 15 we find the first order emergetic indicators, that is, those that stand for the emergetic behavior of the system in general terms. Finally, from rows 16 to 40, second order emergetic indicators are presented.

Some investigations can be revised if the reader is interested in understanding each indicator and its proper interpretation [58] [59]. We specially recommend Lomas' research about the decoupling process between local economic activities and natural capital in Andalusia [60].

As explained previously, offering a measure of the Carrying Capacity of the region under study was the main task we assigned to strong sustainability indicators. Hence, in the present research we focused on three main indicators from the complete set presented in Table 4. The first one is Renewable to Total Emergy (R/U) ratio, that is, the fraction of renewable use in Costa del Sol versus the total amount of emergy used per year in the socioeconomic activity of the conurbation. These figures can be found in row 8 of Table 4. The value of 0,064 for 2007 means that just 6,4% of total activity in Costa del Sol could be sustained by renewable sources. It is not a bad data, if it is compared to the global value of Spain which is around 3% [57], but it is a clear signal of the absolute dependence on non-renewable resources of Costa del Sol. Besides, the same study for 2001 reveals that 6 years ago, the Renewable to Total Emergy ratio in Costa del sol was 0,070, that is, a 7% of the total emergy flowing through the system. In six years, the ratio decreased a 8%.

Nevertheless, although the former value of Renewable to Total Emergy used gives an idea of the Carrying Capacity of the region, Emergy Analysis offers two more accurate approaches [12]. The first one is area-based. In this approach the carrying capacity indices express the land area required to support an economic activity, which is called the *support area*. In row 38 of Table 4 these figures can be found. They have been calculated according to the next formula:

$$SA_r = (IMP + N)/Empd_r \tag{3}$$

$$Empd_r = R/Area \tag{4}$$

Where,
SA_r = Renewable Support Area (m^2)
$Empd_r$ = renewable empower density ($sej/m^2/yr$)
R = renewable imputs (sej/yr)
IMP = purchased inputs (sej/yr)
N = non-renewable inputs (sej/yr)

SA_r is the necessary area of the surrounding region that would be required if the economic activity were achieved using only renewable emergy inputs. The value obtained for Costa del Sol in 2007 is 26.400 km^2, which is almost 16 times bigger than its actual area. In 2001 this area was around 24.300 km^2, it means a 7,84% increase in non-renewable area dependence in 6 years time.

The support area is an extreme lower limit to environmental Carrying Capacity, given that it only takes into account the rough renewable sources, neglecting the capacity of human development to meet their needs with optimized consumption of renewable resources. In order to fix this drawback, Brown proposed to calculate the development Carrying Capacity, sometimes called synchronal support areas, of regions which could be used as standard developed areas [12]. Once these values were obtained, we could apply the next equation:

$$ELR_r = ELR_d \tag{5}$$
$$ELR_r = (IMP + N)/(R) \tag{6}$$
$$ELR_d = (IMP + N)/R^* \tag{7}$$

where:
ELR_r = environmental loading ratio of the region.
ELR_d = environmental loading ratio of the development standard.

The ELR_d is the loading ratio that is necessary to equal that of the region, thus the R^* is the required amount of renewable emergy necessary to lower the ELR of the development standard to that of the region. The equation is solved as follows:

$$R^* = (IMP + N)/ELR_r \tag{8}$$

Once the quantity R^*, is known, the area of landscape required to balance the proposed development is calculated as follows:

$$SA_{ELR} = R^*/Empd_r \tag{9}$$

Two values, obtained according to Lomas and Brown proposal, have been used in the present research: European and Mediterranean Basin development standards in 2000. Fixed values for these standard indicators have been chosen in order not to include a second variable which may distort the comparison between years. These values would constitute the upper limit to the Carrying Capacity and can be found in rows 39 and 40 of Table 4, respectively. Attending at these figures, the area of Costa del Sol in 2007 was 67% and 86% of synchronal support areas of Europe and Mediterranean Basin, respectively. That is, the area of Costa del Sol that would remain after using its territory to reach the standard of Europe and Mediterranean Basin would be 23% and 14% respectively. These values are close to the mean value for Spain. Besides, the same calculation for 2001 reveals that the Carrying Capacity in Costa del Sol was 64% and 84% of Europe and Mediterranean Basin. A loss of 4% of Carrying Capacity from 2001 to 2007 in terms of synchronal support area is revealed.

