

# **A Bibliometric Analysis of Research on Renewable Energy Crowdfunding: An Assessment and Policy Proposals**

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## **Abstract**

Crowdfunding is a new form of financial intermediation able to meet the financial needs of renewable energy projects. Yet, there is a scarcity of research on the significance and evolution of renewable energy crowdfunding. This paper tries to fill this gap by providing a bibliometric analysis of academic work on renewable energy crowdfunding. We identify three main clusters of publications focused on (1) the renewable energy crowdfunding as an innovative solution to overcome technological and financial barriers in the deployment of renewable energy (2) the financial and institutional options relative to the implementation of renewable energy technologies, (3) the links among private actors in the energy transition. Based on this result, we show that public intervention has been overlooked in the literature on renewable energy crowdfunding and we suggest that the state supports the crowdfunding to promote the development of renewable energy projects. Finally, we discuss its intervention as a regulator and as an investor.

JEL: D14, Q28, Q48

Keywords: Renewable energy, crowdfunding, platforms, bibliometric analysis, funding gap, energy transition, public intervention, regulation.

## 1. Introduction

The expansion of renewable energy (RE) is considered as a way to mitigate the risks associated to climate change because they are virtually inexhaustible in duration and limited in the amount of energy that is available per unit of time (Amponsah et al., 2014; OECD/IEA, 2017). However, to achieve large-scale development, multiple barriers of RE (technical, institutional, sociocultural, etc.) must be overcome. Financial constraints would seem to be the most difficult one since the risk-return characteristics of small RE projects do not fit traditional lending conditions (De Broeck, 2018). Besides, while production of RE requires high initial investment costs, RE involves lower operating gains compared to fossil energies (Painuly, 2001). Moreover, RE projects have been greatly affected by the funding gap revealed by the recent financial crisis which has increased due to waning public support (Engelken et al., 2016; Vasileiadou et al., 2016) and lack of private finance (Yildiz, 2014).

To overcome these financial limitations, new forms of financial intermediation have emerged with the development of a digital and collaborative economy as the crowdfunding platforms. Crowdfunding is generally defined as “an open call, essentially through the Internet, for the provision of financial resources either in form of donation or in exchange for some form of reward and/or voting rights in order to support initiatives for specific purposes” (Lambert and Schwienbacher, 2010, p. 3). It is presented as an alternative to finance companies, non-profit organizations, and projects in the aftermath of the 2008 financial crisis, to compensate for loss of credibility of traditional financial services. Very recent crowdfunding initiatives are related to citizens’ funding of RE (Stigka, 2014) at a time of historically low levels of interest on savings accounts (Bruton, 2015).

Renewable energy crowdfunding (RECF) has experienced significant growth worldwide since mid-2010s<sup>1</sup>. Despite its growing importance and the need to mobilize financial resources to foster the energy transition, little research has been conducted on the economics of RECF. To our knowledge, the few existing academic studies on the subject address very specific issues such as the determinants of the success of lending-based and equity-based projects (Bonzanini et al., 2016), the impact of environmental orientation for green crowdfunding projects (Hörisch, 2015) or even the analysis of the potential of crowdfunding as an efficient alternative to traditional finance for renewable energy sector (Lam and Law, 2016; Vasileiadou et al., 2016). Literature on crowdfunding, in general, is more abundant but provides a fragmented representation focusing on customer profiles and the relationship with digital platforms (Ahlers et al., 2015; Belleflamme et al., 2014); general success factors of fundraising campaigns (Belleflamme et al., 2013; Sannajust et al., 2014) and more specific determinants such as informational cascades among investors (Vismara, 2018); specific financing instruments (donations, loans or investments - bonds, equity, and mini-bonds) and the corresponding motivations of financial contributors (Allison et al., 2015 ; Cholakova and Clarysse, 2015).

The aim of this paper is to provide a more precise representation of the literature on RECF and survey its contributions and limitations related to the issue of the RE funding gap. It proposes to position academic research on RECF and identify topics that remain unexplored in this field of analysis. Thus, we address the following research questions: How is academic work on RECF structured? What are the relevant issues that the existing literature still doesn’t raise?

The paper builds a bibliometric analysis of the academic publications and book chapters referenced in five major databases (Science Direct, Business Source Complete, Springer link, Wiley, and Scopus) up to March 2018, to assess how the literature on RECF emerged and

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<sup>1</sup> Statistics on crowdfunded energy projects are limited. A 2015 estimate put the amount raised at €165m worldwide in relation to 300 clean energy projects; at the time of writing both these figures must be substantially higher.

developed. Synthesizing the selected publications should provide references and knowledge about scope and fields of study related to RECF. We identify three main clusters of relatively homogeneous publications covering the topics and dimensions decisive to understand RECF as an alternative means of obtaining financial resources to tackle the challenges related to the energy transition. They correspond to (1) the RECF as an innovative solution to overcome technological and financial barriers in the deployment of RE (2) the financial and institutional options relative to the implementation of RE technologies, and (3) the links among private actors involved in the energy transition. While these clusters raise the issue of the institutional support for the RECF, we show that public intervention has been overlooked in the existing literature on the RECF. In this perspective, we suggest and discuss that the state should both regulate and invest for the deployment of RE projects. Consequently, public intervention could be viewed as a major promoter of RECF and could help to bridge the RE financing gap.

Section 2 describes the data, methodology and the research protocol, and explains the underlying rationale. Section 3 presents the results based on the three clusters constituting the literature on RECF. Section 4 provides a discussion of the findings and makes policy recommendations to develop RECF in an energy transition context. Section 5 concludes and identifies directions for future research.

