UNIVERSITÉ SORBONNE PARIS NORD

Centre d'Économie de l'Université Paris Nord (CEPN, UMR 7234)

École Doctorale Érasme – ED 493

Déploiement des énergies renouvelables : déterminants globaux et financement participatif en France

Thèse soumise pour obtenir le grade de

Docteur en Économie

présentée et soutenue publiquement le 27 novembre 2020 par

Clémence Bourcet

Directrice de thèse : Sandra Rigot, Maître de conférences HDR, Université Sorbonne Paris Nord

Jury

Rapporteur	Catherine Karyotis, Professeure, NEOMA Business School
Rapporteur	Jean-Pierre Ponssard, Professeur émérite, École Polytechnique
Président	Nathalie Lazaric, Directrice de recherche, GREDEG CNRS
Examinateur	Isabelle Girerd-Potin, Professeure, Grenoble IAE
Examinateur	Julien Vauday, Maître de conférences, Université Sorbonne Paris Nord

UNIVERSITÉ SORBONNE PARIS NORD

Centre d'Économie de l'Université Paris Nord (CEPN, UMR 7234)

École Doctorale Érasme – ED 493

Renewable energy deployment: global determinants and crowdfunding in France

Dissertation submitted in order to obtain the degree of

Doctor of Philosophy in Economics

presented and publicly supported on November 27, 2020 by

Clémence Bourcet

PhD advisor: Sandra Rigot, Associate Professor HDR, Université Sorbonne Paris Nord

Jury

Reviewer	Catherine Karyotis, Professor, NEOMA Business School
Reviewer	Jean-Pierre Ponssard, Professor emeritus, École Polytechnique
President	Nathalie Lazaric, Research Director, GREDEG CNRS
Examiner	Isabelle Girerd-Potin, Professor, Grenoble IAE
Examiner	Julien Vauday, Associate Professor, Université Sorbonne Paris Nord

Résumé

Dans le cadre des actions d'atténuation pour réduire les émissions de gaz à effet de serre en lien avec la consommation d'énergie, les sources d'énergies renouvelables (EnR) apparaissent comme une solution pertinente. Elles peuvent être utilisées pour la production d'électricité, de chaleur et de froid et dans le secteur des transports. Pourtant, ces sources d'énergie ont connu un développement lent et des différences importantes existent entre les pays.

Dans cette thèse, j'étudie en premier lieu les déterminants empiriques du déploiement des EnR. Pour ce faire, je réalise une revue systématique de la littérature quantitative existante qui s'intéresse à ce sujet au niveau des pays. Je constate que cette littérature est assez fragmentée et analyse les résultats des auteurs en me basant sur les spécifications considérées pour étudier l'existence d'un consensus sur les déterminants possibles du développement des EnR au niveau national.

Pour compléter cette analyse multi-pays, je m'intéresse à deux barrières qui sont considérées comme des freins importants à une généralisation de l'utilisation des EnR : le financement et l'acceptabilité. Plus particulièrement, je me concentre sur le secteur du financement participatif d'EnR. En effet, le financement participatif, ou *crowdfunding* en anglais, est une moyen de financement innovant qui permet notamment une participation des citoyens au financement de projets d'EnR et donc les implique dans le processus de transition énergétique vers des sources bas-carbone. Plus spécifiquement, j'ai choisi d'étudier le financement participatif d'EnR dans le cas de la France car le secteur a connu une forte croissance dans un contexte réglementaire favorable. Je réalise une étude de cas d'une plateforme de financement participatif spécialisée dans les projets d'EnR afin de présenter son modèle économique et les risques qui y sont associés. Ensuite, afin de mieux cerner les caractéristiques de ce secteur, je donne un panorama des différents acteurs impliqués dans le secteur du financement participatif d'EnR en France : les plateformes, les porteurs de projet et les contributeurs. Finalement, je mène une analyse empirique de données de sondage concernant le processus de décision des citoyens qui ont investi en France dans des projets de financement participatif d'EnR.

Mots clés : Energies renouvelables ; Déploiement ; Politique énergétique ; Finance verte ; Financement participatif ; France.

Summary

In the context of mitigation actions in the energy sector to reduce greenhouse gas emissions, renewable energy (RE) sources appear as relevant solutions. They can be used for electricity production, in the heating and cooling, and the transport sectors. However, these low-carbon sources have only developed slowly and significant differences exist between countries.

In this thesis, I first explore the empirical determinants of RE sources deployment by systematically reviewing the existing quantitative country-level literature on this topic. I find that this strand of literature is quite fragmented and analyze the authors' results based on the framework considered to investigate the existence of a consensus on possible determinants of RE development at a country level.

To complement this multi-country approach, I focus on two significant barriers that have been found to hinder a wide spread use of RE sources: financing and acceptance. More specifically, I look at the RE crowdfunding sector. Indeed, crowdfunding is an innovative financing tool that enables the participation of citizens in the funding of RE projects, thus involving them in the energy transition process towards low-carbon sources. In particular, I focus on the French RE crowdfunding sector because it has experienced a strong growth in the context of a favorable regulatory environment. I conduct a case study of a French crowdfunding platform specialized in RE projects to better understand its business model and the risks associated with it. Then, to shed some light on the characteristics of the sector, I give an overview of the different actors that are involved in the French RE crowdfunding sector: platforms, project promoters, and contributors. Finally, I carry out an empirical analysis of survey data regarding the decision-making process of French citizens that have invested in RE crowdfunding projects.

Keywords: Renewable energy; Deployment; Energy policy; Green finance; Crowdfunding; France.

Remerciements - Acknowledgments

En premier lieu, j'aimerais remercier ma directrice, Sandra Rigot, pour m'avoir permis de réaliser cette aventure doctorale. Tu as toujours été présente et disponible pour me guider et me conseiller dans le cadre de mes travaux de thèse.

Je remercie également très sincèrement les membres de mon jury qui ont accepté de lire et d'évaluer mon travail : Isabelle Girerd-Potin, Catherine Karyotis, Nathalie Lazaric, Jean-Pierre Ponssard et Julien Vauday. Je tiens à remercier tout particulièrement Catherine Karyotis et Jean-Pierre Ponssard d'avoir accepté d'être rapporteurs et Nathalie Lazaric pour avoir présidé ma soutenance.

Je tiens à remercier chaleureusement mes coauteurs : Cécile Cézanne, Sandra Rigot, Laurence Saglietto et Emmanuel Bovari. J'ai beaucoup appris en travaillant à vos côtés et en m'appropriant de nouvelles méthodologies et méthodes de travail. En plus de mes partenaires de recherche, je souhaite remercier toutes les personnes qui ont pu me faire des retours sur mes travaux de recherche et m'ont ainsi encouragée et aidée à les améliorer. Je pense notamment à : Julien Vauday, Florian Fizaine, Antoine Mandel, Nicolas Mottis, Victor Court... Plus largement, je remercie tous les participants aux séminaires et conférences auxquels j'ai présenté mes travaux et qui m'ont fait des retours constructifs.

L'accès aux données est clé pour la recherche et une partie de cette thèse n'aurait pas pu être réalisée sans le soutien des acteurs du financement participatif d'énergies renouvelables en France. C'est pourquoi je souhaite remercier les co-fondateurs de la plateforme Enerfip d'avoir accepté de partager leur expérience lors d'entretiens. Je remercie également chaleureusement Florence de Financement Participatif France (FPF) pour son soutien au projet de recherche dans lequel s'incrivent plusieurs travaux de ma thèse, et notamment pour avoir rendu possible l'utilisation des données collectées par YouGov pour FPF et le MTES. Je remercie aussi Ana de YouGov. Enfin, je remercie les plateformes ayant accepté de remplir le questionnaire pour permettre une analyse du secteur du financement participatif d'énergies renouvelables en France.

J'aimerais remercier les membres, dont les doctorants, et personnels du CEPN et de l'Ecole Doctorale Erasme pour leur accueil et leur soutien tout au long de

cette thèse. Merci notamment à Philippe, Corinne, Viviane, Ariane et Jean-Pierre pour leur disponibilité et leur réactivité. Merci également à Riccardo et Isabelle dont j'ai assuré les TD plusieurs années et qui m'ont permis de mener en parallèle une activité d'enseignement et mes travaux de recherche.

Je tiens également à remercier les chercheurs de la Chaire Energie et Prospérité ainsi que Marion pour le soutien qui m'a été apporté.

Je souhaite remercier les doctorants qui ont participé à l'aventure du séminaire CEMES qui m'a permis de faire des rencontres. Merci tout particulièrement à Vincent B.

Je remercie l'Association des Femmes Diplômées des Universités et du Supérieur ainsi que l'Ecole Doctorale Erasme et le CEPN pour leur soutien financier lors de mon séjour de recherche à l'Université de Brown à l'automne 2019.

At Brown University and in particular at the Institute at Brown for Environment and Society and the Economics Departments, I would like to thank the faculty and PhD students. During my stay, I had the opportunity to take part in very interesting seminars, present my work, and received valuable feedback. In particular, I thank Andrew Foster for his warm welcome. Thank you very much Rui and thanks Xueke for helping me discover Rhode Island.

Je remercie du fond du coeur ma famille qui m'a soutenue tout au long de mes études et encore au cours de cette thèse. J'adresse mes remerciements à mes parents sans qui je ne serais pas là où je suis aujourd'hui. Merci à Marie et Louis d'accompagner les week-ends et autres moments partagés de vos rires et de vos bêtises. Merci à mes grands-parents, ma belle famille et tout particulièrement Monique et Sauro, mes oncles, tantes et cousins, cousines d'avoir cru en moi et de m'avoir permis de passer des bons moments ensemble.

Merci à mes collègues de la Direction générale du Trésor, et en particulier du bureau Multifin3, pour leur soutien dans la dernière ligne droite de cette thèse.

Un grand merci également à mes amis d'avoir été à mes côtés au quotidien pendant ces 3 années pour un repas ensemble ou un week-end qui m'ont permis de m'évader de mes travaux de recherche : Adeline et Laurent, Alexandre, Mathilde et Ulysse, Judith et Anthony, Julien et Camille G., Cindy, Mélodie, Hélène, Camille C., Loïc et Estelle, Maude et Gaëtan, Clémentine, Anaïs V., Violaine et Maël, Kaoutar et Younes, Iréna et Vincent C., Xavier et Guillaume, Magali, Florine, Muriel, Anaïs G., Elodie, Louis, Zineb, Amélie, Brocéliande, Nils...

Pour terminer, je tiens à remercier Emmanuel. Je suis particulièrement reconnaissante de l'amour que tu me portes et de ton soutien sans faille et de tous les instants.

List of publications and conferences

This PhD thesis was the subject of several publications:

- Bourcet, C., Cézanne, C., Rigot, S., & Saglietto, L. (2019). Le financement participatif de projets d'énergies renouvelables (EnR) : éclairages sur le modèle économique et les risques d'une plateforme française. *Innovations*, 59(2), 151-177. Link
- Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Economics*, 85. Link.
- Bourcet, C., Bovari, E. (2020). Exploring citizens' decision to crowdfund renewable energy projects: quantitative evidence from France. *Energy Economics*, 88. Link

This work was presented in several international conferences and seminars:

- July 2020, The ecological transition: towards a monetary and financial paradigm shift? (AFD et Chair Energy and Prosperity), organized online. Link.
- June 2020, 25th annual conference of the European Association of Environmental and Resource Economists (EAERE), organized online. Link.
- October 2019, IBES Tea Time at Brown University, Providence, United States. Link.
- June 2019, 68th annual congress of the French Economic Association (AFSE), Orléans, France. Link.
- October 2018, Université Sorbonne Paris Nord PhD seminar, Villetaneuse, France. Link
- September 2018. 38th annual conference of the Association d'économie sociale (AES), Lyon, France. Link.
- August 2018. 5th annual conference of the French Association of Environmental and Resource Economists (FAERE), Aix-en-Provence, France. Link.
- June 2018. 5th digital economics summer school, Montpellier, France. Link.

Table of Contents

Chapter 1

Introduction

Overview

The recognition of the human influence on climate and the attempt to take action to mitigate climate change raise some global level issues. How to reduce greenhouse gas (GHG) emissions to limit the physical risks associated with climate change? Since energy-related GHG emissions have been substantial, what can be done to decarbonize the energy sector? One solution is the deployment of low-carbon renewable energy (RE) sources that can satisfy the different energy needs. However, so far the deployment of modern RE sources is relatively slow. Moreover, significant differences exist between countries in terms of current levels of development and growth rates.

Are there common global determinants of country-level RE deployment? There is a branch of literature that has developed to specifically address this question using econometric methods. In Chapter 2, published as Bourcet (2020), I review the existing literature to give an overview of the authors' findings, identify potential gaps, and provide recommendations for future research on this specific issue.

In addition to a multi-country econometric approach, authors have investigated the existence of several barriers that can hinder the development of all or some RE sources at a national or a more local level. Among them, financing and acceptance are significant. Thus, how to integrate citizens in the energy transition towards RE sources and as a result influence RE acceptance and redirect retail investors' funds towards RE projects? In this thesis I decided to look at crowdfunding for RE projects because this innovative financing means precisely enables the participation of citizens in the funding of RE sources. In particular, I focus on the case of France because the country designed a favorable regulatory environment that has contributed to a strong growth of funds collected via crowdfunding platforms, including for RE projects. More broadly, France has demonstrated its commitment towards climate change mitigation by taking significant action at a national level.

The literature on crowdfunding is recent and scare, even more in the context of RE projects. In particular, the understanding of the RE crowdfunding sector dynamics is limited. To contribute to bridge this gap, in Chapter 3, published as Bourcet et al. (2019), with my co-authors, we conduct a case study based on interviews to precisely describe the business model and associated risks of a French platform specialized in RE crowdfunding. Then, in Chapter 4, I give an overview of the different actors involved in the RE crowdfunding sector in France taking advantage from answers of platforms to a proprietary

questionnaire and from survey data regarding contributors. Finally, in Chapter 5, published as Bourcet & Bovari (2020), my co-author and I investigate the decision-making process of French citizens that have invested in RE crowdfunding projects relying on an econometric analysis of survey data.

To conclude, as presented in this introduction, in this thesis I aim at contributing to the literature that investigates the deployment of RE sources both with a global approach and in a more local perspective by studying an innovative financing means for RE projects that is crowdfunding in the French context.

Vue d'ensemble

La reconnaissance de l'influence humaine sur le climat et la tentative d'agir pour lutter contre le changement climatique soulèvent un certain nombre de problématiques globales. Comment réduire les émissions de gaz à effet de serre (GES) pour limiter les risques physiques liés au changement climatique ? Une large part des émissions de GES sont liées à l'énergie. Comment alors décarbonner le secteur énergétique ? Les énergies renouvelables (EnR) peu émettrices de carbone et qui permettent de répondre aux différents besoins énergétiques sont une solution. Pourtant, jusqu'à maintenant le développement des EnR est resté relativement limité et des différences significatives existent entre pays en termes de niveau et de taux de croissance du déploiement.

Existe-t-il des déterminants communs et globaux au déploiement national des EnR ? Un courant de littérature s'est développé pour précisément répondre à cette question en utilisant des méthodes économétriques. Dans le Chapitre 2, publié en tant que Bourcet (2020), je réalise une revue de la littérature pour présenter un panorama des résultats des auteurs, identifier les potentielles pistes de recherche et fournir des recommandations en lien.

En complément d'une approche économétrique multi-pays, des auteurs ont étudié l'existence de diverses barrières qui freinent le développement de toutes ou certaines sources d'EnR au niveau national, voire local. Parmi celles-ci, le financement et l'acceptabilité des EnR sont importantes. Comment alors impliquer les citoyens dans la transition énergétique vers les sources EnR et ainsi influencer l'acceptabilité des EnR et rediriger l'épargne des investisseurs individuels vers les projets d'EnR ? Dans cette thèse, j'ai décidé d'étudier le financement participatif de projets d'EnR car cet instrument de financement innovant permet la participation des citoyens au financement des sources d'EnR. Plus spécifiquement, je considère le cas de la France car le pays a développé un cadre réglementaire favorable qui a contribué à soutenir la forte croissance des fonds collectés par les plateformes de financement participatif, notamment pour des projets d'EnR. Plus largement, la France a démontré son engagement dans la lutte contre le changement climatique en prenant un certain nombre de mesures au niveau national.