The second approach to the calculation of the Carrying Capacity by the Emergy Analysis is a people-based one. This approach stands for the amount of people who could survive in the region if only renewable inputs were accessible. The value for the Costa del Sol can be found in rows 28 of Table 4. In 2001, 65.500 people, that is, a 6,5% of the total population, was supported by Renewable resources, whereas in 2007 just a 6% of the total population of Costa del Sol was supported by renewable resources. Nevertheless, similar to the area-based approach, the people-based Renewable Carrying Capacity represents an extreme lower limit. In order to find an upper limit, a similar research developed for the area-based approach is done here. Rows 29 and 30 in Table 4 shows the results. If the European standard were chosen, 1.76 million people could be supported in Costa del Sol in 2007, that is, 1.4 times the real population. Besides, in 2001, using the same standard, the ratio was 1.6 times the population. Moreover, if the Mediterranean Basin were chosen as the standard, in 2007 just 980.000 people could be supported, that is, 81% of the real population, whereas the same calculation for 2001 reveals that 88% of the total population of Costa del Sol in that year could have been supported in that standard of living. Comparing both years, the decrease in Carrying Capacity between both is around 7,3%.

Eventually, after analyzing the emergetic Carrying Capacity analysis of Costa del Sol in 2001 and 2007, a first conclusion can be highlighted: a people based approach reveals more critical than an area-based approach. This fact is consistent with a common characteristic of new urban areas: the continuous increase in population. The present research shows how emergy analysis is able to measure the incapacity of ecosystems to support it. Nevertheless, it is worth mentioning that Carrying Capacity indicators offered by the present research are not absolute limits to the activity. They show a tendency but not limits not be surpassed.

8. Discussion

Two different strategies, i.e. ISEW and Emergy, have been presented in this research and applied to our case study: Costa del Sol conurbation in Spain. The former is based on weak sustainability, whereas the latter is rooted on strong sustainability. Attending at the data obtained, we may notice that both approaches have apparently produced divergent results. On the one hand, the evolution of ISEW for Costa del Sol in 2001 and 2007, although it has not increased at the same rate than GDP, shows a positive tendency, that is, it grew a 35% in that period of time. Thus, from a weak point of view, the sustainable condition of Costa del Sol is improving. In other words, attending to ISEW, socio-economic activity in Costa del Sol has proved to be sustainable. On the other hand, attending at the emergetic data obtained, a clear unsustainable behavior of Costa del Sol is revealed. Although the Carrying Capacity of Costa del Sol is essentially below the upper limits defined by the development standards in Europe and in the Mediterranean Basin, it is extremely far from the limits that the available renewable sources in the area impose.

Hence, a disagreement is presented between both indicators, yet is it an insuperable disagreement? The authors are persuaded that it is just an apparent contradiction. ISEW and Emergy are presenting a complementary reality in Bohr's sense [61]. As mentioned in Section 1, weak sustainability is focused on the socio-economic area of the sustainability triangle [62]; whereas Emergy is centered on the ecological-economic area. In other words, ISEW and Emergy together are able to cover the triple bottom line of sustainability, but if they are analyzed in a separated mode, they show a contradiction which is not reflecting the real sustainable behavior of the urban area under study. Hence, analyzing both contributions at the same time, we notice that Costa del Sol, during the period from 2001 to 2007, presented a sustainable development in socio-economic terms, in which welfare of the population increased significantly. Unfortunately, this development was based on an excessive dependence on non-renewable resources. This unsustainable behavior is imposing a pressure on the ecosystem which surpasses its Carrying Capacity both in a people-based approach as well as in an area-based one.

Besides, althoug the complementary effort has been successful, talking about the limitations of the research is mandatory, and the first one is related to the availability of data. In Table 3, which summarizes ISEW calculations for both years, last column, called data, includes information about the scope in which the data were collected. We notice that only a couple of Items have been directly obtained using local data of Costa del Sol. Most of them were extrapolated from regional (Andalusia) or National (Spain) statistics. Moreover, Emergy calculation suffers from the same problem. Although Tables B.7 and B.10 were mainly calculated using local environmental information, Tables B.8, B.9, B.11 and B.12 which stands for Imports and Exports, where obtained for the region of Andalusia and extrapolated to the population of Costa del Sol. Hence, the applicability of this kind of complementary studies to urban areas will always lack of the accuracy of a national or regional analysis. Nevertheless, although the lack of local data is a serious limitation, the results obtained for Costa del Sol present a real tendency of the social, economic and ecological sustainable contidion of the urban area, which could be reinforced by other kind of studies regarding specific areas.