## **2. Methodology and data**

We assess the research on RECF to identify how this field of analysis is structured and suggest how it could be extended by highlighting relevant unexplored issues. To this end, we develop a bibliometric analysis using a quantitative technique that consists in applying statistical and mathematical methods to sets of bibliographic references (Gaviria-Marin et al., 2019; van Oorschot et al., 2018). This linguistic analysis method quantifies on a large volume of articles the words, the diverse kinds of links and the prevailing ideas – and by inference the absent ideas or unexplored topics – for a given field of analysis. The bibliometric analysis eases the display of the outcomes by collecting items which are similar or have mutual influences. Therefore, it contributes to disclose methodological, theoretical and/or empirical gaps in the studied literature.

We build a research protocol based on previous works such as David and Han (2004), Newbert (2007) and Macpherson and Holt (2007). We follow a step-wise procedure and select items based on the following criteria: databases, keywords, type of publication, nature of the publication content, editorial choice, relevance – based on reading abstracts, consolidation – based on reading the complete article to check the information collected and eliminate duplicates (see table 1). This allows identification of a coherent and focused sample of publications on RECF. This strict protocol, which ends with a complete and careful reading of all the 84 publications of the sample, identifies 37 relevant articles which exactly match with the chosen field of analysis, i.e. the RECF. This figure can be explained by the very recent emergence of crowdfunding platforms. Indeed, generalist platforms came at the end of the 2000s and the platforms which are specialized in financing RE projects are even younger. That is why the first academic works on RECF date back to 2012. Therefore, the RECF is an emerging field of analysis which is not yet well documented in the literature.

**Table 1**

## Research protocol

Filter Type	Description	Databases					
Step 1 – Data bases	Selection of 5 databases	Science Direct	Business Source Complete	Springer link	Wiley	Scopus	TOTAL
Step 2 – Choice of keywords	"Crowdfunding"	688	2952	1822	554	1001	7017
Step 3 – Additional keywords	"Renewable"	84	11	86	28	11	220
Step 4 – Type of publications	Academic articles and book chapter	73	3	71	26	5	178
Step 5 – Nature of the content of publications	Any keywords indicating empirical data or theoretical analysis in their title or abstract	0	0	0	0	0	0
Step 6 – Editorial choices.	No filter	0	0	0	0	0	0
Step 7 – Verification	Reading abstracts for substantive relevance	73	3	47	2	4	129
Step 8 – Consolidation	Reading full articles for substantive relevance	23	3	13	2	2	43
Step 9 – Coherence	Elimination of duplicate articles	2	2	-	2	-	4
Total		21	1	13	0	2	<b>37</b>
Step 10 – Year of publication	Recording the year of publication for each article selected						

- Step 11- Period            No restriction on date of publications
- Step 12 – Language        To improve homogeneity, restriction of the language to English, the most frequent language for research articles
- Step 13 – Authors’ names    Accounting of all author names since each contributes to the development of science.

To analyze the selected articles, we calculate various bibliometric indicators following specific mathematical statistics laws (see table 2).

**Table 2**

**Bibliometric indicators**

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Indicators of distribution	They rank the studied elements in decreasing order of frequency of occurrence, through a core-and-scatter distribution. The core is represented by the group of elements that occur most frequently among all the studied bibliographical references. The scatter corresponds to other less frequent elements. Thus, the core identifies the subject through repetition, while the scatter accounts for the individualization or for the variety existing around this subject. Several statistical laws are useful to calculate these indicators of distribution. Bradford's law identifies the main scientific journals focusing on the given subject. Zipf's law counts and ranks keywords. These laws reveal co-occurrences between the identified elements and the subject. We analyze the appearance of words by counting the number of occurrences and ranking them in decreasing order of frequency (see table 3). We represent the results of this analysis in a wordcloud (see figure 1).
Univariate indicators	They are purely quantitative measures based on counts of different bibliographic elements including the date of publication.
Relational indicators	They study the possible links between the different bibliographic elements: they analyze associated words (repeated segments) in abstracts, co-publications and co-citations. Lotka's law measures the variation in the percentage of authors according to the number of published articles. The indicator of collaboration we use is the number of co-publications (see table 4). This method consists in identifying the groups of authors that are strongly associated and interconnected. We also adopt a descending hierarchical classification of the text (using Alceste software). The results highlight the classes and their profiles. Several analyses are presented (see figures 3 and 4): the descending hierarchical classification represented by dendrogram classes, and the factorial correspondence analysis.

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At this stage of the research protocol, we construct, based on the indicators of the distribution, the bibliometric results that will follow. We describe the word frequency by counting the number of occurrences (in title, keys words and abstracts) and ranking them in decreasing order of frequency (see table 3). After building a dictionary of the complete corpus forms, the Alceste software is used to produce a list of reduced forms. Each reduced form is characterized by several representative key words (example: Research\* = research, researched researchers). Reduced forms (here with at least 20 occurrences) are ranked according to their number in the corpus. Reduced forms with the most frequent occurrences appear in the wordcloud of the bibliometric analysis (see figure 1).