La littérature sur le financement participatif est relativement nouvelle et limitée, et

ce d'autant plus dans le cas particulier des projets d'EnR. Ainsi, la compréhension du secteur du financement participatif d'EnR reste limitée. Pour contribuer à remédier à cela, dans le Chapitre 3, publié en tant que Bourcet et al. (2019), je conduis avec mes co-auteurs une étude de cas qui s'appuie sur des entretiens pour décrire le modèle économique, et les risques en lien, d'une plateforme française spécialisée dans le financement participatif d'EnR. Ensuite, dans le Chapitre 4, je dresse un panorama des différents acteurs impliqués dans le secteur du financement participatif d'EnR en France. Cette analyse s'appuie sur un questionnaire créé pour l'occasion et adressé aux principales plateformes proposant des projets d'EnR et sur des données de sondage collectées auprès de contributeurs. Finalement, dans le Chapitre 5, publié en tant que Bourcet & Bovari (2020), avec mon co-auteur nous étudions le processus de décision des contributeurs français aux projets d'EnR en nous appuyant sur une analyse économétrique de données de sondage.

Pour conclure, comme cela est présenté dans cette introduction, je contribue dans cette thèse à la littérature qui étudie le déploiement des EnR en adoptant une approche globale et également une perspective plus locale en m'intéressant au financement participatif, un outil de financement innovant pour les projets d'EnR, dans le contexte français.

Contents

1.1 How to address climate change?

The influence of human activities on climate has been established. Besides this, the different types of impacts and risks have been investigated. As a result, two different types of actions are taken with the complementary goals to adapt and mitigate climate change. Since climate change is a world-level issue, international cooperation is key to take action to address it. In addition to this, initiatives at a decentralized level are also interesting in this respect.

1.1.1 Recognition of human influence on climate and related risks

There is an international recognition of a human induced climate change. This can be summarized in one sentence published by the Intergovernmental Panel on Climate Change: "[h]uman influence on the climate system is clear" (IPCC,

2014, p.40). As demonstrated in the Synthesis Report of its Fifth Assessment Report (AR5), anthropogenic greenhouse gas emissions (GHG) have increased significantly since the industrial revolution as a result of economic and population growth (IPCC, 2014, p.45-47). The growing trend of annual CO_2 emissions, the main GHG, is presented in Figure 1.1.

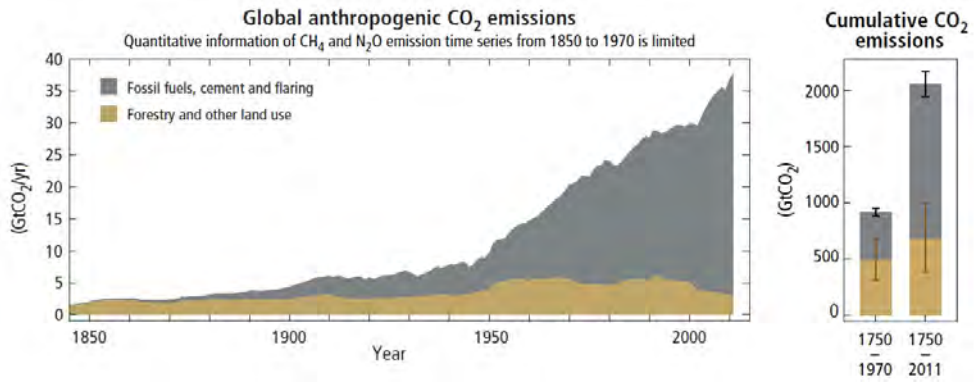


Fig. 1.1 Trend of annual global anthropogenic CO_2 emissions. Cumulative CO_2 emissions are presented on the right-hand side (uncertainties are shown as whiskers).

Source: IPCC (2014, p.45).

As confirmed by the recent IPCC report called "Global Warming of 1.5°C" (2018), the main influence of human activities on climate is a warming of approximately 1°C above pre-industrial levels. In addition to the warming of the ocean and the atmosphere, human activities have already influenced the global water cycle, i.e., decrease in ice and snow, and rise in sea level, and the occurrence of extreme weather events (IPCC, 2014, p.47 and 53).

Future anthropogenic climate change, and in particular global warming, is being largely determined by cumulative CO_2 emissions (IPCC, 2014, p.56). Under all the IPCC (2014, p.58) GHG emissions scenarios, surface temperature is expected to increase. As a result, severe events such as heat waves and extreme precipitations are projected to be more frequent and intense. Besides this, the ocean will also experience a higher degree of warming and acidification, and sea level rise will continue.

As an illustration in the case of France,[1] the country may not be considered as one of the most exposed countries to climate change risks. Nevertheless, as shown in Figure 1.2, climate change is expected to have significant impacts on the French territory by 2050. Compared to the 1976-2005 reference period, temperatures are projected to increase significantly and extreme climate and weather events are likely to become more frequent. The French case illustrate the fact that

[1] As France is considered as a case study in this thesis, the French context is used throughout this introduction for illustrative purpose.

the risks associated with climate change are not the same for different regions, or countries.

Fig. 1.2 Actual or expected by 2050 impacts of climate change in the case of France.

Source: CGDD and I4CE (2019, p.20, based on simulations by "Drias, les futurs du climat" for a RCP 8.5 scenario).

More specifically, as pointed out by the IPCC (2014, p.64-65) the risks associated with climate change affect countries, societies, and economic sectors differently. Despite the different effects, an increasing warming resulting from GHG accumulation is expected to worsen the consequences on ecosystems, biodiversity, and people. This is an outcome of the interaction between hazards related to climate and the exposure, vulnerability, and adaptation ability of people and nature. According to the IPCC report (2014), in addition to the risks of ecosystem and biodiversity losses, the main risks for humans (related to the different types of climate change) are: health issues, disruption of lifestyles and livelihoods, breakdown of infrastructures, and food and water insecurity. As a result, "[c]limate change is a threat to equitable and sustainable development" (IPCC, 2014, p.90).

The precise magnitude of the climate-related risks depends on the intensity of global warming. Indeed, the recent report of the IPCC (2018, p.5) demonstrates that there are higher risks if global warming is larger than 1.5°C in 2100 compared

to pre-industrial levels. Moreover, in case of a high peak temperature, even if there is a stabilization of warming at a lower level by the end of the century, the impacts of the resulting climate change are likely to be irreversible.

In addition, as put forward by the financial sector (see for instance Carney, 2015, TCFD, 2019), climate change can affect economic and financial activities through two main channels. Firstly, physical risks result from the direct consequences of weather and climate-related events on assets and infrastructures and thus production processes. Secondly, transition risks correspond to a large range of policy, market, technology, and reputation risks associated with a shift towards a low carbon economy. Since there is a consensus on the existence of climate change, these risks will necessarily arise and become significant for economic activities.

1.1.2 Mitigation and adaptation actions to address climate change

Climate change is a world-level issue. This raises issues regarding the possibility to take coordinated actions to address it. Indeed, international country level coordination is key. In addition, some scholars have emphasized the useful role of local and collective climate-related actions to complement global policies (see for instance Bauwens & Eyre, 2017, Ostrom, 2012). More specifically, there are two possible and complementary human responses to climate change (IPCC, 2014, p.76). The first is to design actions or mechanisms to adapt to the current and future climate-related changes. The second one includes mitigation actions that aim to reduce climate change physical risks.

Regarding mitigation actions, a first international commitment to reduce GHG emissions in the case of industrialized countries (36 and the European Union) was adopted in 1997 under the name of the Kyoto Protocol based around the United Nations Framework Convention on Climate Change (UNFCCC, 2020b). Due to a complex ratification process, it finally entered into force in 2005. Based on a principle of "common but differentiated responsibility and respective capabilities", this agreement resulted in binding GHG emissions target for developed countries that represented an objective of about 5% emission reduction compared to 1990 levels over the first five year period 2008–2012. Three market-based mechanisms were created in relation to the countries' emission reduction targets: (i) an emission trading scheme, (ii) a clean development mechanism (CDM, investment in GHG emission reduction projects in developing countries), and (iii) a joint implementation mechanism (JI, investment in GHG emission reduction projects in developed countries). Regarding adaptation, an adaptation fund was established to contribute to the funding of adaptation projects in developing countries.

The 2015 Paris Agreement (entered into force one year later) has historically been the first international agreement to extend climate-related obligations to both developed and developing countries (IEA, 2019, p.19). In order to meet the objective set by the Paris Agreement, also based around the UNFCCC (2019), of limiting global warming to a level below 2°C (or even 1.5°C) above pre-industrial levels, annual CO_2 emissions have to be substantially reduced. The commitment set during the Paris Agreement was based on a sum of national GHG reduction targets, the so-called nationally determined contributions (NDCs). Updated NDCs are expected to be submitted to the UNFCCC secretariat every five years. In most of the scenarios presented by the IPCC (2018, p.12) report, a limitation of global warming to below 2°C is associated with a decline of CO_2 emissions of around 25% by 2030. Other GHG are also supposed to decline substantially to reach this global warming target. In addition to mitigation actions, the Article 7 of the Paris Agreement is dedicated to adaptation with the aim to strengthen adaptation efforts at a national level in a context of international cooperation as the issue is of a global nature. Because "[a]daptation solutions take many shapes and forms, depending on the unique context of a community, business, organization, country or region" (UNFCCC, 2020a), countries are encouraged to formulate and implement national adaptation plans. Contrary to mitigation actions that contribute to the limitation of GHG emissions worldwide, adaptation actions have a local aspect. That is why national adaptation actions are key.

Regarding the national implementation of climate adaptation measures, the example of France is interesting (MTES, 2019). Indeed, a *Stratégie nationale d'adaptation au changement climatique* (National climate change adaptation strategy) was validated in 2006 to make recommendations and was complemented by a *Plan national d'adaptation au changement climatique* (PNACC, National climate change adaptation plan) for the period 2011-2015. The first PNACC targeted 20 sectors and areas of actions with four objectives: (i) protect people and assets, (ii) prevent inequalities in relation to the risks faced, (iii) reduce costs and take advantage of the benefits, and (iv) preserve the natural capital. After an evaluation phase, a second PNACC (PNACC-2) was introduced for the period 2018-2022. This plan focuses on several aspects that include governance and territorial actors commitment, the diffusion of information, or else the integration of the different economic sectors.

Table 1.1 French climate change mitigation and energy-related laws or initiatives.

Law or initiative	Main commitments and details
Energy law (POPE, 2005)	An annual mean decrease of 3% of GHG emissions and a support to the definition of an objective to divide by 2 GHG emissions by 2050 at world level, An annual reduction of final energy intensity of 2% starting in 2015 and of 2.5% by 2030, For RE sources: a share of RE 10% in energy consumed by 2010, a share of 21% of electricity generated from RE sources by 2010, an increase of 50% of heat from RE, an increase of biofuels consumption.
Grenelle 1 and 2 laws (2009-2010)	A division by 4 by 2050 of GHG emissions compared to 1990 levels ("factor 4" objective), A share of RE sources in final energy consumption of 23% in 2020, A decrease of the existing buildings sector's energy consumption of at least 38% by 2020, A reduction of GHG emissions in the transport sector of 20% by 2020 to go back to 1990 levels.
Energy transition for green growth law (LTECV, 2015)	A decrease of 40% by 2030 and division by 4 by 2050 of GHG emissions compared to 1990 levels, A reduction of final energy consumption of 20% by 2030 and 50% by 2050 compared to 2012, A decrease of primary energy consumption from fossil fuels of 30% in 2030 compared to 2012, to do so RE sources will represent: 40% of electricity generation, 38% of final heat consumption, 15% of final fuel consumption, and 10% of gas consumption, A share of RE sources in final energy consumption of 23% in 2020 and 32% in 2030, A decrease of nuclear energy in power generation to reach of share of 50% by 2025, An increase of energy performance of building in line with "low-energy building" standards for the entire housing stock by 2050, Fight of fuel poverty, A decrease of 50% of the amount of waste sent to landfill by 2025, A gradual decoupling of economic growth from resources consumption.
Mutli-annual energy plan (PPE, introduced in 2015)	A reduction of final energy consumption of 7.5% by 2023 and 16.5% by 2028 compared to 2012, A decrease of primary energy consumption from fossil fuels compared to 2012 levels of: 10% in 2023 and 22% in 2028 for gas, 19% in 2023 and 34% in 2028 for oil, and 66% in 2023 and 80% in 2028 for coal, A target of installed RE power capacity in GW of: 24.1 in 2023 and between 33.2 and 34.7 in 2028 for inshore wind, 2.4 in 2023 and between 5.2 and 6.2 in 2028 for offshore wind, 20.1 in 2023 and between 35.1 and 44.0 in 2028 for solar PV, 25.7 in 2023 and between 26.4 and 26.7 in 2028 for hydro (including wave power), and 0.27 in 2023 and between 0.34 and 0.41 in 2028 for methanization,

Table 1.1 French climate and energy-related laws or initiatives (cont.)

Law or initiative	**Main commitments and details**
	Production targets are also set for RE heat and gas, and biofuels, Development targets introduced for clean vehicles.
National low carbon strategy (SNBC, introduced in 2015)	Carbon neutrality in 2050, Definition of 5-year global and sectoral carbon budgets to reach carbon neutrality, Commitment to zero GHG emission by 2050 in the transport (excluding domestic flights), energy production, and the construction sectors, A decrease of 46% of GHG emission in agriculture by 2050 compared to 2015 and the development of carbon sinks, A decrease of 81% of GHG emission in industry by 2050 compared to 2015, A decrease of 66% of GHG emission in the waste industry by 2050 compared to 2015.
Energy-climate law (LEC, 2019)	Carbon neutrality in 2050, A decrease of primary energy consumption from fossil fuels of 40% by 2030 compared to 2012, Cessation of coal-fired power generation by 2022 and introduction of a limit of GHG emissions for existing fossil fuel power plants, Large new warehouses and commercial buildings will have to integrate RE technologies or green installations, Introduction of the renewable energy community concept (entity controlled by local shareholders of members of a RE project which can produce, consume, and sell the electricity produced), Support for the low-carbon and renewable hydrogen sector, to reach a share between 20 and 40% of the industrial hydrogen consumption by 2030, Creation of the *Haut Conseil pour le climat* (High Council on Climate) as an independent body to provide advice and recommendations on climate policies, Introduction of a green budget commitment in the form of an annual report regarding the influence of the draft budget bill on the environment, Increased environmental reporting requirements for financial actors and companies, A decrease of nuclear energy in power generation to reach of share of 50% by 2035.

Based on: Legifrance (2005, 2009, 2010), MTES (2017, 2020a,b,c).

In addition to the international agreements context regarding GHG emission reduction targets setting, countries or regional groups of countries can make significant commitments to contribute to a global GHG emission reduction. For instance, in the case of the European Union, in 2009, the EU enacted the 2020 Climate & Energy Package that is known as the "3x20" objectives with a target of a reduction of 20% of GHG emissions compared to 1990 levels (European Commission, 2020a). To continue its commitment, the EU adopted the 2030 Energy-Climate Package in 2014 that set a reduction target of GHG emissions of at least 40% compared to 1990 levels (European Commission, 2020b). In addition, since 2018, the EU has started to develop a 2050 climate-neutral strategy to reach a net-zero GHG emission economy (European Commission, 2020c). The collective EU climate targets are translated into national level targets at member state level. Besides this, member states can also introduce other or more stringent climate objectives. As an illustration, in the French 2005 Energy Law (called POPE[2] Law), an objective of a mean annual reduction of 3% of GHG emissions is stated. The French support towards the definition of a reduction objective (a division by 2 of GHG emisions by 2050 at a global level) is also asserted (Legifrance, 2005). Following the *Grenelle environnement* national round tables and the adoption of two related laws,[3] the objective of a division by four of national GHG emissions by 2050 compared to 1990 levels ("factor 4" objective) was introduced. Then, the 2015 *Loi relative à la transition énergétique pour la croissance verte* (LTECV, Energy transition for green growth law, MTES, 2017) reaffirmed the commitment of France by setting a reduction target of GHG emissions of 40% by 2030 compared to 1990 levels. Finally, the 2019 *Loi énergie-climat* (LEC, Energy-climate law, MTES, 2020a) has set the ambitious carbon neutrality objective of the country in 2050. The different climate-related laws and initiatives implemented in France are presented in Table 1.1.