However, lack of accurate data is not the only important drawback. A second big limition is related to its reductionism. Trying to embed the real sustainable condition in a pair of indicators, whatever weak or strong, is not enough. Moreover, although comparing two years has offered interesting information, wide temporal and spatial series analyses are needed in order to obtain a comparative idea of the relative sustainable condition of Costa del Sol to other Spanish regions.

Eventually, a third limitation of the present study has been found. As explained in the introduction, absolute Carrying Capacity limits of Costa del Sol are to be found in order not to cross an ecological deadline. The present research has calculated two aproximations to this Carrying Capacity but, neither the people-based nor the area-based one represent an absolute limit to the socio-economic activity in the region. They show the negative tendency, but they do not calculate an absolute value representing a deadline for the ecosystem of Costa del Sol. Unfortunately, neither this kind of *static* strong sustainability studies, nor the weak ones will ever be able to get these results. *Dynamic* studies are to be developed in order to achieve them[2].

In summary, although some limitations have been presented, the double ISEW and Emergy Analysis of Costa del Sol conurbation has proved to offer a *static* complementary vision of the sustainable condition of this urban area. However, it is not the last step, dynamic studies based on the present research which are able to complete the insight and to set absolute Carrying Capacity values for the ecosystem of Costa del Sol will be the next one.

9. Conclusion

In the introduction we exposed our aim: to select two indexes which may help us to investigate the possibility for weak and strong sustainable paradigms to cooperate in order to offer a consistent vision of the sustainable condition of an urban area, and to apply them to a real case: Costa del Sol conurbation in the south of Spain. Analyzing the results and the difficulties we had to face, the result of the present research has highlighted that, despite the limitations of both aproaches, the possibility of cooperation between weak

[2]Dynamic Emergy Analysis could be an interesting tool for this purpose [63].

and strong paradigms is not only possible but it is also very useful. On the one hand, ISEW can offer a more accurate measure of wealth than GDP. On the other hand, Emergy contributes with its Carrying Capacity indicators, both area-based and people-based, to the knowledge about the environmental load that socio-economic activity is imposing on the ecosystems.

Besides, Emergy methodology incorporates the economic activity in their ecological paradigm, nevertheless, social aspects of sustainability are not properly taken into account. However, that drawback of Emergy is, at the same time, the best advantage of ISEW studies which are centered on the socio-economic pole of sustainability . Hence, in a sustainability assessment of a urban context, Emergy Analysis would be responsible for describing the relation between the economic activities and the environment which holds it, while ISEW would highlight if economic development is actually being transformed in real wealth for the population. Thus, the complementary co-operation of both approaches reveals as extremely useful. Fortunately, many institutions are awarded of this situation and have been working for years within this mixed paradigm. SEEA effort is a very valuable international example [64], and the reports from BP Chair [56] and OSE [65] at Spanish national level are other ones. They offer an indicator-based adaptable strategy in which these indexes are figures in a wide framework which lacks of the "strong" or "weak" surname. These international and national efforts have proved that the integration of both paradigms is possible. Unfortunately, this cooperation of paradigms will be meaningless if no absolute limits of resilience for our ecosystems are found [66].

Nevertheless, regardless the success of the complementary approach, some important limitations have also been highlighted during the present study that worth being mentioned. Both indexes suffer from the two common ills of all these researches. The first one is the difficulty to find accurate data for urban studies since most statistics are compiled at regional or national level. The second one is related to the reductionism inherent to every single sustainability index proposal. Therefore, even if we could assure that, on the one hand, ISEW is really measuring welfare, and, on the other hand, Emergy is measuring resilience, these two big limitations would be enough for us to be prudently skeptic about the results. However, despite these common drawbacks, some lights have emerged from our research. As Costanza and others point out [23], "a single number for human Carrying Capacity would be meaningless given that the consequences of both human innovation and biological evolution are inherently unknowable. Nevertheless, a general index of the current scale or intensity of the human economy in relation to that of the biosphere is still useful". That is to say, emergy indicators cannot cope with the absolute needs that decision makers need in order to propose infallible sustainable politics, but it helps to check their evolution both spatially and temporally. Similarly, ISEW gives an idea of how far GDP is from taking into account economic, social and ecologic sustainability issues, and it can be used to compare the sustainable behavior of countries, regions or cities. Hence, although a single strong or weak sustainability index is too limited, temporal or spatial series of them produces valuable information.