**Table 3**

**Frequency of representative words**



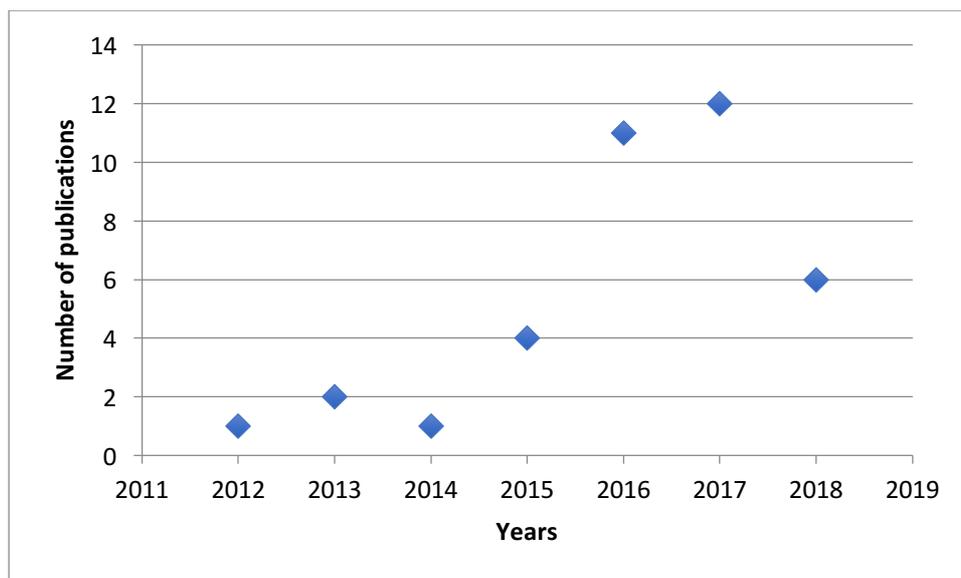
In the wordcloud, the size of the words is proportional to the number of occurrences (the greater occurrence, the larger the size). The color of the words allows to gather the occurrences into coherent sets, as a first step towards bringing publications closer together. Corresponding colors will be found *infra* in the bibliometric outcomes that will provide a classification of publications.

### 3. Results and discussion

#### 3.1. Preliminary bibliometric outcomes

The bibliometric analysis provides quantitative results that shed new light on scientific activity on RECF. The results support the description of the structuration of the literature on the RECF (enumeration of works written by several scholars and published in different journals or books up to March 2018). They also inform about the content of the research on RECF (vocabulary/semantic analysis of manuscripts to understand the key topics and dimensions of this literature).

A time analysis indicates that academic articles and book chapters on RECF have been published between 2012 and 2018, with a steady increase over time (see figure 2). The analysis shows that RECF is a new preoccupation for scholars and corresponds to an emerging field of analysis. It also points out the growing attention that has been paid to the multiple issues addressed by the RECF. Finally, we can expect the number of publications on RECF to increase in the future years based on further research focused on different aspects not yet studied.



**Figure 2.** Number of publications per year

Most work on RECF is published in academic journals including *Energy Policy* (4 articles) and *Journal of Cleaner Production* (3). *Energy Research & Social Science* (2), *Renewable and Sustainable Energy Reviews* (2) and *Renewable Energy Focus* (2) are close to the core of the publications. The journals that publish only one article are at the periphery of this core (see appendix table A).

Collaboration networks, poles of research, and relations among researcher teams can be identified by analyzing co-publications and authors' institutional affiliations (see table 3).

- Co-publications: the publications in our sample were authored by 90 individuals. We identify four groups of authors: single (or solo) authors (24.33% of the sample), pairs

of authors (35.14% of the sample), three co-authors (triads) (24.33% of the sample), and four or more authors (relations circles) (16.20% of the sample).

- Authors’ institutional affiliations: we code author affiliation using two indicators: geographical attachment (country of residence, not author nationality) and institutional roots (public or private: university, research center, business school, etc.). The 90 authors are affiliated to 22 countries and 49 different institutions. The most representative country is China with 10 authors and 3 institutions. Note that 7 of these 10 authors are affiliated to the Academy of Chinese Energy Strategy (ACES) which was established in March, 2012 as an independent research center and postgraduate enrollment unit. As an academy for advanced research on the social, economic, and political aspects of energy issues, this center is affiliated to the China University of Petroleum - Beijing and committed to exchanges of ideas among the government, academia, and enterprises<sup>2</sup>. China is followed closely by Spain with 9 authors and 2 leader institutions on RECF issues. 7 authors are from the Observatorio para una Cultura del Territorio (Madrid) (Observatory for Territorial Culture - OTC) which is a not-for profit organization aimed at improving integration of human societies with their land and its resources. OTC aims principally to promote the co-generation of knowledge and negotiation to achieve consensus between different social domains and communities in the territory such as scientists and policy makers, farmers and consumers, rural and urban dwellers<sup>3</sup>.

Based on this information, we identify several research poles which recently specialized in the field of RECF. These research poles are, in decreasing order: ACES (China) and OTC (Spain) in the same rank, Demos Helsinki and Aalto University (Finland), Utrecht University (Netherlands) Energy Research Institute, Chulalongkorn University (Thailand); School of Management, Politecnico di Milano (Italy); University Magna Graecia of Catanzaro (Italy), Energy Studies Institute, National University of Singapore, University of Erlangen-Nuremberg (Germany), and University of St. Gallen (Switzerland).

The analysis of co-publications and authors’ institutional affiliations highlights the existence of institutional and geographical collaboration networks (see table 3). Scientific collaborations and coauthorships initially develop in individual institutions; they gradually include different institutions in the same geographical area and then partners in different geographical areas.

