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ENERGY SCIENTIFIC PRODUCTION IN THE CONTEXT OF THE GREEN DEVELOPMENT MODELS

Abstract: *The energy sector plays a vital role in addressing the global challenges of achieving sustainability by using the renewable energy sources and by increasing the energy efficiency and conservation, while obtaining energy security and safety. The aim of this paper is to quantitatively observe the evolution and status of the main publications on "green" energy. The study uses the Scopus database and the VOSviewer software to determine the progress of research and the main sub-themes discussed in the field of energy in the context of green economy and sustainable development. The findings suggest slightly different approaches of the scientific production on sustainable-related energy, green-related energy and renewable related-energy. This paper provides insights on the main internationally debated research areas in the energy field.*

Keywords: *bibliometric study, energy, green economy, renewable energy, Scopus literature, sustainable development, sustainable energy, VOSviewer*.

JEL Classification: Q20, Q28, Q30, Q32, Q50

1. Introduction

The energy is fundamental for the development of any society as the current global problems, such as environmental degradation andincrease of the energy demand as the emerging countries are developing, are threatening the future of mankind by shrinking the possibilities of energy security and growth (Manzano-Agugliaro et al., 2013).As a result, several green development models have emerged in the last century, such as bioeconomy, hydrogen economy, steady-state economy, low-carbon economy, circular economy, green economy.This paper approaches the energy field from the perspective of sustainable development and green economy, because the latter has emerged as a way of boosting the former(Zaharia, 2015), which aims to "meet the needs of the present without compromising the ability of

future generations to meet their own needs" (Brundtland et al., 1987). The green economy is considered as a counter-strategy for the economic crisis started in 2008 and aimed promoting intensively the shift towards greening the economy by proposing new ways of doing business and behaving in favor of environmental and social justice (Porfir'ev, 2012; UNEP, 2011).

The energy sector is one of the main priorities of these green development models, as the energy scarcity represents a threat to energy security and, further, to mankind survival (Porfir'ev, 2012; Brundtland et al., 1987). Accordingly, the global problems imposes the transformation of the energy sector from a traditional form to one based on renewable energy and resource savings, that is environmentally friendly and socially just(Manzano-Agugliaroet al., 2013; UNEP, 2011;Brundtland et al., 1987).So, the studies on green energy have increased considerably. Lately, numerous literature reviews have emerged in this field by using a more analytical approach to investigate the scientific production from several multidisciplinary databases, such as Scopus and Web of Science, and by using different types of software(Manzano-Agugliaroet al., 2013).

In this context, the purpose of this paper is to explore the scientific production on green energy, the foundation on which rests the emergence of new public policies and new business shifts towards sustainability. Specifically, this study uses the Scopus database and the VOSviewer software to determine the status and progress of the research, the most cited sources worldwide, as well as, the main sub-themes discussed in the field of energy in the context of green economy and sustainable development.

In view of the above, the main questions that underpin this research are:
How the scientific production on sustainable development and green economy has evolved since 1989 and to what extent is the energy field considered in these studies? How the scientific production on energy has evolved in time and how can its connection with studies on sustainable, green and renewable subjects be characterized by means of publication analysis? How the most cited and recent papers speak about the energy– sustainable/ green/renewable nexus?

To the best of our knowledge, this is the first research on energy literature analyzed in the context of the green economy model. This research identifies more comprehensively the growing trend of the studies regarding the energy–sustainable/green/renewable nexus. By analyzing the existing literature in new combinations, it may lead to new directions of green energy research. However, the limitations of this research refer to the particular focus on Scopus data, as well as to the maximum number of 2000 analyzed titles and abstracts of articles.

2. The state of the art

A growing body of literature investigates the status and progress of the increasing scientific production in the field of green development models

(Golembiewski et al., 2015; Hassan et al., 2014; Tsay, 2008; Kajikawa et al., 2014) and of energy(Du et al., 2013; Manzano-Agugliaro et al., 2013; Mao et al., 2015).

Schoolman et al.(2012) reports the risk of losing the interdisciplinary character of this field due to the publication in only a few interdisciplinary journals while the focus, in the majority of cases, is still on the economic pillar of sustainability. Another study (Kajikawa et al., 2014) approaches the monitoring of sustainability papers by using clustering techniques, concluding that several clusters in energy, technology and systems are emerging. Recent research on change-related energy and sustainability shows that older ideas are still applicable in the field and that sustainability is the most common word used in the Scopus transition and transformation literature(ChappinandLigtvoet, 2014).