In summary, sustainability indexes are relevant information tools, but they themselves are not able to cope with the entire sustainability goals that the humankind is facing nowadays, especially when dealing with urban sustainability issues. In this complex context, strong and weak sustainability paradigms must cooperate. The former is responsible for finding accurate limits of resilience which can assure that our socio-economic activity is within the biophysical limits of planet earth [67]. Once this fact is guaranteed, weak sustainability methodologies would be responsible for the fair, sustainable allocation of wealth in the world. The message for strong sustainability activists could be the following: "Humankind needs exceed subsistence". Besides, weak sustainability researchers should remember that we still need a place to live, and up to now we just know one: a place called Earth, our home.

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Appendix A. ISEW calculations

Item D. Calculation of adjusted private consumption: In our calculations we have included the three different strategies. In the first row of Tables A.5 and A.6, results are presented with PC corrected by Gini's income distribution index. In the second column, results are obtained applying the inequality correction to the final ISEW index. Finally, the third column is calculated excluding the inequality correction.

Item E. Services - Domestic Labour and volunteer work: The method used in this research is based on the mean weekly hours spent by andalusian people, over twenty years old, in non remunerated activities. Using this value and taking into account the population of Costa del Sol in 2001 and 2007, final values were obtained.

Item F. Services - Consumer Durables: In our research, we chose a counting period of 10 years, hence a 10% amortation ratio between services and stock per year. Since no data for Costa del Sol regarding consumer durables expenditures for every year within the accounting periods (1998-2007 and 1992-2001) are registered, an interpolation was done with data for 2007 assuming a 3% decrease in consumption every year [29]. Therefore, taking into account 10 years of active services provided by domestic durables, and 10% of welfare amortization, the value of Item F for Costa del Sol was calculated with the basis of the total expenditure in domestic durables in Andalusia during 2001 and 2007 [53], and weighting it afterwards according to the population of Costa del Sol in those years.

Item I. Costs - Consumer Durables: This Item I includes the 90% of expenses in consumer durables in Costa del Sol during 2001 and 2007, respectively. 90% was chosen instead of 100% in order to be consistent with the hypothesis of 10% welfare amortization of this kind of goods, including the present year.

Item J. Private Defensive Expenditure for Education and Health Care: Data for Costa del Sol has been obtained from INE national statistics in 2001 [68]: 67,9% of students are registered in public schools, whereas the remaining 32,1% go to a private school. Difference among mean private expenditures per year in public and private education was included in order to obtain a more accurate figure.

Item N. Costs of road accidents: Two different evaluation methods were presented in 2000 by AEPO regarding costs of road accidents [55]. Following the former, based on a willingness to pay estimation, and according to data from DGT for Spain in 2001 and 2007 [68], this cost was interpolated for the population of Costa del Sol in both years and added to the present ISEW evaluation.

Item O. Cost of Water Pollution: Following Pulselli's proposal. An estimation of the total costs of purification of water supply were obtained from data on a standard purification plant. The cost has been corrected to 17,56€, applying a 3% cost increase per year, and it is referred to the equivalent inhabitants (E.I.) of the area. Since our research is focused on the conurbation of the Costa del Sol, we did not to include equivalent inhabitants for industrial and agricultural lands.

Item P. Cost of Air Pollution: We focused on external costs per ton of emissions devoted to different pollutants. Data were obtained from BP Chair Annual Report from the Observatory of Energy and Sustainability [56]. An estimation of emissions per citizens of Costa del Sol in 2001 and 2007 according to national data was done. Besides, four kinds of pollutants were considered, that is, CO2, NOx, SOs and PM10.

Item S. Loss of agricultural land: An estimation of lost agricultural lands in Costa del Sol was done according to data from OSE report. Besides, a cost of 12.900€per hectare of lost agricultural land was chosen [29].