**Table 4**

Nature of scientific collaborations according to authors’ attachments

	Institutional	Identical	Different
Geographical			
Identical	Intra-institutional collaborations (64.87% of the sample)		Inter-institutional collaborations (21.62% of the sample)
Different	International collaborations (13.51% of the sample)		

<sup>2</sup> <http://www.cup.edu.cn/internationaloffice/en/faculdep/101430.htm>

<sup>3</sup> [http://observatorioculturayterritorio.org/wordpress/?page\\_id=5](http://observatorioculturayterritorio.org/wordpress/?page_id=5)

As intra-institutional collaborations represent most of the research on RECF, knowledge exchange and sharing of experience on the topic are limited. We believe that more inter-institutional and international collaborations would enable more rapid development and dissemination of ideas in the field.

At this stage, we can argue that few authors work on RECF and that when there are collaborations, they very often take place within the same institution. Besides, the main idea they promote in their research is that financing RE through crowdfunding is a lever for the development of sustainable innovations. A cluster analysis is useful to refine the themes addressed by this literature.

3.2. Classification and appraisal of the RECF literature

Following the semantic analysis, Alceste breaks down the text into various components which it ranks. The cluster analysis of keywords is based on a descending hierarchical classification (DHC). It highlights three major groups of relatively homogeneous articles represented here by the most frequent keywords (see figure 3). Alceste software operates successive splits of the text and extracts representative classes by bringing together the segments that contain the same words. In other words, it forms classes from “sentences” that contain the same words. Then, each class can be examined through a “profile”. For each class, Alceste provides access to the list of the most significant words, of the most significant context units, class-specific dimensions and concordances. Chi<sup>2</sup> ( $\chi^2$ ) is used to determine the level of belonging of a word (strong or weak) to a class. Chi<sup>2</sup> highlights the most representative terms of a given class. A factorial analysis completes this cluster analysis (see figure 4).