Hassan et al. (2014)overviewed the sustainable development studies in order to determine the integration of all its sub-themes in institutes strong in sustainable development and vice versa, while emphasizing the implementation of this models as a strategic research focus, thereby demonstrating the globally acknowledged need of considering the ecological, social and economic challenges in all policies and actions. Golembiewskiet al. (2015) carried out an investigation into the bioeconomy publications by using Scopus and Web of Science databases during 1980-2013, providing the main critical points in developing bioeconomy, namely: the slow evolution of studies conducted at firm or consumer level, the low development of multidisciplinary studies and the need of institutionalizing the bioeconomy.An early study on hydrogen economy traces its development during 1965-2005 by analyzing the growth rate of literature, the document type, the contributing countries, journals and institutions in research (Tsay, 2008).

By integrating the green principles into the sectorial fields, such as construction, Schweber and Leiringer(2012) point out that the studies on social sciences, have expanded considerably, thus creating new opportunities to draw attention about the sectorial changes by engaging a wider audience.

The majority of the scientific production is focused on worldwide analysis of renewable energy and green development models literature (Golembiewskiet al., 2015; Hassan et al., 2014; Manzano-Agugliaroet al., 2013; Mao et al., 2015; Schoolman et al., 2012),while few studies narrow the analysis to regional or national areas (Montoya et al., 2014; Romo-Fernándezet al., 2011; Celiktaset al., 2009). These geographically limited studies present the advantage of identifying the future directions for research in order to accomplish the sustainable development of a country. For example, Celiktaset al.(2009) emphasized the need of studying more thoroughly the development of renewable energy policies in Turkey. Montoya et al.(2014) conducted a keyword frequency analysis by using the Scopus data for investigating the main keywords of the Spanish energy field during 1957-2012. The study (Montoya et al., 2014) revealed that the most used terms are the following: power, energy, system, wind and solar. In addition, Romo-

Fernándezet al.(2011) discussed the European status in terms of renewable energies, concluding that Europe is well positioned globally in the production, citations and impact of the publications in this scientific field.

Some studies analyzed more specific topics of the renewable energy field, such as solar energy (Du et al., 2013),nano-technology (Guan and Liu, 2014), and green supply chain management (Fahimniaet al., 2015).These papers suggest an increasing trend of the scientific production on the previously mentioned green themes during different periods of time, while emphasizing the highly important support given by worldwide studies both for researchers and policymakers. Moreover, the American, Chinese and Indian publications are predominant (Du et al., 2013; Mao et al., 2015), while the technological focus is mainly explored given the debated themes in energy(Du et al., 2013). Similarly, the analysis of the nano-energy field is currently emerging in the scientific literature, with emphasis on the necessity of increasing the energy efficiency and the renewable energy accessibility of consumers through trade (Guan and Liu, 2014).

Finally, the previously mentioned scientific production indicates the necessity of performing similar investigations on various fields in order to identify the current and future research directions for both scientists and policymakers.

3. Methodology

This paper proposes a quantitative analysis of the scientific publications on energy in the context of green development models for the time period of 1989-2015, by using the data extracted on May 20, 2016, from the Scopus database. Scopus is a multidisciplinary database created by Elsevier with over 20000 publications, being the most trustworthy and complete platform when compared with Google Scholar and Web of Science (Jacso, 2005).

The search inquiry on Scopus, presented in *Table 1* below, was conducted by analyzing the title, abstract and keywords of the studies published in the field of economic sciences, namely: business, management and accounting ("BUSI") plus economics, econometric & finance ("ECON") plus decision sciences ("DECI"). The search was limited to the selected publication years.

Table 1.The search of the studies on the green development models, the energy and its association with green economy, green and renewable energy, during 1989-2015,by subject area

Green development models	Number of publications	Search inquiry 1989-2015
Sustainable development	113243 15447	• TITLE-ABS-KEY ("sustainable development") AND PUBYEAR > 1986 AND PUBYEAR < 2016 • TITLE-ABS-KEY ("sustainable development") AND PUBYEAR > 1986 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA,

Green development models	Number of publications	Search inquiry 1989-2015
		"ECON") OR LIMIT-TO (SUBJAREA, "DECI"))
Green economy	898 279	• TITLE-ABS-KEY ("green economy") AND PUBYEAR > 1988 AND PUBYEAR < 2016 • TITLE-ABS-KEY ("green economy") AND PUBYEAR >1986 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI"))
Energy	2752268 40186	• TITLE-ABS-KEY ("energy") AND PUBYEAR > 1988 AND PUBYEAR < 2016 • TITLE-ABS-KEY ("energy") AND PUBYEAR > 1986 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI"))
Energy-sustainable	48788 3800	• (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("sustainable")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 • (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("sustainable")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI"))
Energy-green	53259 1851	• (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("green")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 • (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("green")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI"))
Energy-renewable	78981 4099	• (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("renewable")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 • (TITLE-ABS-KEY ("energy") AND TITLE-ABS-KEY ("renewable")) AND PUBYEAR > 1988 AND PUBYEAR < 2016 AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI"))