Setting general emission reduction targets is key to provide guidelines for the various economic actors. However, it is not enough to effectively prompt them to take relevant actions to achieve these objectives. In the case of France, the *Stratégie nationale bas-carbone* (SNBC, National low carbon strategy, MTES, 2020c) initiative was introduced to translate a general emission reduction objective into specific objectives. The SNBC is a monitoring and steering tool to achieve carbon neutrality by 2050 based on the definition of 5-year global and sectoral carbon budgets (MTES, 2020c).

[2]It stands for *Loi de programme fixant les orientations de la politique énergétique*.

[3]The *Grenelle environnement* national round tables on environmental and sustainable development related policy issues took place in 2007 and two laws called "*Grenelle 1*" and "*Grenelle 2*" were voted in 2009 and 2010 (Connaissance des énergies, 2017). These laws stated that the fight against climate change was considered as a priority (Article 2, I. — "La lutte contre le changement climatique est placée au premier rang des priorités" ("*Grenelle 1*" law, Legifrance, 2009)).

In addition to international and government-level decisions that provide key guidance at a global level, other parties, such as local authorities, private companies, and citizens, can engage in both adaptation and mitigation actions to address climate change risks. Following the seminal work of Elinor Ostrom (e.g., Ostrom, 2012), some scholars have emphasized the useful role of local and collective actions to complement global climate change mitigation policies (in the case of the energy transition, see for instance Bauwens & Eyre, 2017).

1.2 The energy sector and decarbonization challenge

There are different sources of GHG emissions associated with human activities. According to the International Energy Agency (IEA, 2019, p.15), the energy-related activities have been a significant source of GHG emissions since they account for about three quarters of anthropogenic GHG emissions. This is a result of the large increase of energy consumption and more specifically of carbon emitting fossil fuel combustion after the industrial revolution. Figure 1.3 presents the historical evolution of primary energy production since 1800. The substantial growth of fossil fuels was characterized by the increase in energy from coal during the industrial revolution, followed by a significant growth in oil production starting around 1920, and finally a rise in gas production after about 1940.

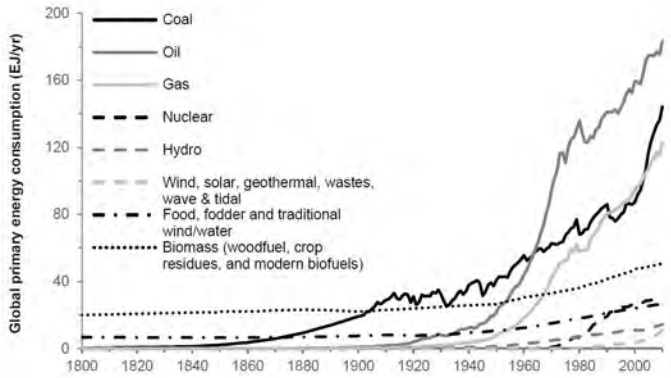


Fig. 1.3 Historical annual evolution of global primary energy production by source.

Source: Court (2016, p.24).

There are differences between countries regarding the precise carbon intensity of their economies. As an illustration, the data of the Emissions Database for Global Atmospheric Research (EDGAR, Crippa et al., 2019) shows that the 28 countries of the EU corresponded to 9.16% of the 2015 total world GHG emissions and France accounted for 0.92% of the world total. From a total of 9.54 tonnes of CO_2 equivalent *per capita* in 1990, the French GHG emissions decreased to 6.98 in

2015. As per the latest data, in 2017, it was of 6.95 tonnes of CO_2 equivalent *per capita* (EEA, 2019). France therefore accounts for only a small fraction of global GHG emissions. However, efforts can still be made to reduce any country's GHG emissions to contribute to global climate change mitigation efforts.

Because the energy sector is responsible for a large share of GHG emissions, climate change mitigation has to integrate energy-related decarbonization actions. This section presents an overview of the energy sector and then details possible means to decarbonize this sector with a specific focus on the deployment of low-carbon renewable energy (RE) sources.

1.2.1 Overview of the energy sector and global recent trend

Energy can be considered as a fuel for economic activities and growth (Negro et al., 2012). Primary energy is derived from nature (sun, wind, rivers) or contained in energy products derived from nature (fossil fuels or wood).[4] Secondary energy is obtained by the transformation of a primary energy or another secondary energy (e.g., production of electricity from gas, petroleum products from crude oil). Final energy is the energy delivered to consumers for final consumption (e.g., electricity in households, gasoline at the gas station, wood used by a collective boiler) (CGDD, 2019b, p.79-80). Thus, as summarized by the IPCC (2012, p.38), primary energy sources are converted first into energy carriers (liquid, solid, or gaseous fuels, and electricity) and then into energy services that are electrical, mechanical, or related to heat. As a result, there are different types of primary energy sources that are renewable or not.

More specifically, when analyzing energy-related dynamics, it is key to understand the difference between primary energy production, primary energy consumption, and final energy consumption. The definitions that are given here are from the report of the CGDD (2019b, p.80-81). Primary energy production corresponds to the level of primary energy produced within a national territory. Primary energy consumption is the sum of the energy consumption of all economic agents of a national territory, i.e., primary energy production minus the balance of foreign trade (exports minus imports), minus the balance of changes in stocks (and minus fuel supplies for sea and air bunkers, for ocean-going vessels and aircrafts operating on foreign routes). Finally, final energy consumption equals the energy consumption from final users (industries, households, services, agriculture, transports...) which means that it is the primary energy consumption minus the consumption of the energy sector.[5]

[4] Primary energy from hydro, solar photovoltaic (PV), wind, and tides is generally accounted for at the level of the corresponding electricity production (CGDD, 2019b, p.79-80).

[5] The energy sector corresponds to the activities relating to the production and transformation of energy (power plants, refineries, distribution losses...). The consumption of the energy sector

According to data from BP (2019), the world primary energy consumption rose from 4,876 in 1970 to 13,865 million tonnes oil equivalent in 2018. This growing trend is presented in Figure 1.4. Moreover, the increase in the world consumption was matched by an increase in fossil fuel consumption. The share of fossil fuels in global primary energy consumption experienced a slow decrease from 94% in 1970 to 85% in 2018. Hence, fossil fuels continue to be the main primary energy sources by far. More specifically, the share of oil in total consumption was of 47% in 1970 and started to decrease slowly in the early 1980's to reach 34% in 2018. Regarding coal, form a share of 30% in 1970, it evolved a little around this value and was of 27% in 2018. Last fossil fuel, the share of gas increased form 17% in 1970 to 24% in 2018. Finally, since the 1970's, alternative sources, i.e., nuclear, hydroelectricity, and other RE sources, have only developed slowly. Indeed, RE sources represented less than 6% of world primary energy consumption in 1970 (mostly from hydropower) and reached 11% in 2018.

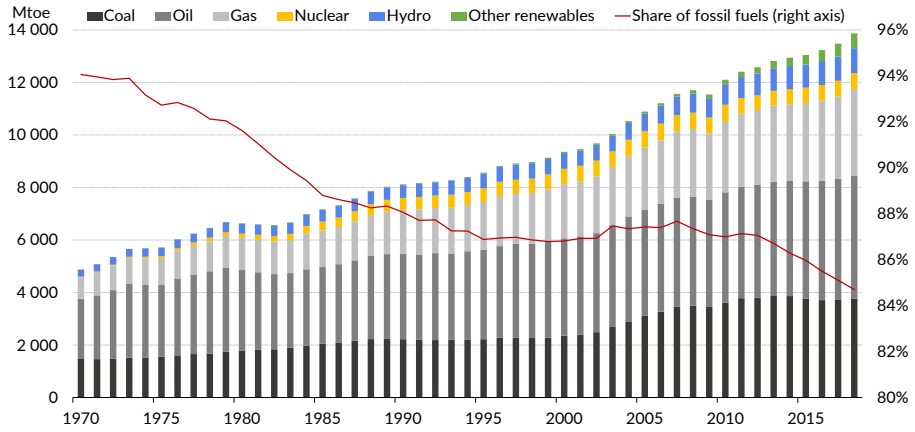


Fig. 1.4 Evolution of world primary energy consumption in million tonnes oil equivalent and fossil fuel share.

Data source: BP (2019).

1.2.2 Possible actions to reduce the carbon content of the energy sector

Because energy has been contributing to economic processes, concerns on availability and affordability of energy sources have been central for energy and economic policies (Negro et al., 2012). The adoption of the Kyoto Protocol and more recently of the Paris Agreement have made climate change a priority including in the context of energy policy due to the carbon intensity of the energy sector. There are large differences in terms of national level of energy consumption between

equals the quantities consumed by energy producers and transformers and the losses incurred during the transformation of energy (e.g., losses during the combustion of fuels or nuclear reaction) and its transmission (e.g., line losses during the transmission and distribution of electricity) (CGDD, 2019b, p.81).

countries. Developed and fossil fuel producing countries have a relatively high energy consumption *per capita* as illustrated in Figure 1.5. France has a higher primary energy consumption *per capita* compared to the world level but a lower one than the EU.

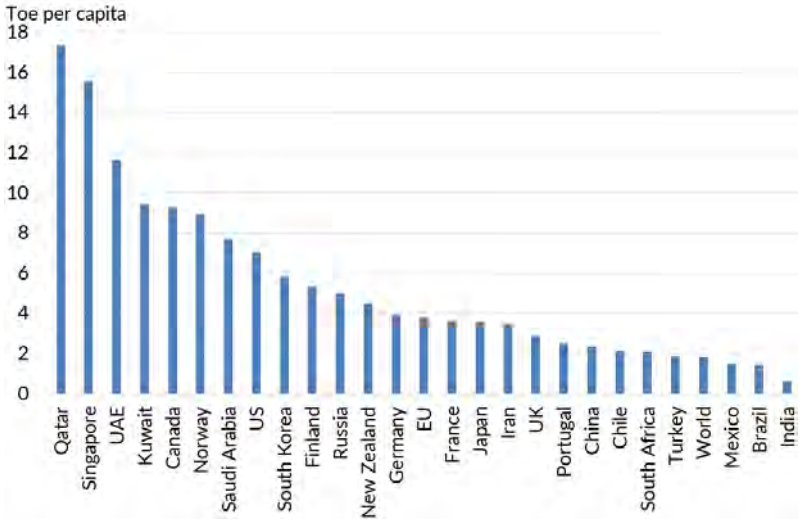


Fig. 1.5 Primary energy consumption in tonnes oil equivalent *per capita* in different countries or groups of countries.

Data source: BP (2019) and World Bank database for population.

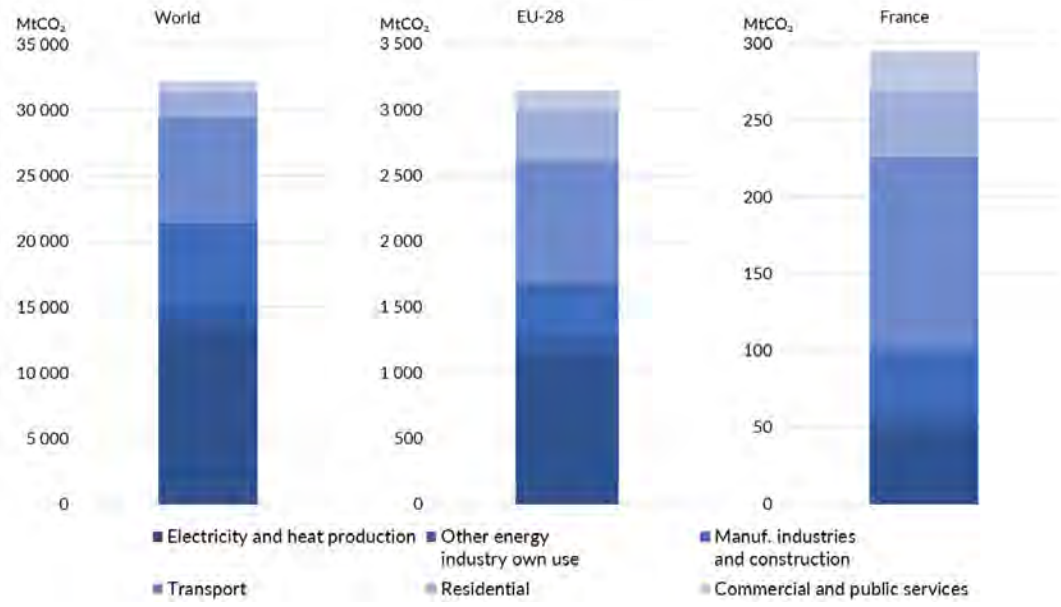


Fig. 1.6 CO_2 emissions from fuel combustion by sector in the world, the EU-28, and France in 2017.

Data source: IEA (2020).

In addition to differences in levels of energy consumption, the sectoral breakdown of CO_2 emissions from fuel combustion varies across countries. As presented in Figure 1.6, in the case of France in 2017, the share of CO_2 emissions from fuel combustion for electricity and heat production is not the largest (16%), compared to the world (42%) and the data for the 28 EU countries (35%). Indeed, the largest emitting sector in France is the transport sector (43% of the total CO_2 emissions from fuel combustion compared to 25% for the world and 30% for the EU-28). Thus, understanding the national context is key to identify possible actions to decarbonize the energy sector at a national level.

A first way to limit the emissions associated with this sector is to increase the energy efficiency of production processes. Indeed, reducing energy consumption by improving efficiency in the use of energy at a world level means a reduction of GHG emissions. However, energy efficiency cannot be considered as the sole solution to reduce GHG emissions in relation to the energy sector because in a perspective of economic development energy needs have to be met. In developing countries for example, some populations still do not have access to energy, thus energy consumption is expected to increase.

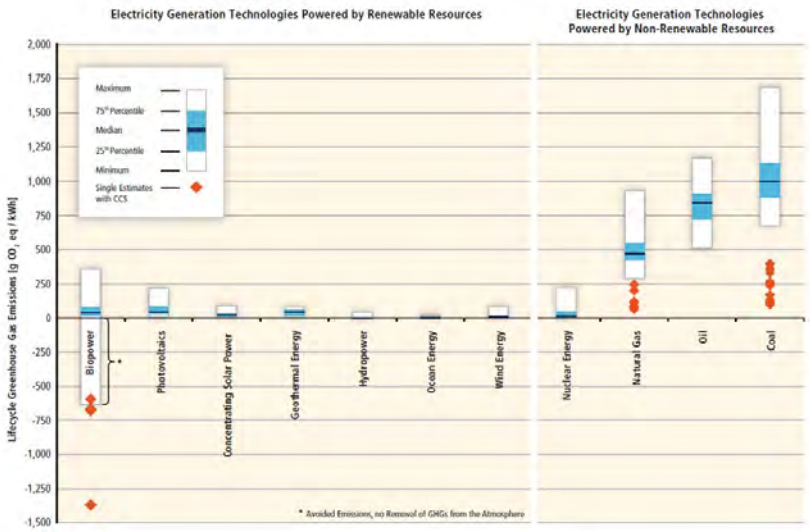


Fig. 1.7 Estimates of lifecycle GHG emissions of electricity generation technologies.

Source: IPCC (2012, p.124).

The different energy sources can be classified based on the degree of GHG they emit to fulfill energy needs. As it can be seen in Figure 1.7, the analysis of the IPCC (2012, p.124) in the case of electricity generation, shows that fossil fuels are high carbon emitting sources. On the other hand, all renewable energy sources and nuclear energy can be considered as low-carbon sources. As a result,

to reduce the carbon intensity of the energy sector, low-carbon energy sources have to be widely developed[6] (IPCC, 2014, p.100).

There are opposed arguments and no clear consensus in the literature regarding the choice of either RE sources or nuclear sources to decarbonize the energy sector (Suna & Resch, 2016). Nevertheless, nuclear energy is not a renewable source and raises several issues. Indeed, the investments needed for a significant development of nuclear energy are very high and their are concerns about the safety of the plants and the disposal of radioactive wastes (Suman, 2018). Following the 2011 Fukushima accident, public perception of nuclear energy has been deteriorating and some countries have decided to phase-down or phase-out, e.g., Germany.

In this context, as developing RE sources is a way to reduce GHG emissions and thus contribute to climate change mitigation (IPCC, 2012, p.40), and because RE sources have received an increased attention from the public authorities, I decided to specifically focus on the dynamics and issues related to RE sources in this thesis. As it will be seen later, RE sources are currently used in different sectors (power generation, heating and cooling, and the transport sector) and could develop further.