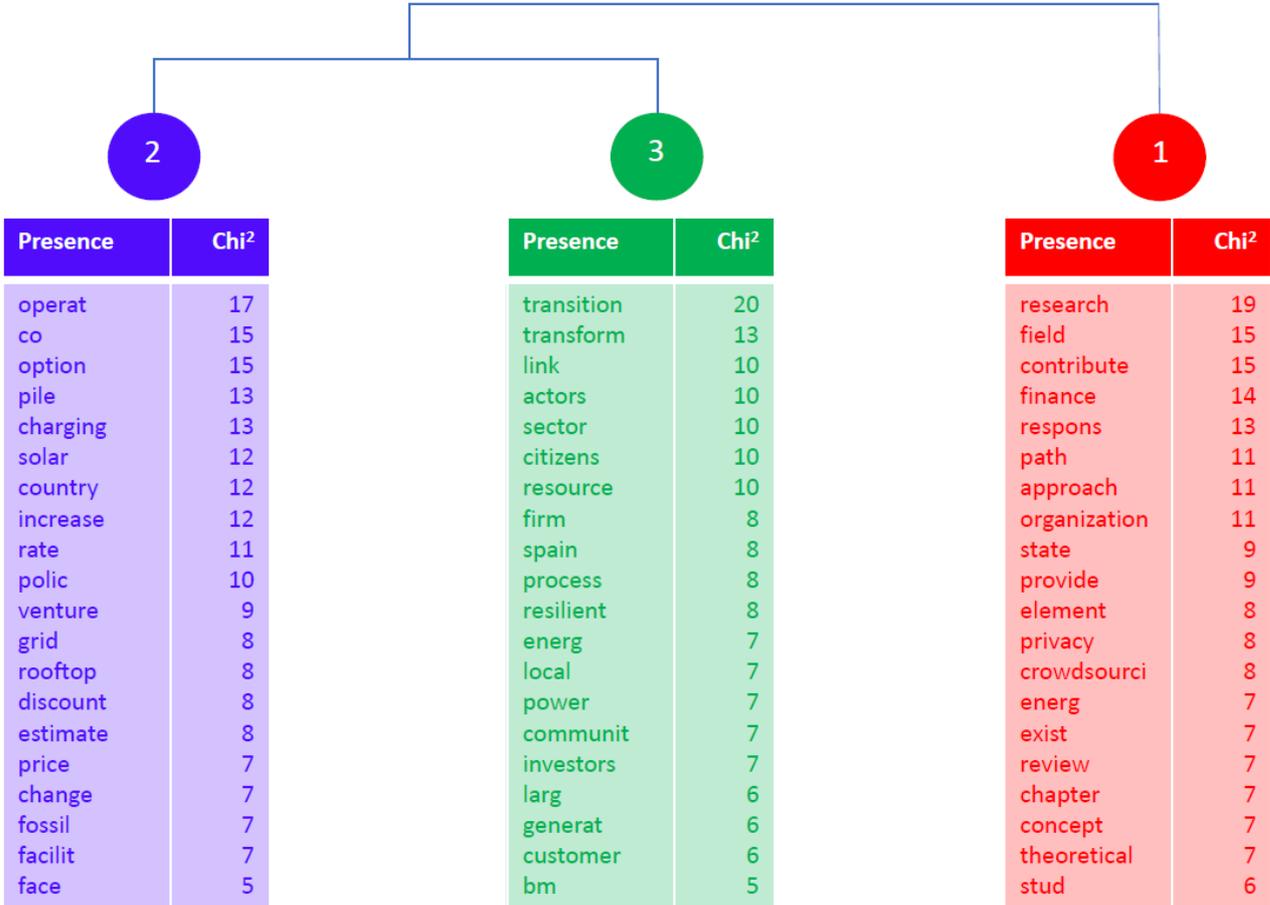
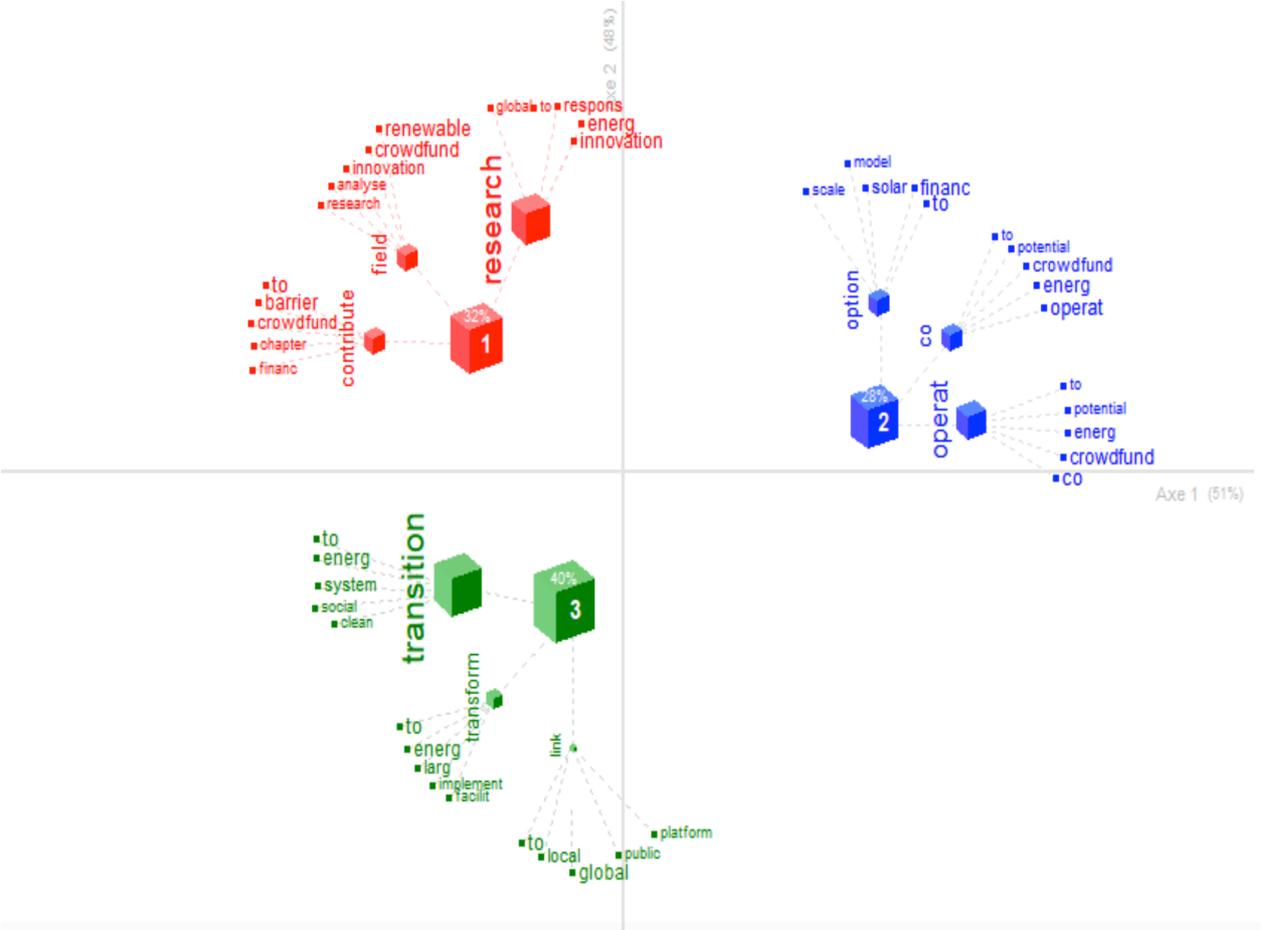


Figure 3. Descending Hierarchical Classification

Cluster 1 (red) counts 63 units and includes 32% of the articles in our sample; cluster 2 (blue) counts 54 units and includes 28% of the articles in our sample; cluster 3 (green) counts 76 units and includes 40% of the articles in our sample. Their respective profile can be described based on a factorial analysis (see figure 4). These three clusters are distributed along two main factorial axes.



**Figure 4.** Factorial Analysis

The horizontal axis (51% of the total variance) can be interpreted as the degree of appliedness of research. It contrasts analytical and generalist works to empirical works dealing with specific technologies, often in country-focused approaches. The vertical axis (48% of the total variance) can be considered to represent the nature of the support for the transition to low-carbon production. It contrasts works on the importance of private actors’ initiatives to works focusing on public actors’ actions. These three clusters cover the dominant topics and dimensions revealed as decisive to understand RECF. Overall, articles in these clusters show consensus about the explanatory factors, and the occurrence and effects of RECF. The headline of cluster 1, cluster 2 and cluster 3 contain many of the keywords highlighted in figure 3 in such a way to synthesize the main idea that emerges from reading the abstracts of the articles in our sample.