Due to the high number of publications on sustainable development, energy, as well as sustainable, green and renewable energy, the analysis was conducted for the first 2000 most cited papers and for the first 2000 most recent papers. Initially, a quantitative analysis was performed in order to investigate the evolution of studies over time, the most cited authors and papers and the geography of publications. Further on, an analysis of the main keywords association for the

green development models and the energy studies was performed in order to generate the main topics concerned with energy in the context of the green economy. As green economy promotes the use of renewable energy, which is also called green energy, the keywords investigated were gathered into general sub-themes of association between energy and green economy or green or renewable.

The analysis was performed by using the VOSviewer software, version 1.6.4.,which allows the illustration of the association strength between the most frequent words and their occurrences found in the analyzed titles and abstracts of literature (Van Eck and Waltman, 2016). The criterion for creating the maps consists in choosing the terms which simultaneously met two conditions: the occurrences of a term must be equal or higher than 20 in the analyzed content, while considering the most 60% relevant terms generated by VOSviewer. The bigger the size of the words illustrated in the figures of this paper, the higher the number of publications that have the corresponding term in their title or abstract. Also, the closer the words are among themselves, the higher the co-occurrences are in the illustration (Van Eck and Waltman, 2016).

Several studies discussed bibliographic analysis in the green energy field (Manzano-Agugliaro et al., 2013; Mao et al., 2015). However, to the best of our knowledge, none of them investigated the relation of energy with the green development models. Our purpose was to discuss the general topics emphasized by the past research and to further investigate the most cited and recent papers in the field of green energy. One methodological constraint of this research consists in the way of searching the analyzed publications represented in this study as "search inquiry" (*Table 1*) and the limitation to the most 2000 cited and recent papers. In addition, the marketing purpose of the titles and abstracts of scientific research should be considered, given the fact that the main corpus of these publications might indicate different results.

4. Results and Discussion

The results are structured in three parts: the importance of the energy field in the studies on green development models is overviewed, the documents on energy research are thoroughly analyzed, and the publications on the association between energy and sustainable/green/renewable terms are thoroughly discussed. The time frame considered in the analysis is 1989-2015.

4.1. The importance of the energy sector revealed by the studies concerning sustainable development and green economy

The scientific production on sustainable development and green economy from Scopus has considerably increased by more than 100 times and 40 times, respectively, since 1989. The increase of sustainable development publications overtime is observed, also, in the study of Hassan et al. (2014). However, the literature on these green development models in the area of economic sciences have grown more slowly than overall subject areas. Since the beginning of 2000,

respectively 2009, the percentage of studies on sustainable development, respectively on green economy, published in the area of economic sciences have grown by around 10-20% yearly, respectively approximately 20-38% yearly, while the studies on other subject areas have stagnated, respectively they have decreased.

In this general framework, the key themes proposed by the academic experts in the field of sustainable development and of green economy are investigated for a more qualitative treatment of this analysis, while emphasizing the importance of the energy sector worldwide.

Figure 1illustrates the main keywords of the most cited 2000 papers on sustainable development between 1989 and 2015, based on the analysis of 311 terms out of 38957 initially considered terms. As suspected, the sustainable development model has the energy topic as one of the most important sub-theme, being represented by the following keywords: energy, biomass, alternative, fuel, biofuel, fossil fuel, renewable energy, hydrogen, energy system, renewable energy technology, renewable energy source and efficiency in the context of environmental pollution. In the area of economic sciences, the energy field in the context of sustainable development deals with production, consumption, other environmental factors, while other topics deal with environmental impact and performance, economic growth, as well as indices and methodologies for assessing different policies and economic activities.

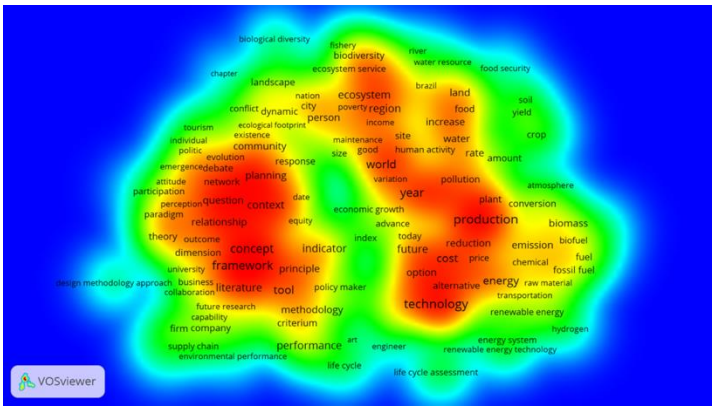

Figure 1. Key sub-themes of sustainable development of the most 2000 cited papers on Scopus, 1989-2016