Item T. Depletion of non-renewable resources: Following the replacement cost method, and Neumayer suggestion of not escalating the marginal social cost per barrel of oil equivalent, in this study for Costa del Sol we recalculated replacement cost values per barrel of oil equivalent used to produce electricity ($102) and for automotive purposes ($36), respectively. These calculations were based on data from BP Chair on Energy and Sustainability [56].

Item U. Long-term Environmental Damage: Tol's value of 50$/ton, was the one used in the present research.

Table A.5: ISEW study for Costa del Sol in 2001

A	**Year**	**2001 (weighted on PC)**	**2001 (weighted on ISEW)**	**2001 (not weighted)**
B	Personal_consumption_expenditure	10.567.742.967,47	10.567.742.967,47	10.567.742.967,47
C	Index_of_distribution_inequality	0,347	0,347	0,347
D	Weighted_personal_consumption_expenditure	7.845.391.958,03	10.567.742.967,47	10.567.742.967,47
E+	Services_of_household_labour	3.024.219.388,80	3.024.219.388,80	3.024.219.388,80
F+	Consumer_durables_services	559.386.179,02	559.386.179,02	559.386.179,02
G+	Services_from_public_infrastructure	668.052.704,68	668.052.704,68	668.052.704,68
H+	Public_expenditure_on_health_and_education	703.640.745,61	703.640.745,61	703.640.745,61
I-	Expenditure_on_consumer_durables	554.456.639,71	554.456.639,71	554.456.639,71
J-	Defensive_private_expenditure_on_health_and_education	712.841.166,65	712.841.166,65	712.841.166,65
K-	Local_advertising_expenditure	Not available	Not available	Not available
L-	Cost_of_commuting	338.350.520,97	338.350.520,97	338.350.520,97
M-	Cost_of_urbanisation	Not computed	Not computed	Not computed
N-	Cost_of_car_accidents	366.600.938,29	366.600.938,29	366.600.938,29
O-	Cost_of_water_pollution	14.568.608,39	14.568.608,39	14.568.608,39
P-	Cost_of_air_pollution	402.537.004,35	402.537.004,35	402.537.004,35
Q-	Cost_of_noise_pollution	Not computed	Not computed	Not computed
R+	Loss_of_wetlands	Not computed	Not computed	Not computed
S-	Loss_of_agricultural_land	46.236.553,18	46.236.553,18	46.236.553,18
T-	Exhaustible_resources_depreciation	508.191.347,11	508.191.347,11	508.191.347,11
U-	Long-term_environmental_damage	65.270.925,62	65.270.925,62	65.270.925,62
V+	Net_capital_growth	Not computed	Not computed	Not computed
W	ISEW=sum_of_all_positive_and_negative_items	10.223.509.135,78	9.610.883.552,50	12.945.860.145,22
X	ISEW_per_capita	10.196,42	9.585,41	12.911,55
Y	GDP	11.383.553.034,50	11.383.553.034,50	11.383.553.034,50
Z	GDP_per_capita	11.353,39	11.353,39	11.353,39

Table A.6: ISEW study for Costa del Sol in 2007

A	Year	2007 (weighted on PC)	2007 (weighted on ISEW)	2007 (not weighted)
B	Personal_consumption_expenditure	17.100.621.488,27	17.100.621.488,27	17.100.621.488,27
C	Index_of_distribution_inequality	0,323	0,323	0,323
D	Weighted_personal_consumption_expenditure	12.695.338.892,55	17.100.621.488,27	17.100.621.488,27
E+	Services_of_household_labour	3.582.070.244,45	3.582.070.244,45	3.582.070.244,45
F+	Consumer_durables_services	833.279.728,43	833.279.728,43	833.279.728,43
G+	Services_from_public_infrastructure	1.116.623.806,23	1.116.623.806,23	1.116.623.806,23
H+	Public_expenditure_on_health_and_education	1.178.055.855,34	1.178.055.855,34	1.178.055.855,34
I-	Expenditure_on_consumer_durables	814.186.224,79	814.186.224,79	814.186.224,79
J-	Defensive_private_expenditure_on_health_and_education	1.060.103.442,99	1.060.103.442,99	1.060.103.442,99
K-	Local_advertising_expenditure	Not available	Not available	Not available
L-	Cost_of_commuting	523.936.829,47	523.936.829,47	523.936.829,47
M-	Cost_of_urbanisation	Not computed	Not computed	Not computed
N-	Cost_of_car_accidents	303.194.531,06	303.194.531,06	303.194.531,06
O-	Cost_of_water_pollution	20.926.247,81	20.926.247,81	20.926.247,81
P-	Cost_of_air_pollution	520.948.826,78	520.948.826,78	520.948.826,78
Q-	Cost_of_noise_pollution	Not computed	Not computed	Not computed
R+	Loss_of_wetlands	Not computed	Not computed	Not computed
S-	Loss_of_agricultural_land	46.236.553,18	46.236.553,18	46.236.553,18
T-	Exhaustible_resources_depreciation	686.483.662,16	686.483.662,16	686.483.662,16
U-	Long-term_environmental_damage	72.369.908,23	72.369.908,23	72.369.908,23
V+	Net_capital_growth	Not computed	Not computed	Not computed
W	ISEW=sum_of_all_positive_and_negative_items	15.732.546.739,83	14.950.133.137,00	20.137.829.335,55
X	ISEW_per_capita	13.043,57	12.394,89	16.695,92
Y	GDP	21.678.429.099,60	21.678.429.099,60	21.678.429.099,60
Z	GDP_per_capita	17.973,20	17.973,20	17.973,20