**Cluster 1: The RECF: an innovative solution to overcome technological and financial barriers in the deployment of RE**

Cluster 1 (red) includes 32% of the articles in our sample. These articles correspond to state-of-the-art reviews aimed at providing key theoretical and empirical insights into the

origins, manifestations, and consequences of research on RE. These publications contribute to research on the overall challenges to sustainable development. The articles in cluster 1 primarily analyze and discuss the technological and financial problems that need to be solved to promote the spread of RE. They recommend a responsible approach involving the integration of research and innovation policies with energy policies to promote effective technology (Carbajo and Cabeza, 2018). In addition to the technological barriers to RE, funding and the need for a more sustainable financial system are crucial (Carè et al., 2018). In this context, crowdfunding seems to be a potential alternative sustainable mode (Kim and De Moor, 2017) of funding RE projects (Lam and Law, 2016; Krupa and Harvey, 2017; Carus, 2013). Crowdfunding incorporates some of principles and practices related to crowdsourcing (Gleasure and Feller, 2016; Kandappu et al., 2015). As part of a dynamic process of collective action and citizen participation, crowdfunding is vital to support environmental innovations at the regional level and contributes to the development of new directions for industrial development (Gjelsvik and Tripl, 2018). Although RECF platforms are a new phenomenon, they are beginning to advance from niche, grass roots initiatives into larger projects and collaborations with the private sector and institutional finance (Candelise, 2016). In a nutshell, green crowdfunding consists in mobilizing private finance for low-carbon innovative projects (Kunkel, 2015; Polzin, 2017). The creation and development of platforms dedicated to finance RE projects are enhanced by a favorable regulatory framework, as it can be seen in the case of France (Kornprobst and Douady, 2017). Therefore, some platforms have become benchmarks, for example, TRILLION FUND, the British crowdfunding platform which specializes in raising money for RE projects worldwide (Groves, 2015). Finally, the articles in cluster 1 focus on analysis of the technological and financial constraints to sustainable development, and present RECF as a significant innovative solution to promote eco-innovation in RE.

### **Cluster 2: Financial and institutional options for the deployment of RE technologies**

Cluster 2 (blue) includes 28% of the articles in our sample. These articles focus on the various financial and non-financial options that help the development of RE, promote low carbon technologies, or discuss the reduction of obstacles to the energy transition. Financing issues are important because off-grid RE which plays a critical role in supporting rural electrification, faces significant challenges due to limited access to finance, low affordability among consumers, and high transaction costs (Shi et al., 2016). Among the financial options considered in the articles in cluster 2 there is a social discount rate adapted to low-carbon investments (Wang and Deng, 2017); there is also the development of social venture capital (Cumming et al., 2017) despite the high technological risks. Other authors highlight the relevance of energy co-operatives for civic participation in the energy transition and argue that equity-based crowdfunding would be suited to energy sector cooperatives (Dilger et al., 2017). Non-financial options, which are institutional options such as public policies, could play a leading role in the development of RE (Cruciani, 2017). For example, market penetration of electric vehicles is limited by charging facility capacity (Suzuki et al., 2016). These two types of options are complementary: for instance, Tongsopit et al. (2016) analyzes business models and financing options for the rapid scale-up of rooftop solar power systems in Thailand and suggests that the emergence of rooftop solar power systems will depend on the policies, regulations, incentives, and market conditions in each country. Finally, we show that the articles in cluster 2 focus on the different financial and institutional options for the deployment of RE technologies.

### **Cluster 3: The links among private actors in the energy transition**

Cluster 3 (green) includes 40% of the articles in our sample. Most of these articles focus on the energy transition issue and use case-study and country-study methods. The energy

transition involves diverse transformations: changes in the way energy is generated, marketed, and distributed (Hewitt et al., 2017); socio-technical (Wainstein and Bumpus, 2016), and financing system transformations (Merritt and Stubbs, 2012). These mutations should be understood as a dynamic social process involving various upstream and downstream actors: citizens, firms, communities, investors, customers. Concerning investors, the energy transition requires greater diversity of financing sources to fit the communities' RE needs. Citizens should play a more active role as local drivers of the national energy transition. They are retail investors who can be added to traditional professional investors (Salm et al. 2016). As far as firms are concerned, the implementation of the energy transition implies changes to their business models or status (Jalas and Mäkinen, 2018). On the one hand, the business model dynamics is a key driver of the transition to low-carbon systems based on active customer participation and social value creation (Wainstein and Bumpus, 2016). On the other hand, an innovative legal status might encourage an energy transition via the emergence of customer-owned firms with specific shareholders (mostly private citizens but also other firms, associations, and municipalities). The goal is to raise awareness about the possibilities and potential of wind power and to extend its use. These firms are specific because they actively support local community projects and citizens in economically sustainable ways. Improving the financing system would require financial innovations and new methods such as time banking, community currencies, community share schemes, and peer-to-peer lending (Merritt and Stubbs, 2012). Crowdfunding for renewable electricity projects can be considered as an innovative and alternative source of financing the energy transition (Vasileiadou et al., 2016) when traditional financial intermediaries have effectively failed to link global financial interests to community needs (Merritt and Stubbs, 2012). Finally, works in cluster 3 focus on the links among private actors in the energy transition, in particular in the case of RECF.

In summary, we identify that the articles of our sample focus on different financial options offered by private investors in response to the constraints of deployment of RE. Among them, the RECF is presented as an innovative solution to promote RE projects. While the issue of institutional support for the RECF is raised, it does not constitute a dominant research issue. However, it is commonly accepted that the development of RE is mainly based on the implementation of public policies<sup>4</sup>: Kreiss et al. (2017) and González and Lacal-Arantequi (2016) focus on the effect of policies based on more recently used market instruments such as respectively auction GHG systems and feed-in premiums while Mazzucato and Semieniuk, 2018 analyze the investment behaviour in innovation of public financial and non-financial actors.