Figure 2 illustrates the main keywords of the most 2000 recent papers on sustainable development after using 280 terms of 44469 initially considered words. It could be easily observed that the energy sub-theme of sustainable development in this case is somewhat similar with the results generated by the sustainable development analysis overall. The similarities are given by the following

keywords: energy, biomass, fuel, biofuel. However, in the last 2000 papers of 2015 the focus regarding the energy topic in the context of sustainable development is on energy consumption, energy efficiency, bioenergy, new technology and performance in this field. This is understandable as the main public policies promoted at international level, such as those promoted by UNEP (2011) focus on encouraging the reduction of energy consumption and the increase of energy efficiency, while the renewable technologies are more and more adopted. In the area of economic sciences, sustainable development generates more specific results concentrated on relating the energy topic with the ones regarding investments, emissions and other environmental factors.

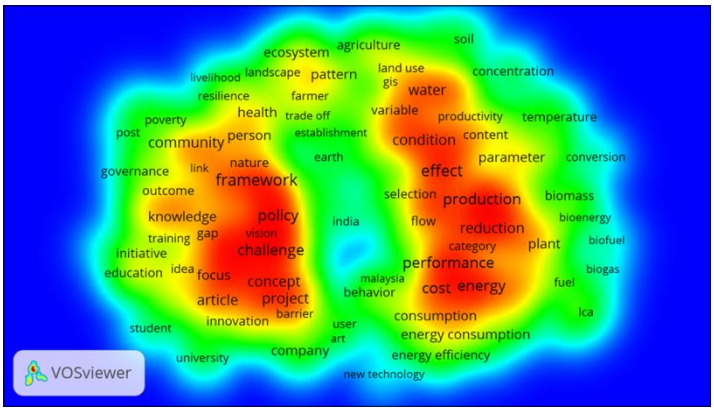

Figure 2.Key sub-themes of sustainable development of the most 2000 recent papers on Scopus, 1989-2016

Moreover, when analyzing the most recent papers – the last 2000 papers published in 2015 – one should conclude that indeed the old worldwide challenges on which sustainable development is focused are also the new ones, as Chappin and Ligtvoet(2014) have stated. Finally, the most frequent topics related to energy in the context of sustainable development are: renewable energy, green technology, bioenergy, energy consumption and energy efficiency.

In the case of green economy, all 898 documents available on Scopus were analyzed, of which 279 publications in the area of economic sciences. Figure 3 illustrates the main topics of the green economy scientific production between 1989 and 2015, based on the analysis of 126 terms out of 16387 initially considered terms. As suspected, the green economy model has the energy field as one of the most important sub-themes, being represented by the keywords such as energy, renewable energy, energy efficiency and fossil fuel. The energy topic is related with emissions, environmental impact and health in the context of climate change and the need of green growth. Several studies emphasize the key roles of China, India, Brazil and Europe in combating climate change and greening the

economy by addressing the national challenges from the energy sector, as well as by promoting and investing in new green policies and technologies. In the area of economic sciences, the energy field in the context of green economy focuses on developing greener policies and adopting greener measures in the energy sector by presenting the opportunity of transition to green economy.

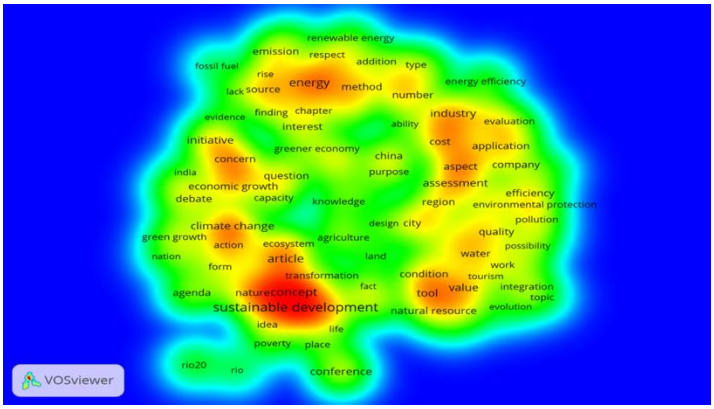

Figure 3.Key sub-themes of the green economy papers, 1989-2016

As it was demonstrated, the energy sector plays a vital role in greening the society and in achieving sustainable development. The energy topics in the green economy framework suggest a strong promotion of using renewable energies and increasing the efficiency of the energy technologies. Different case studies are discussed to sustain these ideas, which are more policy-oriented. In this context, the sustainable development and the green economy models that have captured the interest of the worldwide policymakers and experts in the last 28 years highlight the necessity of transition from fossil fuel-based economy to renewable energy-based one for the sustainable development of society. These findings are somehow similar to a result presented by Chappin and Ligtvoet(2014), who observed the policy focus on the transition of energy towards sustainability, as well as to those presented in the main reviews of scientific literature on energy.