In addition, the role of electricity to satisfy energy needs is key in the perspective of a decarbonization of the energy sector. Indeed, "deeply reducing the carbon footprint of the energy system will require both decarbonising the power sector and promoting the role of electricity" (Cany et al., 2018, p.544). For instance, fossil fuels used in the transport sectors could be replaced by electricity through a wide development of electric vehicles. However, this has a positive influence on GHG emissions (i.e., a reduction) only if the power used by these vehicles is produced with low-carbon sources. To illustrate this dynamic, compared to the 2°C pathways, in the 1.5°C pathways presented by the IPCC (2018), the electrification of energy end-use is projected to be more rapid. Moreover, the share of RE sources in electricity generation is expected to reach 70 to 85% in 2050 in the pathways limiting warming to a level of 1.5°C.

1.2.3 Introduction of energy-related targets: the case of France

A large number of countries have introduced energy-related targets in an effort to decarbonize their energy sector. These targets are set taking into consideration the national context. Figure 1.8 presents the breakdown of primary energy consumption by source in the world and in France in 2018. The share of fossil fuels is smaller in the case of France, in particular for coal that only represents 3% compared to 27% in the world. France has historically had a high share of nuclear

[6] In this thesis, the terms deployment and development are used as synonyms.

energy in its mix (Andriosopoulos & Silvestre, 2017) as also shown in Figure 1.8 for 2018 compared to a low figure at world level. RE sources have a similar share in France than in the world. So far, the development of RE sources is still limited in France.

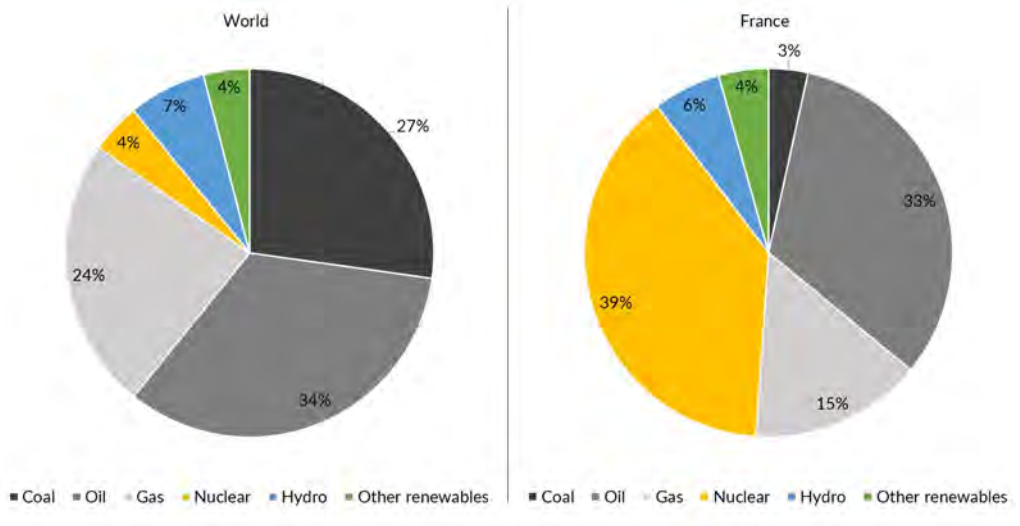


Fig. 1.8 Share of energy sources in total primary energy consumed in 2018 in the world (13,865 Mtoe) and in France (243 Mtoe).

Data source: BP (2019).

As a member of the EU, France has a role to play to meet the collective EU-level energy objectives. In the EU 2020 Climate & Energy Package (European Commission, 2020a), in addition to a reduction target of GHG emissions, two energy-related objectives were set: (i) a target of a 20% share of RE sources in final energy consumption (translated into national targets at the member states level) and (ii) an improvement of 20% of energy efficiency. Moreover, the 2030 Energy-Climate Package enacted in 2014 (European Commission, 2020b) also includes energy-related commitments: (i) a share of RE sources of at least 32% in final energy consumption and (ii) an improvement of at least 32.5% of energy efficiency. Besides this, member states can also introduce other or more stringent energy-related objectives.

In the case of France, the 2005 POPE Law introduced national RE development target by 2010 (Legifrance, 2005). In the context of the "*Grenelle 1*" and "*Grenelle 2*" laws (Connaissance des énergies, 2017), a target of RE development of 23% in final energy consumption by 2020 was set. In addition, the 2015 LTECV (MTES, 2017) reaffirmed the commitment of France by setting several energy-related objectives for the country in relation to energy consumption, and fossil fuel, nuclear, and RE consumptions. Following the 2015 LTECV and the 2019

LEC (MTES, 2020a) laws, the *Programmation pluriannuelle de l'énergie* (PPE, Mutli-annual energy plan, MTES, 2020b) initiative was launched. The PPE is a 5-year planing that sets energy-related priorities and objectives regarding: energy security, energy consumption and energy efficiency, RE sources levels, energy price competitiveness and cost for consumers, and development of energy related infrastructures. The details regarding the energy-related objectives set by the different French laws and initiatives are presented in Table 1.1.

As a summary, the main energy-related objectives set by the French Government are: (i) a commitment to zero GHG emission in the energy production sector by 2050, (ii) a reduction of final energy consumption of 20% by 2030 and 50% by 2050 compared to 2012, (iii) a decrease of primary energy consumption from fossil fuels of 40% by 2030 compared to 2012, (iv) a share of RE sources in final energy consumption of 23% in 2020 and 32% in 2030, (v) a decrease of nuclear energy in power generation to reach of share of 50% by 2035. As a result of the objectives set by France regarding the energy sector, RE sources have to be largely developed in the country. This is key to achieve the GHG emission reduction target and at the same time reach a share of nuclear energy in power generation of 50% by 2035. Moreover, as per the latest data available concerning final energy consumption, RE sources represented about 16% of the total in 2017 in France which means that this level is below the projected level (19,5%) to reach a share of 23% in 2020 (CGDD, 2019b, p.17). There is a development delay for both electricity and heat-related energy. As a result, a large development of RE sources raises a number of issues as it will be presented later, among which funding and acceptance of RE sources are significant challenges.

1.3 Introduction to RE sources

Not all energy sources are renewable. Indeed, "RE is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use" (IPCC, 2012, p.38). As a result, the following sources can be considered renewable: solar, geothermal, marine, and wind energies, bioenergy (wood, waste, agricultural and food residues, biogas, and biofuels), and hydropower. The technologies associated with RE sources are diverse. Hence, they can be used for the provision of all three types of energy services and have specific characteristics. An overview of possible uses of the main RE sources is given in Table 1.2.

RE sources	Power	Heating and cooling	Transports
Hydropower	X		(X)
Marine energy (hydrokinetic, wave, or tidal)	X		(X)
Wind energy (onshore or offshore)	X		(X)
Photovoltaic and concentrated solar energies	X		(X)
Thermal solar energy		X	
Heat pumps		X	
Geothermal energy	X	X	(X)
Solid biomass (wood, waste...)	X	X	(X)
Biogas	X	X	X and (X)
Biofuels			X

Table 1.2 Possible uses of the main RE sources.

Source: CGDD (2019b, p.76).
Note: "(X)" means that it can be used in the transport sector through power generation.

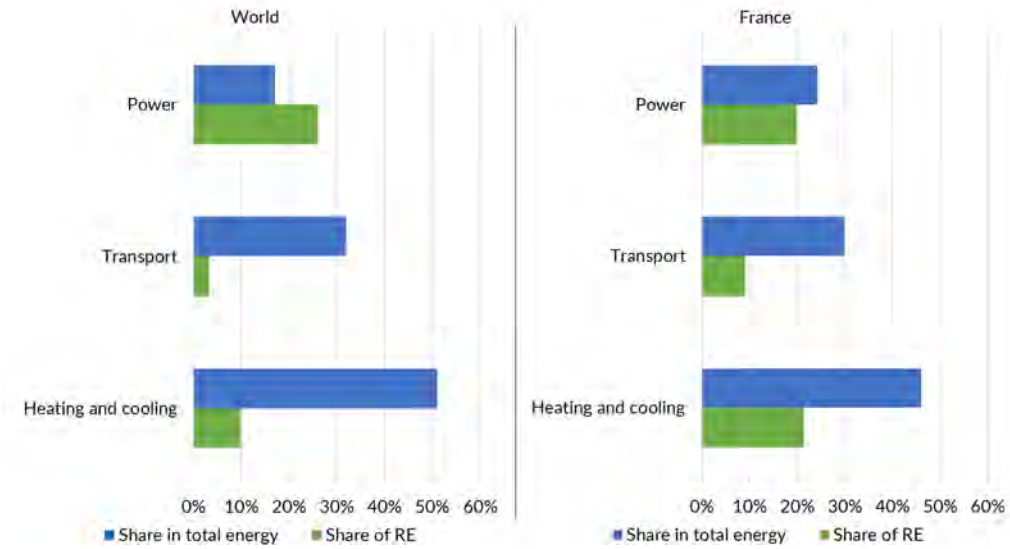


Fig. 1.9 Share of sectors in final energy consumption and share of RE in the consumption of each sector in the world in 2016 and in France in 2017.

Data source: REN21 (2019, p.33), CGDD (2019b, p.18), and CGDD (2019a, p.22-23,28).
Note: The figures for the share of each sector in total final energy consumption in France is based on calculation with figures for 2017 or 2018.

In particular, a specific share of the final energy is used for power generation, in the transport sector, or else for heating and cooling. In addition, RE sources can be used to meet the energy needed for these three sectors as shown in Figure 1.9 for the year 2016 in the world and 2017 in France. If the share of the three sectors in final energy consumed is comparable in the world and in France (the power sector consumption is slightly higher and the heating and cooling one marginally

lower in France), the RE share *per* sector varies. In France in 2017, RE sources represented 20% of the final energy consumed in the power sector (slightly lower than the world share), the share of RE was of about 21% for heating and cooling (twice the world share), and of 9% for the transport sector (three times the world share). Thus compared to global data, France had a marginally lower share of RE in the power sector but a higher one in the heating and cooling, and transport sectors.

1.3.1 RE sources for power generation

As seen in Figure 1.9, globally the power sector represents less than one fifth of the global final energy consumption (about 1 fourth in France). The RE sources used for power generation only are: hydro, photovoltaic and concentrated solar, wind, and marine energies (CGDD, 2019a, p.75). Moreover, geothermal energy can be recovered in the form of electricity, and solid biomass and biogas can be used to produce electricity (CGDD, 2019b, p.76). In Figure 1.10, the breakdown of RE sources used to produce electricity in the world in 2018 and in France in 2017 is presented. Both at the world level and in France, hydro represented more than half of the RE electricity generated. Wind and solar were respectively the second and third RE power sources with a share of respectively more than 20% and about 10%. The share of other sources is less significant in the electricity mix. In recent years, global additions of RE power capacity was dominated by wind and solar PV energies and hydropower (REN21, 2019, p.40).

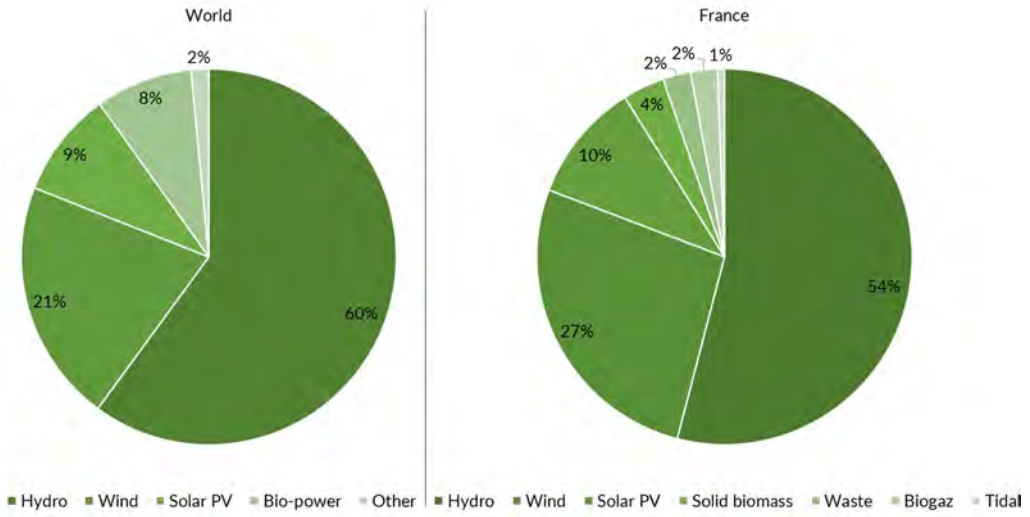


Fig. 1.10 Share of each source in RE electricity production in the world in 2018 and in France in 2017.

Data source: REN21 (2019, p.41), CGDD (2019b, p.8).

1.3.2 RE sources for heating and cooling

In Figure 1.9, it can be seen that about half of the final energy is consumed by the heating and cooling sector. More precisely, demand for cooling is increasing but heat demand is still the most significant (REN21, 2019, p.35). At a global level, traditional biomass[7] represents about 60% of the RE supply of heating and cooling demand (REN21, 2019, p.35). Figure 1.11 presents the share of the different RE sources used for heat production in France. Wood is by far the main RE source used for heat production in the country, followed by heat pumps. Other RE sources possibly used for heat production are: other types of solid biomass such as incinerated crop residues and wastes, biogas, thermal solar energy, and geothermal energy recovered in the form of heat[8] (CGDD, 2019b, p.76).

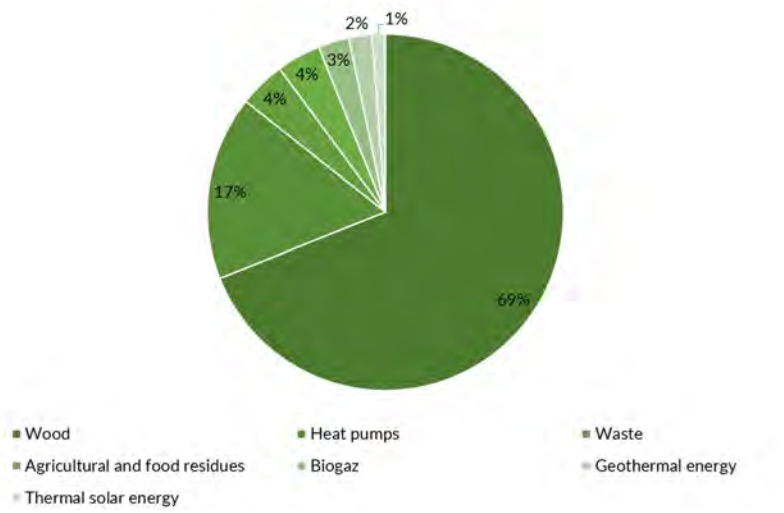


Fig. 1.11 Share of each source in primary consumption for heat production in France in 2017.

Data source: CGDD (2019b, p.8).

1.3.3 RE sources for the transport sector

As presented in Figure 1.9, the transport sector accounts for about 30% of the final energy consumed both at world level and in France. The only type of RE source that can be used directly in the transport sector is biofuels (CGDD, 2019b, p.76). It includes liquid biofuels blended or not with conventional fuels and vehicles or infrastructures that run on biomethane (REN21, 2019, p.37). In addition, electricity-based transport means can also use RE sources through electricity.

[7] "The traditional use of biomass for heat involves the burning of woody biomass or charcoal as well as dung and other agricultural residues in simple [...] devices" (REN21, 2019, p.71).

[8] Geothermal energy is also recovered in the form of electricity but this is marginal in the case of France (CGDD, 2019b, p.44).

1.3.4 Potential issues and co-benefits associated with RE sources

The development of RE sources raises some challenges related to the characteristics of these technologies. They can block or reduce the speed of their development. "Unlike fossil fuels RE is site specific" (Sen & Ganguly, 2017, p.1175). Indeed, as summarized by Suman (2018, p.168) "RE sources are dependent upon geographical location, climatic conditions, and require a very large land footprint". At a local level, the installation of RE technologies can raise some environmental issues in relation to natural habitat stress or degradation[9] and the environmental impact of components manufacturing (Suman, 2018). In addition, an increasing integration of variable RE, e.g., solar and wind energies, requires the adaptation of energy systems to ensure their reliability and cost-effectiveness (IRENA, IEA, and REN21, 2018, p.11). As a result, the power sector in particular needs to be flexible in order to manage uncertainty and variability of RE power sources and meet the demand (Cany et al., 2018). Last but not least, a large scale development of RE sources raises concerns about the use of raw materials (including regarding their price and availability), and in particular the rare-earth materials, to produce the different RE equipment (Apergis & Apergis, 2017, Suman, 2018).