Appendix B. Emergy Tables

Table B.7: EMERGY FLOWS. COSTA DEL SOL 2001

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref.Trans.	Emergy 2000	Emergy 2010
	Renewable inputs (R)							
1	Sunlight	J/yr	7,88E+18	[69]	1	[70]	7,88E+18	7,57E+18
2	Rain (chemical potential)	J/yr	2,72E+15	[69]	3,06E+04	[70]	8,34E+19	8,01E+19
3	Rain (geopotential)	J/yr	1,69E+15	[69]	1,76E+04	[70]	2,98E+19	2,86E+19
4	Wind kinetic energy	J/yr	2,25E+16	[69]	2,52E+04	[70]	5,67E+20	5,45E+20
5	Waves	J/yr	3,19E+16	[69]	5,14E+04	[70]	1,64E+21	**1,57E+21**
6	Tides	J/yr	4,86E+14	[69]	7,39E+04	[70]	3,59E+19	3,45E+19
7	Earth cycle	J/yr	1,70E+15	[57]	1,20E+04	[70]	2,04E+19	1,96E+19
	Indigenous non-renewable inputs (N0)							
8	Net topsoil loss	J/yr	8,57E+12	[49]	1,05E+05	[70]	9,00E+17	8,64E+17
	Indigenous non-renewable inputs (N1)							
9	Limestone	g/yr	0,00E+00	[71]	9,50E+09	[70]	0,00E+00	0,00E+00

Table B.8: IMPORTS. COSTA DEL SOL 2001

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref. Trans.	Emergy 2000	Emergy 2010
10	Oil and petroleum derived products	J/yr	4,38E+16	[71]	9,06E+04	[70]	3,97E+21	3,81E+21
11	Coal	J/yr	5,60E+14	[71]	6,71E+04	[70]	3,75E+19	3,61E+19
12	Natural gas	J/yr	7,11E+15	[71]	8,05E+04	[70]	5,72E+20	5,50E+20
13	Electricity	J/yr	1,31E+16	[71]	3,36E+04	[70]	4,39E+20	4,22E+20
14	Livestocks and products	J/yr	2,82E+14	[72]	5,33E+06	[70]	1,50E+21	1,44E+21
15	Agriculture and forest products	J/yr	1,74E+15	[72]	1,75E+05	[70]	3,04E+20	2,92E+20
16	Food industry products	g/yr	1,69E+11	[72]	3,36E+04	[70]	5,67E+15	5,44E+15
17	Plastics	g/yr	7,22E+10	[72]	3,20E+09	[70]	2,31E+20	2,22E+20
18	Minerals	g/yr	3,15E+12	[72]	1,68E+09	[70]	5,30E+21	5,08E+21
19	Steel and pig iron	g/yr	4,22E+11	[72]	3,69E+09	[57]	1,56E+21	1,49E+21
20	Mechanical and transport equipment	g/yr	1,68E+11	[72]	1,13E+10	[70]	1,90E+21	1,82E+21
21	Leather and products	J/yr	9,54E+13	[72]	1,44E+07	[70]	1,37E+21	1,32E+21
22	Textils	J/yr	5,24E+14	[72]	6,38E+06	[70]	3,34E+21	3,21E+21
23	Wood and products	J/yr	2,79E+15	[72]	5,86E+04	[70]	1,63E+20	1,57E+20
24	Paper	g/yr	7,57E+10	[72]	6,55E+09	[70]	4,96E+20	4,76E+20
25	Chemicals	g/yr	2,29E+11	[72]	6,38E+08	[70]	1,46E+20	1,40E+20
26	Rubber	g/yr	1,88E+10	[72]	7,22E+09	[70]	1,36E+20	1,30E+20
27	Total Services	$/yr	8,66E+08	[73]	1,85E+12	[12]	1,60E+21	1,54E+21
28	Total Tourism	$/yr	1,87E+08	[73]	1,85E+12	[12]	3,47E+20	3,33E+20