4.2. The analysis of the energy scientific production during 1989-2015

The energy scientific production has risen by 4.5 times since 1989, the US and Chinese studies prevailing over the energy literature from Scopus database. The main types of the energy publications are articles and conference papers, with 71.13% and 21.81% of the total of 2752268 analyzed studies, while the main disciplinary areas of publication are physics and astronomy, engineering, material sciences and chemistry.

In the case of economic sciences, the energy literature has increased 16 times since 1989.The main types of publications in this area are articles and conference papers, with64.92% and 14.57% of the total of 40186 analyzed studies. The US and Chinese studies are predominant. This finding backs up the main results concerning the geographical provenience of the energy studies provided by several research insights (Du et al., 2013; Mao et al., 2015).

Figures 4 and 5 illustrate the main keywords of the most 2000 cited papers, respectively the most 2000 recent ones on energy, between 1989 and 2015, based on the analysis of 256 terms out of 42725 initially considered terms, respectively of 196 words out of 46176 initially considered words.

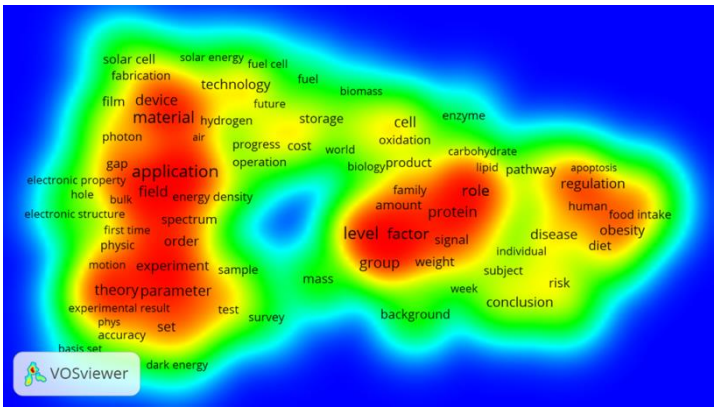

Figure 4.Key sub-themes of the energy research of the most 2000 cited papers on Scopus, 1989-2016

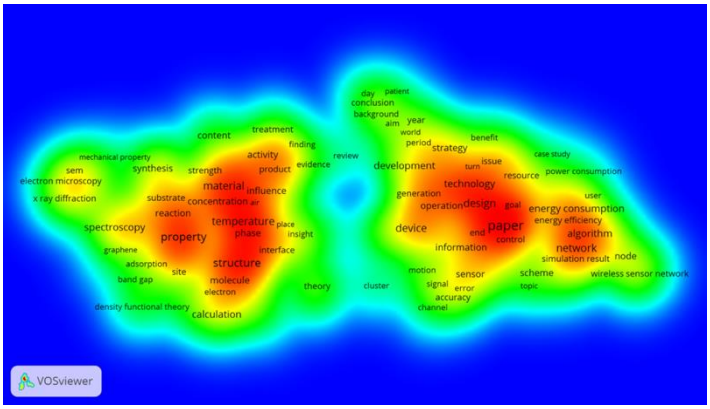

Figure 5.Key sub-themes of the energy research of the most 2000 cited papers on Scopus, 1989-2016

On the one hand, when analyzing the main sub-themes of the overall energy field in the most 2000 cited papers on Scopus, it can be noted that efficiency, protein, cell, performance, experiment, production, atom and technology are among the most frequent keywords found in the titles and abstracts of analyzed studies. Hence, the prevalence is, as previously stated, on the technological progress of the energy field(Du et al., 2013). However, when considering only the most cited energy studies in the economic sciences area, the main topics are focusing on the following keywords: price, production, relationship, market, energy consumption, emission, management, energy use and growth.