If it is essential to be aware of the issues that arise in the perspective of RE deployment, in recent years, "renewable energy technologies have achieved massive technological advances and sharp cost reductions", this is why "[m]ost countries now see renewable energy as a technologically mature, affordable and clean option in their development strategies" (IRENA, IEA, and REN21, 2018, p.17). In addition to being low-carbon sources and thus representing a means to decarbonize the energy sector, there are other interesting socio-economic and environmental benefits to the development of RE sources (Brunnschweiler, 2010). These potential co-benefits are related to: energy access, air pollution reduction, energy supply concern mitigation, or else job creation. Indeed, RE sources can contribute to increase access to clean energy through for instance RE stand-alone, off-grid systems, or minigrids (REN21, 2019, p.133).[10] In addition, energy access in developing countries can have a positive influence on socioeconomic development (Sen & Ganguly, 2017). RE sources can also have a positive impact on air quality that is related to health (IPCC, 2014, p.110). Moreover, deploying RE sources is a way to secure concerns related to energy supply and, more broadly, energy security (IPCC, 2012, p.40). Indeed, the price volatility and geopolitical issues have a

[9] Suman (2018) gives the examples of hydroelectricity (affecting aquatic ecosystems) or else wind farms (birds collision with the blades).

[10] In the world in 2018, 860 million people did not have access to electricity, and above 2.6 billion people did not have access to clean cooking facilities (about 2.5 million premature deaths annually are linked to household air pollution, and in particular cooking smoke) (IEA, 2019).

significant influence on the cost and availability of imported (fossil) energy (Negro et al., 2012). Finally, the RE sector is also a source of employment creation. According to the International Renewable Energy Agency (IRENA, 2019, p.7), the jobs linked to the RE sector increased from 7.28 million in 2012 to 10.98 million in 2018.

1.4 Why do RE sources develop so slowly?

Fossil fuels continue to dominate world energy consumption and RE sources have been developing slowly despite their potential to contribute to the decarbonization of the energy sector. Indeed, as historically seen, an energy transition takes time and requires a favorable environment to occur (Fouquet, 2016). If there is a slow deployment of RE sources at the world level, there are significant differences between countries in terms both of share of RE sources in energy and growth rate. Indeed, considering the period 1990 to 2010 and a sample of 39 countries with different levels of economic development, Reboredo (2015) analyzes that RE adoption presented heterogeneous trends across countries with different temporal patterns. Besides this, he finds that there is evidence of a convergence of the share of RE in energy supply at a common level across countries. However, there is no evidence of a reduction of the dispersion of countries' RE share in energy supply over time.

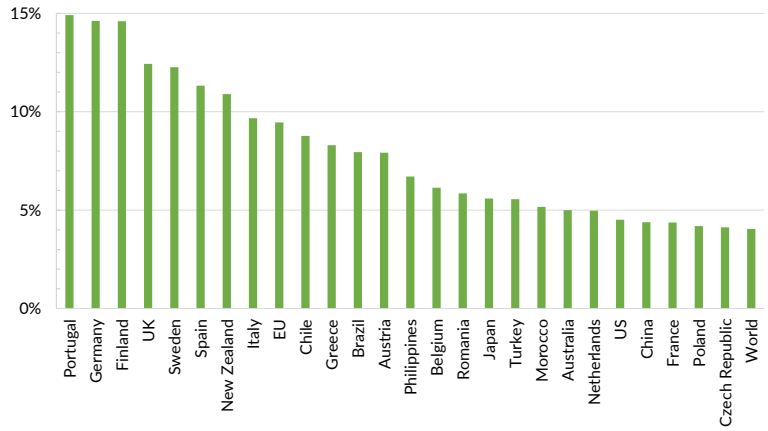


Fig. 1.12 Share of RE sources (excluding hydro power) in the total primary energy consumption in different countries or group of countries, in 2018.

Data source: BP (2019).

Moreover, significant variance in terms of RE consumption can be observed today. An illustration of this can be found in Figure 1.12 for the year 2018. It can be seen that there is a substantial gap between the world level of RE sources (4%), excluding hydro, in primary energy consumption, and the level of about 15% for

Portugal, Germany, or Finland in 2018. It is also interesting to see the level of the European Union (9%), compared to the United States (5%), and China (4%), that are the three largest GHG emitters (from fuel combustion as per IEA (2019, p.17)).

In this context, and taking into consideration the potential issues and co-benefits related to RE development, some authors have tried to better identify the reasons behind the relatively slow development of RE sources. More specifically, two complementary strands of literature have developed. The first one investigates country-level empirical determinants of RE deployment in order to identify common factors that contribute or hinder the development of these low-carbon energy sources. The second strand is broader and based on both qualitative and quantitative methods to study the barriers to RE development with sometimes a focus on specific technologies or specific issues such as financing and acceptability. As will be seen, these two potential barriers can substantially hamper the development of RE sources.

1.4.1 Identifying country level determinants of RE deployment

In recent years, and following the seminal papers of Sadorsky (2009a,b) and Chang et al. (2009), a flourishing literature has indeed emerged to identify the quantitative factors that prompt RE deployment at a country level. More precisely, some authors have explored the relationship between RE aggregates and, among others, macroeconomic, environmental, and other energy variables at a country level. The aim of such an analysis is to try to identify common determinants that have either a positive or a negative influence on the pace of RE deployment at the country level.

Better exploring the literature on the empirical determinants of RE sources is of great interest. The literature on the factors that impact RE deployment was surveyed in two major contributions. Şener et al. (2018) reviewed both qualitative and quantitative papers to identify categories of determinants but the detailed methodologies, indicators, and economic mechanisms identified are not precisely discussed. In a slightly older paper, Darmani et al. (2014) reviewed papers focusing only on a limited sample composed of eight European countries, and restricted the analysis to four RE sources (solar, wind, and wave energies, and biomass), for which they propose a typology of drivers. As a result, no comprehensive literature review of the empirical determinants of RE deployment at a country level had been carried out so far.

In this strand of literature, RE development is assessed with different scopes and specifications (i.e., RE supply, consumption, or installed capacity taken as absolute level, *per capita* level, or share in total energy or electricity). Furthermore, varying RE sources are considered. Authors generally investigate a specific set

of determinants among all possible and the main control variables taken are: income, fossil fuel prices, electricity or energy consumption, CO_2 emissions, and regulatory variables (in particular RE support policies). As a result, it is not easy to identify common determinants of RE development at the country level and to assess the significance of the different determinants considered. In addition, most of the authors that have studied the empirical determinants of RE sources development argue that investigating this topic is key for the formulation of public policy recommendations. However, the very diversity of frameworks raises concerns regarding the relevance of such public policy recommendations. This is why the precise objective of Chapter 2, published as Bourcet (2020), is to review existing literature on the empirical deployment of RE sources at a country level to investigate the existence and the relevance of common determinants, including to identify gaps and formulate recommendations for future research.

1.4.2 Barriers to RE deployment

In addition to a multi-country econometric approach to investigate RE deployment dynamics, it is essential to understand the national, or even the local, context that influences the RE development dynamics.

There is a variety of RE technologies that can be used to produce electricity, for heating and cooling services, or else in the transport sector. As seen before, there are general issues and co-benefits associated with the deployment of RE sources. Moreover, some authors have tried to classify the elements that can slow down the development of RE sources, i.e., barriers that can be overcome in certain circumstances. Based on the early paper of Painuly (2001), the paper of Negro et al. (2012), and the IPCC (2012) report, a global overview of potential barriers to RE development is presented in Table 1.3. More specifically, some market imperfections might slow down the development of RE sources. They mainly results from energy market concentration and non-consideration of external effects of energy use risks and environmental impacts. RE sources might also face economic and financial barriers that relate to financial risk, high up-front investments, and access to financial institution and capital. In addition, current policy and institutional context might hinder RE deployment. Indeed, existing regulatory frameworks regarding research and development or energy market might be detrimental to RE sources. Moreover, some technical and informational barriers are likely to reduce the speed of RE diffusion. Last but not least, socio-cultural concerns related to norms and values might create socio-cultural barriers to RE development.

Categories of barriers	Examples of barriers
Market imperfections	Highly controlled and centralized energy sector and lack of competition Restricted access to technology and underinvestment in R&D High transaction costs Missing market infrastructure Non-consideration of externalities
Economic and financial	High up-front investment requirements (high discount rates and payback period) Market size small Availability and cost of capital Financial risk (uncertainty in maturity of technology, future electricity price, and fossil fuel price) Lack of financial institution, instruments
Institutional and policy	Lack of or inconsistent regulatory framework (in time and between policy levels) Unstable macroeconomic environment Lack of involvement of stakeholders in decision making Clash of interests and lobbying by incumbents in concentrated energy sector Absence of liberalization of the energy sector Lack of research and development culture and professional institutions Subsidies to conventional energy and taxes on RE technologies Tariff and non-trade barriers
Technical and informational	Lack of standard, codes, and certification Lack of skilled labor and entrepreneurs Lack of operation and maintenance facilities or existence of other system constraints Deficient data about RE potential (natural resources) Lack of public and institutional awareness (legitimacy issue)
Socio-cultural	Lack of social acceptance (values and norms, public participation)

Table 1.3 Typology of barriers to RE deployment.

Adapted from: Painuly (2001), Negro et al. (2012), and IPCC (2012).

"Some barriers may be specific to a technology, while some may be specific to a country or a region" (Painuly, 2001, p.75). Indeed, the potential barriers identified in the literature might be more or less prevalent, and might have a different influence depending on RE technologies and also the characteristics of the country and local area of the projects. Financing and acceptance are significant barriers to RE deployment that have received attention in the literature. These two types of issues will be particularly investigated in this thesis. At a national level, public policies can be designed to favor the development of RE sources by reducing the influence of existing barriers.

1.4.2.1 Public policies can help overcome barriers to RE deployment

Public policies are useful to overcome potential barriers to RE deployment. Indeed, for Marques & Fuinhas (2012, p.110) "[there] is broad consensus in the literature concerning the need for public intervention to promote RE use". According to the IRENA, IEA, and REN21 (2018, p.5) report, public policies dedicated to RE sources are primarily focused on the power sector and there is significant room for improvement regarding the heating and cooling, and the transport sectors. Regarding the precise policy support options, a description of the different types of policies related to RE sources deployment is presented in Table 1.4. The direct policies and instruments are: (i) push policies (e.g., quotas, biding targets, biofuels mandates), (ii) pull policies (i.e., incentivising certain actions *via* for instance regulatory or pricing instruments), and (iii) fiscal and financial policies. The second type of policies aims at favoring the incorporation of RE sources in the broad energy system and includes policies related to infrastructure (e.g., transmission and distribution network), system flexibility enhancement (e.g., energy storage deployment support), research, development and demonstration support. In addition, enabling policies contribute to a favoring wider environment for RE deployment regarding for instance the expected development, the energy market context, labor and education policies, or else innovation and financing issues. There are also other policies that are both related to enabling and integrating RE sources such as governance and awareness-related policies.

As an illustration and as will be presented later, the French authorities have developed a favorable regulatory environment for RE crowdfunding. Indeed, this innovative financing means enables the participation of French people in the funding of RE projects. In addition to redirecting funds, it contributes to raise awareness among citizens concerning the energy transition towards RE sources. By doing so, it can be assumed that RE crowdfunding can contribute to favor RE projects acceptance.

Types of policies		Examples of policies
Direct policies	Push	Binding targets for use of RE Electricity quotas and obligations Building codes Mandates (e.g., solar water heaters, RE in district heating) Blending mandates
	Pull	Regulatory and pricing policies (e.g., feed-in tariffs and premiums, auctions) Tradable certificates Instruments for self-consumption (e.g., net billing and net metering) Measures to support voluntary programs
	Fiscal and financial	Tax incentives (e.g., investment and production tax credits, accelerated depreciation, tax reductions) Subsidies Grants
Integrating policies		Measures to enhance system flexibility (e.g., promotion of flexible resources such as storage, dispatchable supply, load shaping) Policies to ensure the presence of needed infrastructure (e.g., transmission and distribution networks, electric vehicles charging stations, district heating infrastructure, road access) Policies for sector coupling R&D and demonstration support for technology development (e.g., storage) Better alignment of energy efficiency and RE policies, and incorporation of decarbonization objectives into national energy plans Adaptation measures of socio-economic structure to the energy transition
Enabling policies		Policies to level the playing field (e.g., fossil fuel subsidy reforms, carbon pricing policies) Measures to adapt the design of energy markets (e.g., flexible short-term trading, long term price signal) R&D and demonstration and innovation policies (e.g., grants and funds, partnerships, facilitation of entrepreneurship, industry cluster formation), policies to ensure the reliability of technology (e.g., quality and technical standards, certificates) National RE policies (e.g., objectives, targets) Policies to facilitate access to affordable financing for all stakeholders Education policies (e.g., inclusion of RE in curricula, coordination of education and training with assessments of actual and needed skills Labor policies (e.g., labor-market policies, training and retraining programs) and public health policies Land-use policies and urban policies (e.g., local mandates on fuel use)
Other policies		Supportive governance and institutional architecture (e.g., streamlined permitting procedures, dedicated institutions for RE) Awareness programs on the importance and urgency of the energy transition geared toward awareness and behavioral change Social protection policies to address disruptions Measures for integrated resource management (e.g., the nexus of energy, food, and water)

Table 1.4 Typology of policy options to promote a transition towards RE sources (installation and generation).

Adapted from: IRENA, IEA, and REN21 (2018, p.103).

1.5 Involving citizens in the funding of RE sources

According to Mazzucato & Semieniuk (2018, p.8), "a major concern in the transition to low-carbon energy provision is how to obtain enough finance to steer investments into the RE direction". As shown in Figure 1.13, overall annual RE sources investment flows[11] have grown significantly since the early 2000s. According to the 2019 Global trends in renewable energy investment report from Frankfurt School-UNEP Centre, Bloomberg NEF (2019, p.11), about USD 273 billion were invested globally in RE capacity in 2018 with about 49% for solar projects and 47.5% for wind projects. However, economic and financial barriers to RE development have been identified as significant by the literature. Indeed, the deployment of RE technologies generally requires a high upfront investment which raises the issues of availability and access to capital (Mignon & Bergek, 2016). Besides this, the evaluation of financial risk associated with RE projects is related to the uncertainty regarding the future electricity or energy service price, the maturity of RE technologies, and also to a certain extent the volatility of the fossil fuel prices (IPCC, 2012, p.44). In addition to these aspects, RE projects can have a relatively lower energy generation density, compared for instance to fossil projects, and as certain RE technologies are site-specific there are information costs associated with research and data collection (Kim & Park, 2016, Sen & Ganguly, 2017). As a result and as seen before, public policies are key to support the deployment of RE sources and including to favor a reorientation of private financial flows not only towards innovation but also in relation to RE capacity installation (Mazzucato & Semieniuk, 2018).

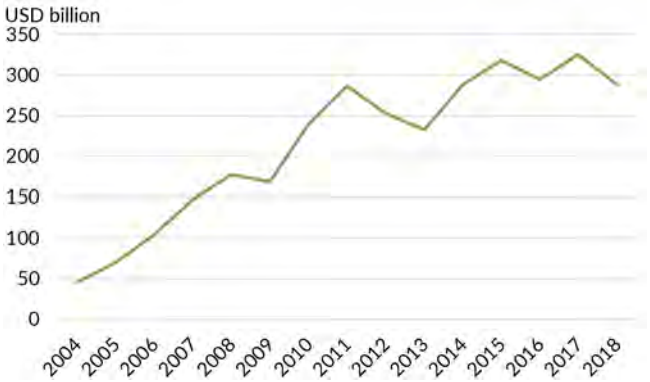


Fig. 1.13 Global annual investment flows in RE power and fuels (excluding hydro-electric projects of more than 50MW).

Data source: Frankfurt School-UNEP Centre, Bloomberg NEF (2019, p.32).

[11] The report covers "the following types of asset: all solar, biomass and waste-to-energy, geothermal, and wind generation projects of more than 1MW; all hydropower projects of between 1MW and 50MW; all wave and tidal energy projects; all biofuel projects with a capacity of one million litres or more per year" (Frankfurt School-UNEP Centre, Bloomberg NEF, 2019, p.9).