Theoretically, market failures (externalities, provision of public goods, natural monopolies, incomplete information, imperfect competition, etc.) explain the regulatory role of the state to achieve economic efficiency (Mazzucato, 2015). Indeed, there are specific conditions related to the rationality of agents and the organization of information when the allocation of resources becomes optimal. In the RECF framework, the state intervention may be justified by the presence of information asymmetries among the actors participating in the crowdfunding campaign (De Broeck, 2018; Nigam et al., 2018). For the platform, information asymmetries concerned the project quality. Before fundraising, the platform has less

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<sup>4</sup> According to De Serres et al. (2010), we can distinguished these public policies into market instruments and non-market instruments. The purpose of market instruments is to give an explicit price to environmental externalities. These are instruments that directly affect these prices, such as taxes (e.g. on GHG emissions) and subsidies (tax credits, net metering, feed-in tariffs on renewable energy production), or instruments that influence quantities, such as tradable allowance systems (e.g. carbon certificates, clean development mechanisms or renewable energy certificates) and tenders. Non-market instruments are command-and-control regulations, which impose decisions on actors through technological or performance standards (e.g. renewable portfolio standards), active technology support policies (e.g. public R&D subsidies, public investment in infrastructure) and voluntary approaches (label).

information on the project than the project holder. After fundraising, the investor has less information on the project than the platform. Thus, in a crowdfunding campaign, these three parties experienced different risks. While the platform has regulatory, image and fundraising failure risks, investor has image risks and liquidity and non-repayment risks; and for the project holder, the risks are multiple: image, non-selection of the project, fundraising failure, default. In this perspective, the state could play a role as a regulator (i.e. repairing market failures) *via* the adoption of policies to generate financing flows in RE. We think, according to Cruciani (2017); Carbajo and Cabeza (2018) and Tongsopit et al., (2016) that a primary pillar of such public policies would consist in promoting the crowdfunding as a vector for the development of RE. In other words, we believe that the state intervention which aims at reducing these information asymmetry risks would favor the financing of RE by crowdfunding. Consequently, public intervention could be viewed as a major promoter of RECF and could help to bridge the RE financing gap. Our proposal can be considered original insofar as it prescribes a top-down solution, whereas crowdfunding is part of a bottom-up approach, in which the project owners contact investors (often citizens) directly, without a publicly regulated intermediary. In the last section, we suggest some possible orientations about the forms of this intervention to help governments to implement the energy transition based on RECF which thus will provide a largely benefit for current and future generations (Karlsson-Vinkhuyzen et al., 2012).

#### **4. Discussion and policy implications**

A first political solution to the rise of RECF consists in further regulating platforms to protect retail investors from bankruptcies. To achieve this objective, platforms could be subject to stronger transparency requirements (mandatory information disclosure on the status, environmental quality and risks of projects, etc.) for investors and for project holders. Compliance with this standard would allow investors to compare projects based on similar criteria. In addition, the state could require the platform to hold sufficient regulatory capital to cope with substantial losses in the event of bankruptcy. This would improve the platform reputation and image. We believe these recommendations are relevant in the context of the current flexible regulatory framework which leaves considerable room for maneuver, and leaves investors and project owners bearing a large part of the risk.

A second political solution would be to develop market (system of electricity buy-back bonuses) and non-market (environmental quality labels or certifications) supportive public policies. Environmental quality labels would indicate compliance with voluntary requirements. They would allow project leaders to signal to stakeholders (platform and investors) their environmental commitment, their distinctiveness compared to competitors, and their good image and reputation. A labeling system would reduce the information asymmetries between the platform and investors or citizens since the platform communicates about RE projects labels. It would also reduce information asymmetries between the project owner and the platform by guaranteeing compliance with the regulation. Nevertheless, a labelling mechanism would have some drawbacks. Unlike in the case of certification, there would be no accreditation by a public authority; labeling is relatively unsupervised compared to certification. Similarly, the cost of labeling might outweigh the expected benefits. Finally, the existence of too many labels can make it difficult for consumers to make decisions. These public policies could also be based on market instruments such as such as calls for tender which include a bonus for participatory financing dedicated to different types of RE. Calls for tender would select RE projects on the basis of price, technology, and environmental quality criteria. The state could introduce a participative bonus system for project leaders who would finance their RE installations by participative financing in the territory of the installation. Again, the idea is to encourage the financing of RE projects by citizens and local authorities via platforms that invest in candidate companies. This tool would have the advantage to guarantee acceptance of projects by local

actors (inhabitants and communities) and offering the territories concerned a fair share of the fruits of their resources. These ex-post rewards would act to reduce information asymmetries and risks among RECF stakeholders throughout the fundraising process. Responding to a call for tender would allow the project holder to signal to the platform the viability of the project. This has positive effects for investors and their returns. It inspires confidence in those investors that traditionally are reluctant to participate in projects and reduces the need to involve local authorities or residents. In our view, this type of incentive mechanism makes it possible to increase the investor base of RE project platforms while removing obstacles linked to territorial appropriation. The state also could recommend that some of the property rights on RE projects under construction be allocated to citizens participating in RECF campaigns. This would allow citizen investors in RE to reap direct returns (Steffen, 2018; Yildiz et al., 2019).