On the other hand, when analyzing the main sub-themes of the energy field in the most recent 2000 papers on Scopus, it can be observed that the terms: temperature, surface, density, interaction, network, power, technology, algorithm, cost, development and behavior are among the most frequent keywords found in the titles and abstracts of analyzed studies. Hence, the most recent studies on energy confirm again the physics and engineering perspectives (Du et al., 2013), although social sciences are gaining momentum in this area. The energy studies in the economic sciences focus on the following most discussed sub-themes: energy consumption, market, policy, price, power, economy, performance, emission, challenge, China and electricity. This result indicates a small change in the energy topics debated intensively worldwide, as well as more applicable policy orientation studies at national level. The high occurrences of the term “China” in the analyzed studies lead to two conclusions: first, as already mentioned, the Chinese literature on energy is predominant and, secondly, China is one of the most debated country in the energy scientific production due to its highly negative impact on worldwide environmental, social and economic dimensions of sustainable development, as China has an intensive economy in terms of energy consumption and pollution, while facing many challenges in terms of the big number of population.

4.3. The analysis of the association between energy and sustainable, green and renewable keywords in the scientific production during 1989-2015

The scientific production on the association between energy and sustainable, green and renewable keywords from Scopus has considerably increased overtime since 1989. The launch of the great interest in the green energy research field was registered in the economic crises period of 2008-2010, as one can observe in Figure 6. This interest emerged in order to find new solutions for economic growth, social justice and environmental protection.

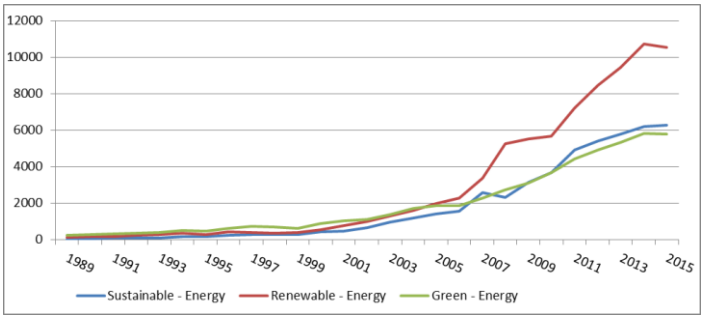

Figure 6.Key sub-themes of the sustainable-related energy research of the most 2000 cited papers on Scopus, 1989-2016

The increase of green energy publications is also observed in the previously conducted studies (Manzano-Agugliaro et al., 2013; Mao et al., 2015).The main form of publication on Scopus is the documentation article, while the main countries developing research in the green energy field are, as expected, the US, China and the Great Britain. The most frequent energy-related journal in which economic studies authors are publishing their works on the association between the terms sustainable/green/renewable and energy is the Journal of Cleaner Production, which is followed, not in this order, by the journals: Energy Economics, Ecological Economics and Petroleum Economist.

The present paper advances with a more qualitative analysis of the scientific production on green energy field by using the VOSviewer software to identify the main areas of research worldwide. Figures7 and 8 illustrate the main keywords of the most 2000 cited papers, respectively the most 2000 recent ones, on the association of the strictly searched duo“sustainable and energy” on Scopus, published between 1989 and 2015.

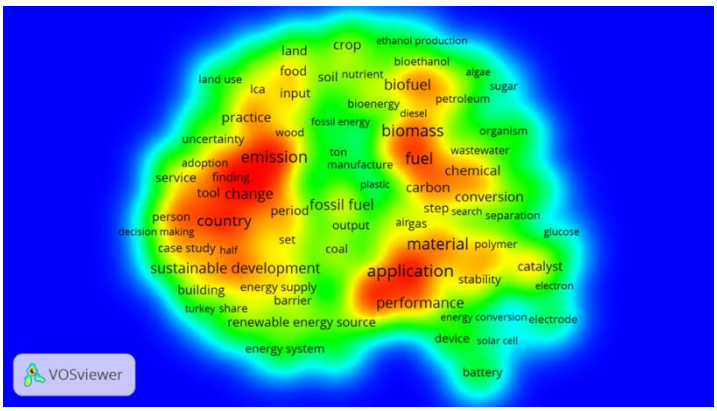

Figure 7.Key sub-themes of the sustainable-related energy research of the most 2000 cited papers on Scopus, 1989-2016

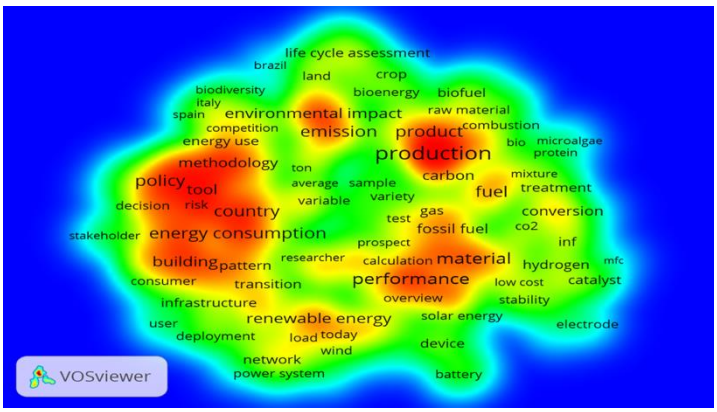

Figure 8.Key sub-themes of the sustainable-related energy research of the most 2000 cited papers on Scopus, 1989-2016

In order to illustrate the findings presented in figures 7 and 8, this paper analyzed the most 2000 cited studies from a total of 48788 works on sustainable-related energy, respectively the most 2000 recent studies, by extracting 327 terms out of 43268 initially considered terms, respectively of 298 words out of 47108 initially considered words in order to determine the main sub-themes of the sustainable-related energy scientific production.