In France since the early 2010's, the Institute for climate economics (I4CE) think tank has been publishing an annual report entitled "Landscape of domestic climate finance" to systematically track domestic climate-related investment and associated financing flows. According to the 2019 edition of the report (I4CE, Hainaut et al., 2019, p.3), all climate-related investments[12] in France have increased from EUR 35.8 billion in 2011 to EUR 45.7 billion in 2018. In 2018, households made about 37%[13] of the total climate-related investments, public entities represented around 33%, and businesses about 30% (Hainaut et al., 2019, p.5). Moreover, the same report shows that in 2018 EUR 7.5 billion were invested in RE sources. Regarding RE electricity, it reached EUR 4.6 billion of investments the same year with onshore wind energy representing the largest share with 43% of the total (Hainaut et al., 2019, p.12). To be in line with the SNBC and PPE objectives set, I4CE states that the annual investments in RE electricity have to reach EUR 7 or 8 billion during the period 2019-2023.

1.5.1 Possible contributions of citizens to RE-related investments

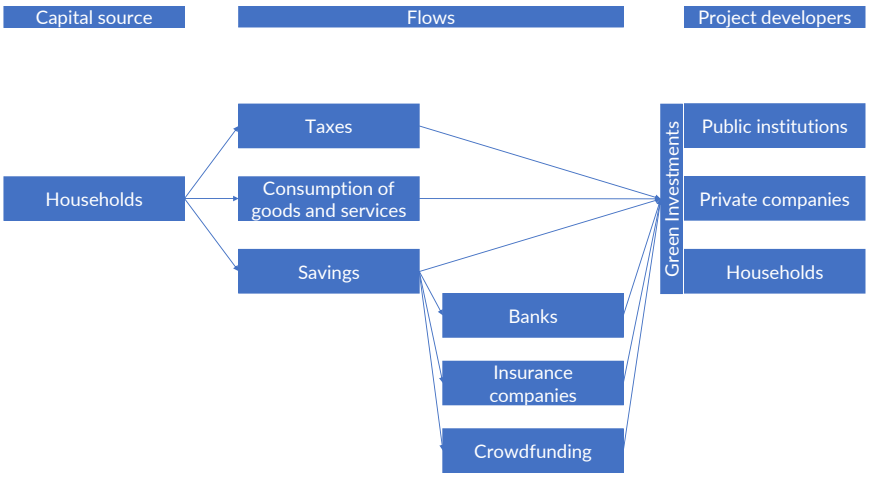


Fig. 1.14 Simplified financial value chain from households to green investments.

Adapted from: WiseEuropa, NewClimate Institute, and I4CE (2019, p.8).

As presented by the financial value chain adapted from WiseEuropa, NewClimate Institute, and I4CE (2019, p.8) in Figure 1.14, households contribute directly and indirectly to the funding of climate-related and in particular RE projects. These projects are developed by public institutions, private companies, or by

[12] The scope of climate-related investments accounted for in this report is: energy efficiency, RE, sustainable infrastructures, nuclear energy, non-energy contributing to a low-carbon transition.

[13] Households primarily invested in dwellings' construction and retrofitting, and private vehicles.

households themselves. The financing flows are related to consumption choices, tax payments, and savings located at banks, insurance companies, or invested in climate-related projects *via* crowdfunding platforms (it will be defined in the following section). Households can also invest their savings directly (without any intermediary institution) in RE projects for instance *via* cooperatives.

To the best of my knowledge, there is no precise data regarding the contribution of households, either directly or indirectly, to the funding of RE sources in the world and in particular in the case of RE crowdfunding. If it can be assumed that the contribution of citizens to RE funding remains limited compared to global investments, there is a potential to mobilize households' savings and direct them towards RE projects. In addition to providing financial flows for climate-related projects, involving citizens in the funding of RE technologies is also a means to integrate them in the energy transition process (McInerney & Bunn, 2019). Indeed and as summarized by the IPCC (2012, p.129), societal and personal values and norms are likely to affect citizens' perception and acceptance of RE sources. People's preference for traditional energy is one example of an element associated with this type of socio-cultural barrier (Painuly, 2001). The IPCC (2012) report also emphasizes the key role of public awareness and support in the realization of a large-scale development of RE sources. For Mignon & Bergek (2016), RE might face a lack of legitimacy or even an active opposition. "Legitimacy is not given but rather formed through conscious actions by various organisations and individuals in a socio-political process of legitimation, which incorporates cognitive, normative as well as regulative aspects" (Negro et al., 2012, p.3842). To increase RE sources legitimacy, attention has to be given to socio-cultural concerns, and more specifically the impact of RE sources on behaviors, natural habitats, and human heritage sites (IPCC, 2012, p.129). Indeed, reasons for social opposition to RE sources can be classified into 3 categories: environmental, visual, and socio-economic impacts (Enevoldsen & Sovacool, 2016). Moreover, communication to all stakeholders, including people living in areas where RE sites are located, is key to support local acceptance (Negro et al., 2012). "At the same time, however, public participation in planning decisions as well as fairness and equity considerations in the distribution of the benefits and costs of RE deployment play an equally important role and cannot be side-stepped" (IPCC, 2012, p.129).

In addition to public acceptance, there might also be a local acceptance challenge. For instance, there might be concerns about the visual impact of solar or wind projects leading to a local opposition. "This lack of local acceptance is often cited as "not in my backyard" (NIMBY) syndrome, although this may oversimplify the actual motives of locals" (Hu et al., 2018, p.739). For the same authors, it is probably better explained by local concerns about the perceived impacts of RE

sources and the perceived unfairness (regarding the distribution of outcomes and the treatment of stakeholders). Moreover, some scholars have argued that activities that contribute to inform and involve local stakeholders help to reduce social opposition and as such increase local acceptance of RE projects (see for instance Enevoldsen & Sovacool, 2016, Jobert et al., 2007, for the case of wind projects in France).

1.5.2 Introduction to crowdfunding

Crowdfunding can be defined as "a method of pooling often small amounts of capital from a potentially large pool of interested funders" (Short et al., 2017, p.149). If raising money from a variety of citizens and other actors is not new – this technique was used in 1885 to complete the funding of the Statue of Liberty's pedestal (National Park Service, 2019) – the democratization of the Internet and the emergence of dedicated online platforms resulted in a significant development of online crowdfunding (hereafter crowdfunding) *via* intermediary platforms. Since the end of the 2000's crowdfunding has experienced a strong growth globally. The 2008 financial crisis is likely to have fueled the development of crowdfunding due to increased difficulties for economic agents, and in particular entrepreneurs, to access funds (Bruton et al., 2015). Different instruments are used by online intermediary platforms – e.g., donation, peer-to-peer lending, other debt-instruments, or shares. On these platforms, it is possible to contribute to the funding of a wide range of projects: innovative (Agrawal et al., 2014, Bruton et al., 2015), artistic (Bannerman, 2013, Boeuf et al., 2014), or else environmental (Hörisch, 2015, Lam & Law, 2016). Some platforms are specialized in a specific sector and/or other specialize on a limited range of funding instruments.

To the best of my knowledge, there is no precise and recent data regarding the amounts collected by crowdfunding platforms and in particular for RE projects at a global level. In the case of France, crowdfunding has experienced a strong growth following the regulation of the sector in 2014. As shown in Figure 1.15, in the context of a supportive regulatory framework, the evolution of the amounts collected by crowdfunding platforms for RE projects is substantial too. More specifically, the average annual growth rate of the amounts collected by RE projects on crowdfunding platforms between 2016 and 2019 is of around 80% based on the data published by GreenUnivers & FPF (2017, 2018, 2019, 2020). As per the latest results of their barometer (GreenUnivers & FPF, 2020), RE crowdfunding reached EUR 67.17 million collected in 2019, corresponding to 476 projects. This has made France the European leader in RE crowdfunding (Rüdinger, 2019) and thus an ideal case study for this sector.

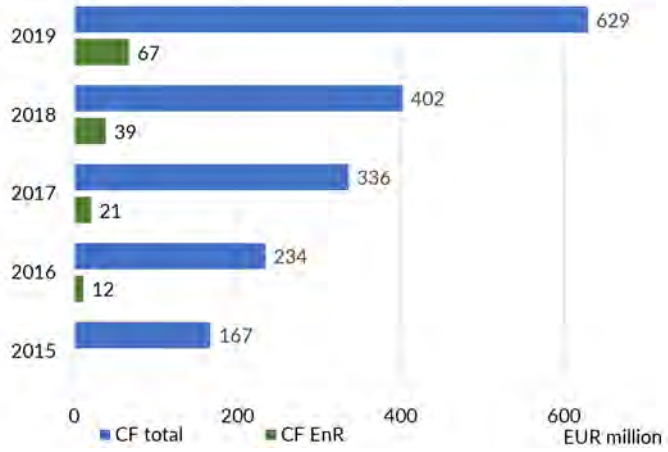


Fig. 1.15 Amounts collected *via* crowdfunding platforms, all sectors combined and for RE projects, in France.

Data sources: GreenUnivers & FPF (2017, 2018, 2019, 2020), Mazars & FPF (2020).

1.5.3 Understanding the business model of RE crowdfunding platforms

The literature looking at the crowdfunding sector is relatively new and mainly focuses on entrepreneurial finance (Martínez-Climent et al., 2018). Indeed, crowdfunding is an innovative financing means that enables entrepreneurs or project promoters to access funds. Crowdfunding can be considered as a two-sided market (Armstrong, 2006, Rochet & Tirole, 2003, 2006) where platforms are key intermediaries between contributors, i.e., citizens and project promoters. In addition, it is likely that the precise sector of the project influences the behavior of the actors involved in crowdfunding. Some authors have specifically looked at crowdfunding for RE projects. So far, the understanding of the precise operations of the platforms specialized in RE projects is limited and the literature has focused on the success condition of campaigns, the description of the diversity of platforms and projects funded (e.g., Bento et al., 2019, Bonzanini et al., 2016, Cumming et al., 2017, de Broeck, 2018, Lam & Law, 2016, Nigam et al., 2018, Vasileiadou et al., 2016). When authors describe platforms, they mainly give an overview of the projects displayed and of the investment instruments used.

In Chapter 3, published as Bourcet et al. (2019), my co-authors and I precisely aim at better understanding how a crowdfunding platform specialized in the funding of RE projects operates. To do so, we rely on the Business Model Canvas framework of Osterwalder (2004), Osterwalder & Pigneur (2011)[14] to present the business model and analyze the risks faced by a French platform called Enerfip. This analysis is conducted based on a qualitative analysis of public information

[14] As will be seen later, this framework is particularly interesting because it enables a detailed presentation of a business model based on 4 pillars and 9 blocks.

and interviews. It enables us to shed some light on the interactions of the platform with its two categories of customers that are contributors and project promoters. We also analyze the risks faced by the platform, including in relation to its clients, and give some recommendations to improve their management.

1.5.4 Overview of the RE crowdfunding sector in France

The literature on crowdfunding mainly looks at the sector as an innovative entrepreneurial funding means (Martínez-Climent et al., 2018). Due to the specific characteristics of the energy sector, it can be assumed that RE crowdfunding has some particularities, e.g., regarding the profile of project promoters. As detailed in the previous section, the French RE crowdfunding sector has experienced an impressive growth in recent years. According to the data available, about EUR 138 million were collected for RE projects in France since 2016 (GreenUnivers & FPF, 2017, 2018, 2019, 2020). The national regulatory environment is very likely to have favored this development (Rüdinger, 2019). This is why there might be specific national dynamics associated with RE crowdfunding and the actors involved in this sector. Due to data availability issues and to the best of my knowledge, there is no comprehensive overview of the RE crowdfunding sector at a country level and in particular in the case of France.

In Chapter 4, I precisely aim at giving an overview of the RE crowdfunding sector in France. The analysis builds on data collected based on a questionnaire sent to French platforms that have a history of organizing crowdfunding campaigns for RE projects. More precisely, in order to describe at best the sector, platforms were asked to give information about the projects funded, how they operate, and the profile of both contributors and project promoters. In addition, survey data from contributors are used to describe their motivation and RE invest behavior. Finally, better understanding the characteristics and the interactions between the major platforms offering RE projects and their customers is particularly interesting as "crowdfunding renewable energy projects does not only have the direct impact of financing a project, but could also have a more indirect impact: creating a positive feedback loop of support for a renewable energy transition" (Vasileiadou et al., 2016, p.144).

1.5.5 Determinants of citizens' decision to crowdfund RE projects

Due to the specificities of crowdfunding (online platforms, decentralized pool of investors, *etc.*) with regards to traditional financing instruments, it is key to better understand the various factors that shape the decision-making process of crowdfunding contributors. The literature that have tried to shed some light on this process has primarily relied on past campaigns data, thus looking at compaigns'

conditions of success, and rarely on survey data (Hoegen et al., 2018). However, it can be assumed that collecting quantitative survey data using a questionnaire better enables to precisely investigate contributors' decisions and behaviors *per se*.

In particular, to the best of my knowledge and due to data availability constraints, no authors have specifically analyzed the decision of citizens to contribute to RE crowdfunding projects. In Chapter 5, published as Bourcet & Bovari (2020), we use a novel survey dataset collected by YouGov France for FPF and the MTES (2019) in the case of France, to investigate the influence of opinion variables on the RE sector, investment behaviors, and other socio-economic characteristics on the decision of French citizens to contribute to RE crowdfunding. In the case of France where the regulatory environment has been favorable to the RE crowdfunding sector, conducting such an econometric analysis is also relevant to put in perspective both the results obtained and the policy initiatives implemented by national authorities.

1.6 Bibliography

Agrawal, A., Catalini, C., & Goldfarb, A. (2014). Some simple economics of crowdfunding. *Innovation Policy and the Economy*, *14*, 63–97.

Andriosopoulos, K. & Silvestre, S. (2017). French energy policy: A gradual transition. *Energy Policy*, *106*, 376–381.

Apergis, E. & Apergis, N. (2017). The role of rare earth prices in renewable energy consumption: The actual driver for a renewable energy world. *Energy Economics*, *62*, 33–42.

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics*, *37*(3), 668–691.

Bannerman, S. (2013). Crowdfunding culture. *Journal of Mobile Media*, *7*(01), 1–30.

Bauwens, T. & Eyre, N. (2017). Exploring the links between community-based governance and sustainable energy use: Quantitative evidence from flanders. *Ecological Economics*, *137*, 163–172.

Bento, N., Gianfrate, G., & Groppo, S. V. (2019). Do crowdfunding returns reward risk? evidences from clean-tech projects. *Technological Forecasting and Social Change*, *141*, 107–116.

Boeuf, B., Darveau, J., & Legoux, R. (2014). Financing creativity: Crowdfunding as a new approach for theatre projects. *International Journal of Arts Management*, *16*, 33–48.

Bonzanini, D., Giudici, G., & Patrucco, A. (2016). The crowdfunding of renewable energy projects. In V. Ramiah & G. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 429–444). Elsevier.

Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Economics*, *85*, 104563.

Bourcet, C. & Bovari, E. (2020). Exploring citizens' decision to crowdfund renewable energy projects: Quantitative evidence from France. *Energy Economics*, *88*.

Bourcet, C., Cézanne, C., Rigot, S., & Saglietto, L. (2019). Le financement participatif de projets d'énergies renouvelables (EnR) : éclairages sur le modèle économique et les risques d'une plateforme française. *Innovations*, *2*, 151–177.

BP (2019). *Statistical Review of World Energy*.

Brunnschweiler, C. N. (2010). Finance for renewable energy: an empirical analysis of developing and transition economies. *Environment and Development Economics*, *15*(3), 241–274.

Bruton, G., Khavul, S., Siegel, D., & Wright, M. (2015). New financial alternatives in seeding entrepreneurship: Microfinance, crowdfunding, and peer–to–peer innovations. *Entrepreneurship Theory and Practice*, *39*(1), 9–26.

Cany, C., Mansilla, C., Mathonnière, G., & da Costa, P. (2018). Nuclear contribution to the penetration of variable renewable energy sources in a french decarbonised power mix. *Energy*, *150*, 544 – 555.

Carney, M. (2015). Breaking the tragedy of the horizon - climate change and financial stability - speech.

CGDD (2019a). Chiffres clés de l'énergie édition 2019. septembre 2019.

CGDD (2019b). Chiffres clés des énergies renouvelables édition 2019. mai 2019.