However, political support will need to increase to change the scale of citizen financing of RE projects, including production, storage, etc. associated to the development of RE facilities. In this context, a third complementary political solution to promote RECF would be to create a public crowdfunding platform. Such a public policy would place the state in the role of investor, while the first two solutions are related to the state as a regulator (repairing market failures). The state, as a centralized player, is the only actor with the power to resolve market failures and bear the cost of effectively linking financing requirements to needs in utilities projects. In acting as the financial intermediary, the state, driven by collective interest and the search for a social return might achieve mutually an advantageous organization of remittances and the guarantee of high levels of investment and savings to promote positive social welfare. This direct action to bridge the RE financing gap would require public platforms rather than private RECF platforms which would offer the widest possible range of financing instruments. In other words, we would argue that alongside investment (crowdinvesting via shares, bonds, mini-bonds and partners' current accounts) which is the only facility currently offered by private platforms, a public platform could use crowdlending, and possibly donation-based crowdfunding. These joint solutions have two advantages: on the one hand, they should raise significant amounts for large-scale projects and, on the other hand, they should promote loans and grants as a better mode of financing small RE installations (like solar panel installations for schools, etc.). This would broaden the scope of fundraising campaigns and reduce the risk of lack of finance and project failure. These financing solutions would make it possible to expand the resource base via the mobilization of different types of crowdfunders according to the nature and scale of the RE projects. In this perspective, targeting more savers wanting to become major players in the fight against climate change could allow a public platform to encourage the commitment of communities of investors federated around common values linked to the production and consumption of "clean" energy (protection of the environment and future generations, territorial development, etc.). The community nature of contributor bases is recognized as a key to successful entrepreneurial projects fundraising (Belleflamme et al., 2014; Josefy et al., 2017), including for energy efficiency projects. Therefore, extending RECF campaigns would rely on the participation of various groups (local, activists, etc.) that identify the energy transition as a goal.

## **5. Conclusion and future research**

This paper considered the crowdfunding as a new form of financial intermediation able to meet the financial needs of RE projects. While RECF has experienced significant growth worldwide since mid-2010s, little attention has been paid to its significance and evolution. We conducted a bibliometric analysis of the academic literature on RECF. Based on the five widely used databases, we identified three main homogeneous clusters of publications focused on (1) the RECF as an innovative solution to overcome technological and financial barriers in the deployment of RE, (2) the financial and institutional options relative to the implementation of

RE technologies, (3) the links among the private actors in the energy transition. While these clusters of articles raise the issue of institutional support for the RECF, we showed that it does not constitute a dominant research question. However, it is commonly accepted that the development of RE is mainly based on the implementation of public policies. In this perspective, we advance that the state could play a role as a regulator (disclosure requirements, financial incentives) and as an investor (the creation of a public RECF platform). Consequently, public intervention could be viewed as a major promoter of RECF and could help to bridge the RE financing gap. Public support to the RECF could be adjusted according to the institutional setting of countries as it affects the diffusion of green crowdfunding campaigns (Butticè et al., 2018).

However, the potential amounts raised through crowdfunding are likely to be insufficient in the short term to finance massive RE infrastructure projects which will need to be numerous and large to achieve decarbonization worldwide. A future avenue of research will consist in studying modes of financing able to meet this challenge, such as the analysis of public development banks (Campiglio, 2016; Geddes et al., 2018).

**Compliance with Ethical Standards:** The authors declare that they have no conflict of interest.

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## Appendix

**Table A.**

List of references

<b>References (academics journals and book chapter)</b>	<b>Number</b>	<b>Years</b>
Applied Energy	1	2018
Clean Technologies and Environmental Policy	1	2017
Crowdfunding for Sustainable Entrepreneurship and Innovation	1	2016
Current Opinion in Environmental Sustainability	1	2017
Energy	1	2017
Energy Economics	1	2017
Energy Policy	3	2016
Energy Policy	1	2017
Energy Procedia	1	2016
Energy Research & Social Science	2	2017
Information and Organization	1	2016
Journal of Cleaner Production	3	2016
Journal of Environmental Management	1	2017
Public Administration and Development	1	2012
Renewable and Sustainable Energy Reviews	1	2016
Renewable and Sustainable Energy Reviews	1	2017
Renewable Energy	1	2016
Renewable Energy Focus	1	2013
Renewable Energy Focus	1	2015
Research Technology Management	1	2013
Strategic Change	1	2017
Handbook of Environmental and Sustainable Finance	1	2015
Designing a Sustainable Financial System: Development	2	2018
Goals and Socio-Ecological Responsibility		
Marketing Renewable Energy: Concepts, Business Models and Cases	1	2017
Progressive Business Models: Creating Sustainable and Pro-Social Enterprise:	1	2018
Privacy in a Digital, Networked World: Technologies, Implications and Solutions	1	2015
Factor X: Challenges, Implementation Strategies and Examples for a Sustainable Use of Natural Resources	1	2018
Financial Regulation in the EU: From Resilience to Growth	1	2017
Green Crowdfunding: A Future-Proof Tool to Reach Scale and Deep Renovation?	1	2015
Understanding Alternative Investments: Creating Diversified Portfolios that Ride the Wave of Investment Success:	1	2014
New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons	1	2108

### **Notation list**

ACES: Academy of Chinese Energy Strategy

GHG: Greenhouse gas

OTC: Observatory for Territorial Culture

RE: Renewable energy

RECF: Renewable energy crowdfunding