The most frequent keywords identified in the most 2000 cited papers on sustainable-related energy from Scopus are: biomass, emission, fuels, performance, sustainable development, change, policy, fossil fuel, environmental impact, power, biofuel, electricity, conversion and hydrogen, while the most frequent sub-topics in the most recent papers are: production, performance, energy consumption, product, policy, emission, building, power, fuel, biomass, renewable energy, environmental impact, electricity and waste. In the field of economic sciences, the results are similar for both cited and recent papers. Yet, high attention is given to the market, governance, innovation, construction, transportation, as well as on the assessment of the relationship between economic growth, emissions and energy consumption in the most cited papers and important consideration is granted to energy saving, energy security, index, manufacturing and household.

Further, figures9 and 10 illustrate the main keywords of the most 2000 cited papers, respectively the most 2000 recent ones, on the association of the strictly searched duo “green and energy” on Scopus, between 1989 and 2015.

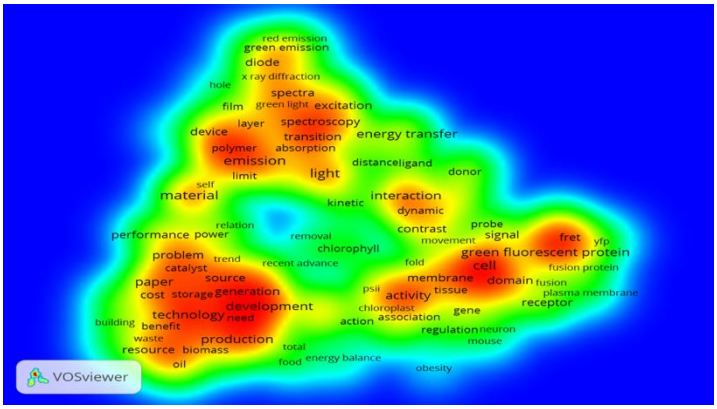

Figure 9. Key sub-themes of the green-related energy research of the most 2000 cited papers on Scopus, 1989-2016

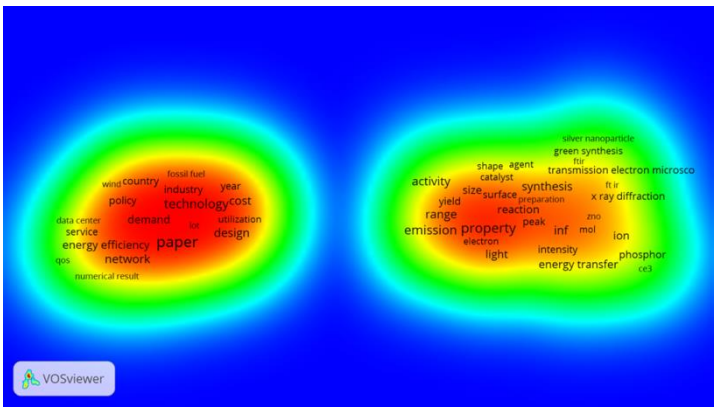

Figure 10. Key sub-themes of the green-related energy research of the most 2000 cited papers on Scopus, 1989-2016

In order to illustrate the data presented in figures9 and 10, this paper analyzed the most 2000 cited studies from a total of 53259 works on sustainable-related energy, respectively the most 2000 recent studies, by extracting 255 terms out of 46919 initially considered terms, respectively of 235 words out of 47487 initially considered words in order to determine the main sub-themes of the green-related energy scientific production.

The most frequent keywords identified in the most 2000 cited papers on green-related energy area from Scopus are: cell, protein, emission, green, interaction, development, production, energy transfer, technology, green fluorescent protein, product, fluorescence resonance energy transfer, transition, spectroscopy and green emission, while the most frequent keywords in the most recent papers are: emission, technology, cost, energy consumption, network,

concentration, power, spectroscopy, impact, energy transfer, demand, generation. In the field of economic sciences, the results emphasize the keywords: emission, policy, production, sustainability, economy, government, building, performance, power, water, investment, renewable energy, price, generation, climate change and innovation.