CGDD and I4CE (2019). Key figures on climate france, europe and worldwide - 2020 edition. november 2019.

Chang, T.-H., Huang, C.-M., & Lee, M.-C. (2009). Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from oecd countries. *Energy Policy*, *37*(12), 5796–5802.

Connaissance des énergies (2017). Grenelle environnement.

Court, V. (2016). *Energy, EROI, and Economic Growth in a Long-Term Perspective*. Ph.d. dissertation, Université Paris Nanterre.

Crippa et al. (2019). Fossil co2 and ghg emissions of all world countries - 2019 report. Emissions Database for Global Atmospheric Research (EDGAR) - Publications Office of the European Union.

Cumming, D. J., Leboeuf, G., & Schwienbacher, A. (2017). Crowdfunding cleantech. *Energy Economics*, *65*, 292–303.

Darmani, A., Arvidsson, N., Hidalgo, A., & Albors, J. (2014). What drives the development of renewable energy technologies? toward a typology for the systemic drivers. *Renewable and Sustainable Energy Reviews*, *38*, 834–847.

de Broeck, W. (2018). Crowdfunding platforms for renewable energy investments: an overview of best practices in the EU. *International Journal of Sustainable Energy Planning and Management*, *15*, 3–10.

EEA (2019). Country profiles - greenhouse gases and energy 2019.

Enevoldsen, P. & Sovacool, B. K. (2016). Examining the social acceptance of wind energy: Practical guidelines for onshore wind project development in france. *Renewable and Sustainable Energy Reviews*, *53*, 178–184.

European Commission (2020a). 2020 climate & energy package.

European Commission (2020b). 2030 climate & energy framework.

European Commission (2020c). 2050 long-term strategy.

Fouquet, R. (2016). Historical energy transitions: Speed, prices and system transformation. *Energy Research & Social Science*, *22*, 7–12.

Frankfurt School-UNEP Centre, Bloomberg NEF (2019). *Global Trends in Renewable Energy Investment 2019*. Full report.

GreenUnivers & FPF (2017). Baromètre 2016 du crowdfunding EnR.

GreenUnivers & FPF (2018). Baromètre 2017 du crowdfunding EnR.

GreenUnivers & FPF (2019). Baromètre 2018 du crowdfunding EnR.

GreenUnivers & FPF (2020). Baromètre 2019 du crowdfunding des EnR.

Hainaut, H., Ledez, M., & Cochran, I. (2019). *Panorama des financements climat Edition 2019*.

Hoegen, A., Steininger, D. M., & Veit, D. (2018). How do investors decide? an interdisciplinary review of decision-making in crowdfunding. *Electronic Markets*, *28*(3), 339–365.

Hu, J., Harmsen, R., Crijns-Graus, W., & Worrell, E. (2018). Barriers to investment in utility-scale variable renewable electricity (vre) generation projects. *Renewable Energy*, *121*, 730–744.

Hörisch, J. (2015). Crowdfunding for environmental ventures: an empirical analysis of the influence of environmental orientation on the success of crowdfunding initiatives. *Journal of Cleaner Production*, *107*, 636–645.

IEA (2019). *CO2 Emissions from Fuel Combustion 2019 Highlights*.

IEA (2019). Sustainable development goal 7.

IEA (2020). *CO2 Emissions from Fuel Combustion: Overview*.

IPCC (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. Technical Summary.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC (2018). *Global Warming of* $+1.5°C$*. Summary for Policymakers. An IPCC Special Report on the impacts of global warming of* $+1.5°C$ *above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

IRENA (2019). *Renewable Energy and Jobs – Annual Review 2019*.

IRENA, IEA, and REN21 (2018). *Renewable Energy Policies in a Time of Transition*.

Jobert, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: Factors of success identified in french and german case studies. *Energy Policy*, *35*(5), 2751–2760.

Kim, J. & Park, K. (2016). Financial development and deployment of renewable energy technologies. *Energy Economics*, *59*, 238–250.

Lam, P. T. & Law, A. O. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Legifrance (2005). Loi n2005-781 du 13 juillet 2005 de programme fixant les orientations de la politique énergétique.

Legifrance (2009). Loi n2009-967 du 3 août 2009 de programmation relative à la mise en oeuvre du grenelle de l'environnement (1).

Legifrance (2010). Loi n2010-788 du 12 juillet 2010 portant engagement national pour l'environnement (1).

Marques, A. C. & Fuinhas, J. A. (2012). Are public policies towards renewables successful? evidence from european countries. *Renewable Energy*, *44*, 109–118.

Martínez-Climent, C., Zorio-Grima, A., & Ribeiro-Soriano, D. (2018). Financial return crowdfunding: literature review and bibliometric analysis. *International Entrepreneurship and Management*

Journal, *14*(3), 527–553.

Mazars & FPF (2020). *Baromètre annuel du crowdfunding en France 2019*.

Mazzucato, M. & Semieniuk, G. (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change*, *127*, 8–22.

McInerney, C. & Bunn, D. W. (2019). Expansion of the investor base for the energy transition. *Energy Policy*, *129*, 1240–1244.

Mignon, I. & Bergek, A. (2016). System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. *Journal of Cleaner Production*, *128*, 105–115.

MTES (2017). Loi de transition énergétique pour la croissance verte.

MTES (2019). Adaptation de la france au changement climatique.

MTES (2020a). Loi énergie-climat.

MTES (2020b). Programmations pluriannuelles de l'énergie (ppe).

MTES (2020c). Stratégie nationale bas-carbone (snbc).

National Park Service (2019). Joseph pulitzer—statue of liberty national monument new york.

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? a review of innovation system problems. *Renewable and Sustainable Energy Reviews*, *16*(6), 3836–3846.

Nigam, N., Mbarek, S., & Benetti, C. (2018). Crowdfunding to finance eco-innovation: Case studies from leading renewable energy platforms. *Journal of Innovation Economics and Management*, *2*(26), 195–219.

Osterwalder, A. (2004). *The Business Model Ontology: a proposition in a design science approach*. Ph.d. dissertation, Université de Lausanne, Ecole des Hautes Etudes Commerciales.

Osterwalder, A. & Pigneur, Y. (2011). *Business Model nouvelle génération - Un guide pour visionnaires, révolutionnaires et challengers*. Pearson.

Ostrom, E. (2012). Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? *Economic Theory*, *49*(2), 353–369.

Painuly, J. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, *24*(1), 73–89.

Reboredo, J. C. (2015). Renewable energy contribution to the energy supply: Is there convergence across countries? *Renewable and Sustainable Energy Reviews*, *45*, 290–295.

REN21 (2019). *Renewables 2019 Global Status Report*.

Rochet, J.-C. & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Rochet, J.-C. & Tirole, J. (2006). Two-sided markets: a progress report. *The RAND Journal of Economics*, *37*(3), 645–667.

Rüdinger, A. (2019). *Participatory and citizen renewable energy projects in France - State of play and recommendations (in French)*. Study number 03/19.

Sadorsky, P. (2009a). Renewable energy consumption and income in emerging economies. *Energy Policy*, *37*(10), 4021–4028.

Sadorsky, P. (2009b). Renewable energy consumption, co2 emissions and oil prices in the g7 countries. *Energy Economics*, *31*(3), 456–462.

Sen, S. & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development – a discussion. *Renewable and Sustainable Energy Reviews*, *69*, 1170 – 1181.

Short, J. C., David J. Ketchen, J., McKenny, A. F., Allison, T. H., & Ireland, R. D. (2017). Research on crowdfunding: Reviewing the (very recent) past and celebrating the present. *Entrepreneurship Theory and Practice*, *41*(2), 149–160.

Suman, S. (2018). Hybrid nuclear-renewable energy systems: A review. *Journal of Cleaner Production*, *181*, 166 – 177.

Suna, D. & Resch, G. (2016). Is nuclear economical in comparison to renewables? *Energy Policy*, *98*, 199 – 209.

TCFD (2019). Task force on climate-related financial disclosures: Status report.

UNFCCC (2019). The Paris Agreement.

UNFCCC (2020a). What do adaptation to climate change and climate resilience mean?

UNFCCC (2020b). What is the Kyoto Protocol?

Vasileiadou, E., Huijben, J., & Raven, R. (2016). Three is a crowd? exploring the potential of crowdfunding for renewable energy in the netherlands. *Journal of Cleaner Production*, *128*, 142–155.

WiseEuropa, NewClimate Institute, and I4CE (2019). *Domestic Landscape of Climate Finance. Why systemic approach to climate finance matters?*

YouGov France for FPF and the MTES (2019). Enquête sur le financement participatif des énergies renouvelables.

Şener, S. C., Sharp, J., & Anctil, A. (2018). Factors impacting diverging paths of renewable energy: A review. *Renewable and Sustainable Energy Reviews*, *81*, 2335–2342.

Chapter 2

EMPIRICAL DETERMINANTS OF RENEWABLE ENERGY DEPLOYMENT

This chapter has been published as
Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Economics*, 85. Link.

Abstract *Renewable energy (RE) appears to be a means to decarbonize economies and the energy sector in particular. Thus, it is essential to understand the empirical determinants of RE deployment for public policy guidance and to foster future research. This chapter aims to review the body of literature that has emerged in the late 2000s to study the quantitative determinants of RE development at a country level. Results show that there is little consensus on the influence of the economic, environmental, and energy-related determinants predominantly studied. The other main determinants considered are regulatory, political, and demographic. Results are often tempered by the fact that authors use diverse measures of RE deployment and have a variety of frameworks. This chapter ends with several recommendations to improve the comparability of future papers to enhance their potential to make credible public policy recommendations.*

Résumé *Les énergies renouvelables (EnR) sont un moyen de décarboner les économies et plus particulièrement le secteur énergétique. Il est donc essentiel de mieux cerner les déterminants empiriques de leur déploiement pour guider les politiques publiques et encourager la recherche sur le sujet. Ce chapitre est une revue de la branche de littérature, qui a émergé à la fin des années 2000, et étudie les déterminants quantitatifs du déploiement des EnR au niveau des pays. Les résultats montrent qu'il y a peu de consensus concernant les déterminants principalement étudiés qui sont de nature : économique, environnementale, énergétique, réglementaire, politique et démographique. Cependant, cela peut être tempéré en considérant que les auteurs utilisent différentes mesures du déploiement des EnR et ont des cadres d'analyse différents. A la fin du chapitre, différentes recommandations sont formulées pour améliorer la comparabilité des articles et leur potentiel à fournir des recommandations de politiques publiques pertinentes.*

Contents

2.1 Introduction

The international recognition of the impact of human activity on climate change (IPCC, 2014) has led to calls for concrete political actions, as highlighted by the recent "Global Warming of 1.5°C" report of the Intergovernmental Panel on Climate Change (IPCC, 2018). As more than two-thirds of anthropogenic greenhouse gas (GHG) emissions are related to the energy sector (IEA, 2018, p.3), low-carbon renewable energy (RE) sources (IPCC, 2012, p.124) are likely to help curb emissions. However, fossil fuel sources have continued to dominate total energy consumption over the past few decades, while RE consumption increases slowly. Indeed, even though RE technologies, in particular wind and solar, have been known for decades, their large scale deployment takes time (Fouquet, 2016). This reveals the existence of barriers to, and factors facilitating, RE technologies' deployment (see for instance Painuly, 2001). Furthermore, significant differences exist between countries regarding RE development levels (Reboredo, 2015).[1]

Building on this context, this chapter aims to better understand the empirical determinants of RE deployment at the country level. It thus contributes to the energy economics literature by exploring the relationship between renewable energy aggregates and, among others, macroeconomic, environmental, and other energy variables at a country level. In the recent years, and following the seminal papers of Sadorsky (2009a,b) and Chang et al. (2009), a flourishing literature has indeed emerged to identify the quantitative factors that prompt RE deployment at a country level. However, the very understanding of the determinants of RE development remains limited, in part due to the use of different methodologies and frameworks (Şener et al., 2018). The literature on the factors that impact RE

[1] For example, computed based on data from BP (2019) (excluding hydropower) the share of RE sources in primary consumption (resp. in electricity generation) in 2018 reached 15% in Germany (32%), 9% in the European Union (21%), 5% in the United States (10%), 4% in China (9%), and is still close to zero in many countries.

deployment has been surveyed in two major contributions. Şener et al. (2018) review both qualitative and quantitative papers to identify categories of determinants but the detailed methodologies, indicators, and economic mechanisms identified are not precisely discussed. In a slightly older paper, Darmani et al. (2014) review papers focusing only on a limited sample composed of eight European countries, and restrict the analysis to four RE sources (solar, wind, and wave energies, and biomass), for which they propose a typology of drivers.

In this chapter, I extend these contributions by carrying out a comprehensive literature review of the empirical determinants of RE deployment at a country level. This allows me to identify and classify the main quantitative determinants investigated by econometric papers with samples of at least five countries. In addition to identifying the main directions for future research, investigating empirical determinants of RE deployment helps to shed some light on relevant policy recommendations. To do so, this chapter follows the guidelines prescribed by the Collaboration for Environmental Evidence (2018) and Pickering & Byrne (2014), Pickering et al. (2015) to conduct a systematic literature review. The methodology relies on a precise search strategy coupled with explicit paper selection criteria and specific research questions to systematically review the existing literature and provide objective results.

Regarding the design of econometric analyses, this chapter shows that RE development is assessed with different scopes and specifications (i.e., RE supply, consumption, or installed capacity taken as absolute level, *per capita* level, or share in total energy or electricity). Furthermore, varying RE sources are considered. Authors generally investigate a specific set of determinants among all possibles and the main control variables taken are: income, fossil fuel prices, electricity or energy consumption, CO_2 emissions, and regulatory variables (in particular RE support policies). Regarding the results, the review shows that (at first sight) there is little consensus regarding the influence of the determinants considered on RE deployment partly due to the differences in frameworks. However, a consensus emerges on a few mechanisms: (i) RE support policies and Kyoto Protocol (overall positive effect), (ii) lobby effect from traditional (or preexisting) energy sources (overall negative effect), (iii) population size (overall positive effect), (iv) ambiguous income effect (positive effect for developing countries, negative effect for European countries), (v) unclear effect of CO_2 emissions (negative effect for European countries, and dependent variable specified as a share in total energy supply, but positive when specified as a *per capita* level of consumption), (vi) counter-intuitive effect of energy security for European countries (negative effect), and (vii) local financial sector development and institutional quality levels

(overall no consensus based on papers count but positive effect when considering estimation results). In addition, some recommendations can be formulated for comparability between the papers, and to reduce misspecifications and production of misleading results in the perspective of policy guidance. In particular, they address the specification of dependent, and independent variables, and methodologies.

This chapter is organized as follows. Section 2.2 presents the literature review methodology used. Section 2.3 gives an overview of the frameworks of reviewed papers. Section 2.4 describes the determinants investigated by authors and their econometric results. Section 2.5 discusses the frameworks and formulates recommendations for future research. Finally, Section 2.6 concludes this review.

2.2 Survey methodology and search strategy

This section briefly presents the methodology used to carry out this literature review and details the data collection process and results.

2.2.1 Systematic review methodology

This chapter aims to systematically review the quantitative literature investigating the determinants of RE deployment. Contrary to conventional narrative literature reviews, this review relies on an explicit and detailed protocol to identify papers and produce an analysis and discussion of the existing literature. More precisely, the protocol is centred around the choice of a combination of keywords that form a search string used to identify papers. By relying on precise criteria and formulating specific research questions to select relevant contributions and review them, this methodology limits selection and analysis bias and strives to offer a comprehensive and objective view of the surveyed literature (Pickering et al., 2015).

In this chapter, I follow the methodology proposed by Pickering & Byrne (2014) and the Collaboration for Environmental Evidence (2018). First, the precise topic is defined and relevant research questions are formulated. Second, relevant keywords are selected for use in a chosen database. Third, precise selection criteria are formulated to select papers relevant to the topic investigated. Finally, the analysis is conducted by creating a database with explicit indicators selected to synthesize the information needed to answer the research questions. The systematic literature review methodology was first presented by health science researchers. It was used over the past few years for instance to review the literature in education (Riebe et al., 2016), urbanism (Boulton et al., 2018), sustainable and resilient urban food systems (Vieira et al., 2018), or place attachment in relation

to climate change engagement (Nicolosi & Corbett, 2018). However, to the best of my knowledge, it has not been used for RE related subjects.