Table B.9: EXPORTS. COSTA DEL SOL 2001

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref. Trans.	Emergy 2000	Emergy 2010
29	Livestock and products	J/yr	2,41E+14	[72]	5,33E+06	[70]	1,28E+21	1,23E+21
30	Agriculture and forest products	g/yr	1,11E+15	[72]	1,75E+05	[70]	1,95E+20	1,87E+20
31	Food industry products	g/yr	1,07E+11	[72]	3,36E+04	[70]	3,58E+15	3,44E+15
32	Plastics	g/yr	6,20E+10	[72]	3,20E+09	[70]	1,98E+20	1,90E+20
33	Minerals	g/yr	8,79E+11	[72]	1,68E+09	[70]	1,48E+21	1,42E+21
34	Steel and pig iron	g/yr	1,61E+11	[72]	3,69E+09	[57]	5,95E+20	5,71E+20
35	Mechanical and transport equipment	g/yr	1,61E+11	[72]	1,13E+10	[70]	1,82E+21	1,75E+21
36	Leather and products	J/yr	3,59E+13	[72]	1,44E+07	[70]	5,17E+20	4,97E+20
37	Textils	J/yr	3,43E+14	[72]	6,38E+06	[70]	2,19E+21	2,10E+21
38	Wood and products	J/yr	8,42E+14	[72]	5,86E+04	[70]	4,93E+19	4,74E+19
39	Paper	g/yr	5,64E+10	[72]	6,55E+09	[70]	3,69E+20	3,55E+20
40	Chemicals	g/yr	1,76E+11	[72]	6,38E+08	[70]	1,12E+20	1,08E+20
41	Rubber	g/yr	1,63E+10	[72]	7,22E+09	[70]	1,17E+20	1,13E+20
42	Total Services	$/yr	8,15E+08	[73]	3,09E+12	[12]	2,52E+21	2,42E+21
43	Total Tourism	$/yr	2,81E+09	[73]	3,09E+12	[12]	8,69E+21	8,34E+21

Table B.10: EMERGY FLOWS. COSTA DEL SOL 2007

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref.Trans.	Emergy 2000	Emergy 2010
	Renewable inputs (R)							
1	Sunlight	J/yr	7,88E+18	[69]	1	[70]	7,88E+18	7,57E+18
2	Rain (chemical potential)	J/yr	2,78E+15		3,06E+04	[70]	8,50E+19	8,16E+19
3	Rain (geopotential)	J/yr	1,72E+15	[69]	1,76E+04	[70]	3,03E+19	2,91E+19
4	Wind kinetic energy	J/yr	2,25E+16	[69]	2,52E+04	[70]	5,67E+20	5,45E+20
5	Waves	J/yr	3,19E+16	[69]	5,14E+04	[70]	1,64E+21	**1,57E+21**
6	Tides	J/yr	4,86E+14	[69]	7,39E+04	[70]	3,59E+19	3,45E+19
7	Earth cycle	J/yr	1,70E+15	[57]	1,20E+04	[70]	2,04E+19	1,96E+19
	Indigenous non-renewable inputs (N0)							
8	Net topsoil loss	J/yr	5,36E+12	[49]	1,05E+05	[70]	5,63E+17	5,40E+17
	Indigenous non-renewable inputs (N1)							
9	Limestone	g/yr	0,00E+00	[74]	9,50E+09	[70]	0,00E+00	0,00E+00