Considering these identified keywords linked to the green-energy nexus, the main sub-themes of the scientific production on green-related energy are: electro-physics, information and technology, bioenergy and energy policies.

Furthermore, the paper advances with the figure 11 which illustrates the main keywords of the most 2000 cited papers on the association of the strictly searched duo "renewable and energy" on Scopus, between 1989 and 2015.

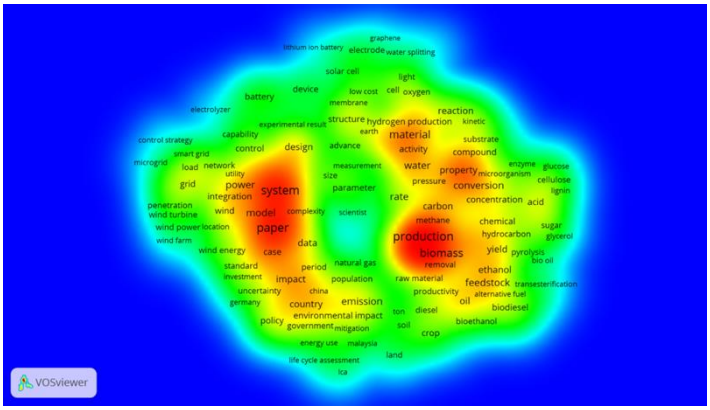

Figure 11. Key sub-themes of the renewable-related energy research of the most 2000 cited papers on Scopus, 1989-2016

In order to illustrate the figure 11, this paper analyzed the most 2000 cited studies from a total of 78981publications on renewable-related energy, by extracting 308 terms out of 40678 initially considered terms. The most frequent keywords identified in these papers on renewable-related energy area from Scopus are: system, production, fuel, biomass, power, product, emission, hydrogen, water, conversion, feedstock, temperature and yield. In the field of economic sciences, the results emphasize the keywords: production, policy, market, power, price, generation, capacity, economy, emission, grid, fossil fuel, product, wind, climate change, plant, growth, investment, fuel and energy consumption.

Considering these identified keywords linked to the renewable-energy nexus, the main sub-themes of the scientific production on renewable energy are: information and innovation, renewable technology, electrical network, bioenergy, pollution, market and energy policy.

Finally, it is concluded that the three words associated with the energy term, i.e. sustainable, green and renewable, generate studies meant for greening the society by focusing on similar sub-themes, as well as different ones in terms of approach. However, it must be remembered that these results are limited as this research aimed to analyze only the titles and abstracts of the most 2000 cited and recent papers on greening the energy field. Future studies on the actual content of these studies might point out more insightful results.

5. Conclusions

In order to explore the importance of the energy sector in the worldwide scientific production, the Scopus studies regarding the sustainable development and the green economy were analyzed by creating words density maps for illustrating the main topics of these two green development models. Further, the study aimed to highlight the main areas of research on the energy field associated with the keywords sustainable, green and renewable in order to explore their evolution, as well as possible differences in the areas of investigation.

The findings suggest that studies on reviewing the energy publications and/or on the green development models have recently emerged with the aim of identifying the state of the art in the field or of envisaging new research areas(Fahimniaet al., 2015). The importance of exploring the terms used generally in the titles and abstracts of publications reveals which topics and challenges are mainly approached in a certain field without accessing the full scientific papers. However, the marketing function of the title and abstract of scientific production should be considered as a limitation of this paper.

The results of this study suggest increasing trends of the publications on sustainable development and green economy, as well as of those on the association between sustainable/green /renewable and energy in the past years, considering the worldwide challenges, such as fossil fuel depletion, increased energy consumption, overpopulation, poverty, environmental degradation and climate change. The importance of the energy field is acknowledged by observing its association in the two green development models analyzed during 1989-2015.

Although the terms sustainable, green and renewable in correlation with the energy field suggest that the focus is mainly on renewable energies, the findings of this study show that the main research speaks about more energy-related fields, such as electro-physics, energy policies, pollution, green technologies and energy assessment framework.

Unlike previous research, this paper illustrates the current energy debated themes in the scientific literature during 1989-2015. In addition, to the best of our knowledge, no other study analyzed so far the association between energy and the keywords green, sustainable and renewable from a bibliometric point of view. However, the paper analyses only the co-occurrences and the strengths association

among the main sub-themes resulted from the 2000 titles and abstracts of the reviewed studies from Scopus.

This study indicates current and future directions in the energy field. Future studies might emerge by investigating the total corpus of severalanalyzed studies in this field in order to better emphasize the main approaches towards green energy.

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