Table B.11: IMPORTS. COSTA DEL SOL 2007

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref. Trans.	Emergy 2000	Emergy 2010
10	Oil and petroleum derived products	J/yr	5,80E+16	[74]	9,06E+04	[70]	5,25E+21	5,04E+21
11	Coal	J/yr	2,26E+14	[74]	6,71E+04	[70]	1,51E+19	1,45E+19
12	Natural gas	J/yr	1,48E+16	[74]	8,05E+04	[70]	1,19E+21	1,14E+21
13	Electricity	J/yr	1,97E+16	[74]	3,36E+04	[70]	6,62E+20	6,35E+20
14	Livestocks and products	J/yr	1,36E+14	[75]	5,33E+06	[70]	7,26E+20	6,97E+20
15	Agriculture and forest products	J/yr	1,56E+15	[75]	1,75E+05	[70]	2,73E+20	2,62E+20
16	Food industry products	g/yr	3,16E+11	[75]	3,36E+04	[70]	1,06E+16	1,02E+16
17	Plastics	g/yr	3,49E+10	[75]	3,20E+09	[70]	1,12E+20	1,07E+20
18	Minerals	g/yr	6,28E+12	[75]	1,68E+09	[70]	1,05E+22	1,01E+22
19	Steel and pig iron	g/yr	3,23E+11	[75]	3,69E+09	[57]	1,19E+21	1,14E+21
20	Mechanical and transport equipment	g/yr	2,33E+10	[75]	1,13E+10	[70]	2,63E+20	2,53E+20
21	Leather and products	J/yr	2,45E+13	[75]	1,44E+07	[70]	3,52E+20	3,38E+20
22	Textils	J/yr	1,38E+14	[75]	6,38E+06	[70]	8,81E+20	8,46E+20
23	Wood and products	J/yr	1,93E+15	[75]	5,86E+04	[70]	1,13E+20	1,09E+20
24	Paper	g/yr	2,24E+10	[75]	6,55E+09	[70]	1,47E+20	1,41E+20
25	Chemicals	g/yr	1,50E+11	[75]	6,38E+08	[70]	9,57E+19	9,19E+19
26	Rubber	g/yr	1,88E+09	[75]	7,22E+09	[70]	1,36E+19	1,31E+19
27	Total Services	$/yr	1,54E+09	[76]	1,85E+12	[12]	2,84E+21	2,73E+21
28	Total Tourism	$/yr	3,83E+08	[76]	1,85E+12	[12]	7,09E+20	6,81E+20

Table B.12: EXPORTS. COSTA DEL SOL. 2007

No	Input	Unit	Amount	Ref. Amount	Transformity	Ref. Trans.	Emergy 2000	Emergy 2010
29	Livestock and products	J/yr	1,21E+14	[75]	5,33E+06	[70]	6,44E+20	6,18E+20
30	Agriculture and forest products	g/yr	2,13E+15	[75]	1,75E+05	[70]	3,73E+20	3,58E+20
31	Food industry products	g/yr	1,99E+11	[75]	3,36E+04	[70]	6,69E+15	6,42E+15
32	Plastics	g/yr	1,88E+10	[75]	3,20E+09	[70]	6,01E+19	5,77E+19
33	Minerals	g/yr	1,30E+12	[75]	1,68E+09	[70]	2,18E+21	2,09E+21
34	Steel and pig iron	g/yr	1,01E+11	[75]	3,69E+09	[57]	3,73E+20	3,58E+20
35	Mechanical and transport equipment	g/yr	6,09E+10	[75]	1,13E+10	[70]	6,89E+20	6,61E+20
36	Leather and products	J/yr	3,30E+12	[75]	1,44E+07	[70]	4,75E+19	4,56E+19
37	Textils	J/yr	9,36E+13	[75]	6,38E+06	[70]	5,97E+20	5,73E+20
38	Wood and products	J/yr	5,01E+14	[75]	5,86E+04	[70]	2,94E+19	2,82E+19
39	Paper	g/yr	2,19E+10	[75]	6,55E+09	[70]	1,44E+20	1,38E+20
40	Chemicals	g/yr	1,93E+11	[75]	6,38E+08	[70]	1,23E+20	1,18E+20
41	Rubber	g/yr	1,62E+09	[75]	7,22E+09	[70]	1,17E+19	1,12E+19
42	Total Services	$/yr	1,39E+09	[76]	3,09E+12	[12]	4,28E+21	4,11E+21
43	Total Tourism	$/yr	3,98E+09	[76]	3,09E+12	[12]	1,23E+22	1,18E+22