2.2.2 Data collection and analysis

The methodology described previously was applied to the topic of empirical determinants of RE deployment, as detailed in Table 2.1. More precisely, this chapter seeks to address a primary research question related to the significance of the different determinants of RE deployment at a country level. To do so, several sub-research questions are formulated linked to: (i) the RE deployment measurements, (ii) the econometric framework of the reviewed papers, (iii) the determinants and the influence found (to map the existing literature and identify potential gaps), and (iv) possible recommendations for future research.

In relation to the research questions, a search string was designed with different categories of keywords to identify papers specifically looking at: (i) renewable energy sources, (ii) their use, (iii) potential related determinants, and with: (iv) an econometric approach, (v) conducted at a country level. Different synonyms are integrated to each categories linked with a Boolean "OR" and categories are linked using a Boolean "AND".[2] In addition to the combination of keywords, two specifications were also added to the search string: articles from disciplines not related to the research questions are excluded, and only articles and reviews in English are included to identify papers that can be found and understood by any reader. Besides this, as the review process started in early 2018, the articles published after December of 2017 are not considered. The search string was used in the Scopus database. The choice of Scopus is motivated by its interdisciplinary coverage (approximately 21,000 journals) and because it has been recently used to conduct literature reviews and bibliometric analyses in relation to renewable energy (Alcayde et al., 2018, Perea-Moreno et al., 2018).[3]

The database keywords search strategy enabled to identify 1,725 results (see Table A.1 in Appendix A.1 for the number of document results obtained at each step and a more precise description of the search string). First, the title and abstract of the 1,725 results were read in order to evaluate their accordance with the topic investigated. Then, if an article was considered eligible or if there was any doubt, the full article was read. To be included in the list of reviewed papers, several criteria were defined in relation to the research questions. More

[2]It should be noted that authors investigating the determinants of RE deployment use very different phrases that is why a large number of synonyms are considered to prevent any article from being missed.

[3]For these reasons and due to the similarities of coverage between Scopus and Web of Science, I decided to rely on Scopus. I expect that the number of relevant papers that could have been identified using the Web of Science database would be similar.

precisely, only papers using a measure of RE deployment as the main dependent variable, with the aim to investigate its determinants, are considered. The focus of this chapter is on RE sources in general. Thus, the papers reviewed look at three or more RE sources. In addition, for public policy recommendations and to reduce country-specific results, papers considering fewer than five countries are excluded from this review.

1. – Topic
Country level empirical determinants of RE deployment
2. – Research questions
Primary research question: What is the significance of the different determinants of RE deployment at a country level? *Sub-research questions:* – What are the different measures of RE deployment? – What kind of econometric models and estimation techniques are used to assess the influence of potential determinants on RE deployment? – What are the different determinants that were investigated and what is the influence found on RE deployment? – What recommendations can be formulated for future research?
3. – Keywords of the search string
(renewable* OR "renewable energ*" OR "renewable electric*") AND (invest* OR source* OR generat* OR technolog* OR consum* OR deploy* OR diffus* OR develop*) AND (motiv* OR factor* OR driv* OR promot* OR determin* OR influence* OR relation* OR impact* OR potential* OR affect*) AND (panel OR estimat* OR regression OR data*) AND (countries* OR states*)
4. – Papers' database
Scopus
5. – Selection criteria
– The econometric paper was published in English in a peer-reviewed journal, – A measure of RE deployment is the main dependent variable to investigate RE development determinants, – Three or more RE sources are considered, – The analysis is conducted at a country level and the sample population is composed of at least five countries.

Table 2.1 Methodology for identification and selection of relevant papers.

Source: author's work based on Pickering & Byrne (2014), Pickering et al. (2015), and the Collaboration for Environmental Evidence (2018).

To conduct the analysis, a database[4] was created with quantitative information extracted from the papers. Adapting the typology of Şener et al. (2018), this chapter reviews the literature based on the following categories of determinants: (i) Economic (income, prices, international flows, and local financial sector development), (ii) Energy (security, consumption, mix, and local fossil fuels), (iii) Environmental, (iv) Population, (v) Regulatory and political, and (vi) RE potential. Table A.2 in Appendix A.2, presents the different categories of independent variables considered in each of the papers reviewed. To report the influence of an independent variable on RE deployment, a results count (positive, negative, or not significant) for each inclusion in an econometric model estimated was done. To aggregate all the results for one variable, it is considered to be a consensus on the positive (respectively negative) influence only if there is a majority of positive (respectively negative) results. The so-called no consensus result derives from a majority of not significant results or from an absence of majority of positive or negative results.

2.2.3 Result of the search strategy: overview of the relevant papers identified

The 48 papers included in this review were published between 2009 and 2017. Figure A.1, in Appendix A.3, presents the breakdown of papers per publication year. 2011 and 2014 were particularly prolific years and a growing number of papers were published in recent years. In addition, as it can be seen in Table A.3 in Appendix A.3, the papers reviewed were mostly published in energy specialized journals with Energy Economics, Energy Policy, and Renewable and Sustainable Energy Reviews composing the top three. It is also to be noted that certain authors have contributed several times to this strand of literature, e.g, Marques and Fuinhas, Apergis and Payne, and Romano and Scandurra.

Besides this, the reviewed papers do not systematically make reference to previous papers that investigate the empirical determinants of RE deployment. Table A.2 in Appendix A.3, presents a citation network of the different papers reviewed. The central position of the following articles is noticeable: Sadorsky (2009a,b) (only cited) and Marques et al. (2010) (that cites previous articles and is cited many times). Interestingly enough, despite the fact that the article of Chang et al. (2009) was published early, it was relatively rarely cited. The clustering operated by the software (VOSviewer) also reveals that some researchers are mainly referring to a limited group of articles which makes this branch of literature quite

[4]The database constructed is available upon request. In addition to descriptive information about the papers reported in lines, diverse columns are used to describe the dependent and independent variables and the framework of the authors (methodology, period of time, and sample of countries considered).

fragmented. Finally, four articles that were identified do not either cite any previous papers nor are being cited by any reviewed papers.[5]

2.3 Current frameworks to investigate RE deployment determinants

This chapter aims to better understand RE deployment dynamics at a country level. As suggested by Kalimeris et al. (2014), this section reviews the methodologies considered in the literature to analyze the comparability of the results that will be discussed in Section 2.5.

2.3.1 RE deployment measurement

Interestingly enough, relatively few authors precisely define RE sources. Furthermore, authors consider different indicators of RE deployment with diverse specifications and types of energy sources included as presented in Table 2.2. Indeed, in the reviewed papers RE sources are used in: absolute levels (21% of the papers), *per capita* levels (29%), or levels as a share of total energy or electricity (46%). A small number of papers take two different types of indicators (Carley et al., 2017, Lin & Omoju, 2017). Moreover, the scope of the indicator selected can be energy supply (59% of the papers), energy consumption (31%), or installed capacity (8%). A small number of papers includes two different scopes (Nicolini & Tavoni, 2017).

[5]Despite this and due to the limited number of papers identified, these papers (Apergis & Eleftheriou, 2015, Bayulgen & Ladewig, 2017, Bengochea & Faet, 2012, Cheon & Urpelainen, 2013) were included in the list of reviewed papers.

	Absolute level	***Per capita* level**	**Share**	**Absolute level and share**	**Total**
Supply	– All RE (2.1%) – All RE elec. (2.1%) – All RE elec. and non-hydro RE elec. (2.1%)	– All RE (2.1%) – All RE elec., hydro and non-hydro RE elec. (2.1%) – Non-hydro RE elec. (2.1%)	– All RE (18.8%), – All RE elec. (8.3%) – Non-hydro RE elec. (10.4%) – All RE elec., hydro and non-hydro RE elec. (2.1%) – Hydro and non-hydro RE elec. (2.1%)	– All RE elec., non-hydro RE elec. (2.1%) – Non-hydro RE elec. (2.1%)	58.5%
Cons.	– All RE (8.3%) – Non-hydro RE (2.1%)	– All RE elec. (8.3%) – All RE (6.3%) – Non-hydro RE (2.1%)	– All RE (4.2%)		31.3%
Installed capacity	– Non-hydro RE elec. (2.1%)	– Non-hydro RE elec. (6.3%)			8.4%
Supply and capacity	– All RE and incentivized RE elec. (2.1%)				2.1%
Total	20.9%	29.3%	45.9%	4.2%	100%

Table 2.2 Dependent variables and RE sources considered by reviewed papers (percentages in total, small differences due to rounding).

Source: author's work.
Note: "elec." = "electricity", "cons." = "consumption".

Unlike Şener et al. (2018), it is difficult here to distinguish which RE sources are integrated given that this level of detail is rarely provided in the papers. Generally speaking, nearly half of the papers look at RE sources for energy in general whereas the other half investigate electricity generated from RE sources. Furthermore, certain authors exclude or account for differences in the development of hydroelectricity compared to other RE sources (40% of the papers). Besides this, several authors (e.g., Best, 2017, Popp et al., 2011, Zhao et al., 2013), show separate results for each RE source to investigate the influence of determinants at a disaggregated level.

2.3.2 Samples and methodologies

As can be seen in Table 2.3, the countries sampled vary among papers. Overall, authors either carry out a global analysis with developed and developing countries together (35% of the papers), or focus on developed (42%) or developing countries (23%).[6] The overall average number of countries is 41. The average reaches 72 countries for samples at a global scale (developed and developing countries taken together). The number of countries selected ranges from 5 (Nicolini & Tavoni, 2017, Zeb et al., 2014) to 164 (Carley et al., 2017). Additionally, 21% of the papers focus on European countries in a broad or a narrow sense (all or some members of the European Union (EU)). These papers mostly consider a dependent variable reflecting the development of all RE sources as a share of total energy produced. Furthermore, the majority of papers considering samples of countries at a global scale were published in 2016 and 2017 with a particular focus on dependent variables specified as a share of RE sources in electricity generation. It is worth mentioning that, with the exception of Romano & Scandurra (2014), papers focusing on developing countries do not measure RE deployment as a share of the energy mix.

In addition to the economic development and geographic criteria,[7] some authors also select countries based on: (i) the human development index (Carley et al., 2017), (ii) the carbon intensity of gross domestic product (GDP) (Romano & Scandurra, 2011), (iii) membership to the Organization of the Petroleum Exporting Countries (OPEC) (Romano & Scandurra, 2014) and more broadly the production of oil (Ackah & Kizys, 2015), or (iv) the presence of nuclear power plants (Romano & Scandurra, 2016). Certain authors use these typologies to compare their results.

[6] Whenever authors refer to emerging or transitioning countries, they are here considered as developing countries.

[7] A few authors also specifically look at countries in Central or South America, Africa, and Asia. Furthermore, in accordance with the selection criteria, all papers focusing solely on the United States with state level data were not reviewed in this chapter.

Economic development level	Papers	Countries				Period			
	(%)	(min)	(max)	(av)	(sd)	(min)	(max)	(av)	(sd)
Global (developed and developing)	35	16	164	72	50	3	39	21	9
Developing	23	5	119	31	42	10	42	29	8
Developed (European)	21	5	30	21	7	8	24	16	5
Developed (global)	21	6	30	20	8	10	32	20	8
Total	100	5	164	41	42	3	42	22	9

Table 2.3 Settings of the reviewed papers.

Source: author's work.
Note: "'%" = "percentage", "min" = "minimum number", "max" = "maximum number", "av" = "average number", "sd" = "standard deviation".

As shown in Table 2.3 the analysis time frame ranges from 3 (Narbel, 2013) to 42 years (Ackah & Kizys, 2015), with an average of 22. For more than one third of the papers, the analysed period starts in 1980 or earlier, for about another third it begins in 1990, and for the last third it commences in the 1990's or later. Due to a lack of data availability, the dataset generally ends several years before the analysis.

Table 2.4 shows the econometric methodologies used by the various papers. Almost all papers conduct panel data analyses to take advantage of time-varying differences between countries. More precisely, 21% of the papers conduct cointegration analysis and Granger causality tests, 44% of them adopt static panel model with a diversity of estimation techniques (see Table A.2 in Appendix A.2 for more details), and 19% of the authors use dynamic panel model (mostly with Generalized Method of Moments (GMM) estimators). In addition, three papers compare both static and dynamic model results (Ackah & Kizys, 2015, Brunnschweiler, 2010, Marques & Fuinhas, 2011). There is no specific pattern of methodologies used based on papers publication year. However, with the exception of Marques & Fuinhas (2011) that also use dynamic model, papers focusing on European countries only consider static panel model estimation techniques. In relation to the types of dependent variables, as can be seen in Table A.4, in Appendix A.4, no dynamic panel model estimation technique was tested for installed capacity, either in absolute terms or normalized *per capita*. For papers with dependent variables specified as a share in total energy or electricity, more than half of the papers opt for static panel model estimation techniques and more than one fourth for dynamic models. Dynamic panel model estimation techniques have been used mostly with samples of countries at a global scale and particularly for dependent variables specified as a share of RE sources in electricity generated. Additionally,

cointegration techniques, are mainly applied for dependent variables specified as *per capita* level of consumption of RE sources.

Methodologies	**Papers (%)**
Static panel model estimation techniques	44
Panel cointegration and Granger causality tests	21
Dynamic panel model estimation techniques	19
Static and dynamic panel model estimation techniques	6
Others	10

Table 2.4 Methodologies of the reviewed papers.

Source: author's work.
Note: "'%" = "percentage".

2.4 Determinants investigated

To complete the overview of the empirical frameworks used in the relevant literature, this section focuses on the different categories of factors addressed, the mechanisms investigated, and the results for each determinant of RE deployment. The data sources for the different variables are presented in Table A.5 in Appendix A.4.

2.4.1 Overview

As illustrated by Şener et al. (2018), various categories of potential RE deployment determinants can be distinguished. The empirical literature is split accordingly. The authors either, simultaneously investigate several categories of determinants to identify the main ones (usually relying on a sample of international countries), or focus on a specific category of factors (controlling for one or several others). Table 2.5 presents the main topic of interest to authors as stated in the papers. If in early years the literature concentrated on economic and environmental factors, it expanded and diversified over the past few years to various categories of determinants. More recently, a growing number of papers has investigated the impact of regulatory and political changes (together or separately), especially with dependent variables expressed as a share and for global samples of countries or samples of European countries. Economic factors are also a major and regular interest of this literature, especially with regards to financial aspects. Other subject matters include energy security with a dependent variable representing a share of RE, and technological innovation for samples of developed countries at a global scale.

Authors' categories of interest	Papers (%)	Maximum number of independent variables (av)	(sd)
Regulatory and political	27	14	4
Diverse	23	13	8
Economic and environmental	23	4	2
Economic	19	6	3
Energy security	4	10	5
Technological innovation	4	9	6
Total	100	10	6

Table 2.5 Determinants' categories of interest of the reviewed papers and maximum number of independent variables considered simultaneously.

Source: author's work.
Note: "%" = "percentage", "av" = "average number", "sd" = "standard deviation".

As shown in Table 2.5, the maximum number of variables considered simultaneously varies depending on the author's categories of interest. More specifically, when authors investigate primarily economic, and economic and environmental determinants, the maximum number of independent variables is the lowest with an average respectively of 6 and 4. This average reaches 14 for the authors investigating specifically regulatory and/or political aspects. Overall, the average maximum number of variables considered simultaneously is 10.

2.4.2 Main determinants considered

I will now review in further detail the categories of determinants. Table 2.6 presents the main independent variables considered in the papers,[8] and their expected and estimated impact on RE deployment.

[8]Other determinants considered by few authors include: population characteristics (human capital, poverty, female or working-age population ratios) (Ackah & Kizys, 2015, Apergis & Eleftheriou, 2015, Pfeiffer & Mulder, 2013, Romano et al., 2017, Zeb et al., 2014, Zhao et al., 2013), official development assistance and clean development mechanism (Baldwin et al., 2017, Brunnschweiler, 2010, Carley, 2009, Pfeiffer & Mulder, 2013), physical potential of RE sources in general (Bayulgen & Ladewig, 2017, Best, 2017, Marques et al., 2010, 2011) or specific to some RE technologies (Aguirre & Ibikunle, 2014), political system related variables (Apergis & Eleftheriou, 2015, Cadoret & Padovano, 2016, Cheon & Urpelainen, 2013), EU membership (Biresselioglu & Karaibrahimoglu, 2012, Cheon & Urpelainen, 2013, Marques et al., 2010, 2011), knowledge accumulation related to RE patents (Cheon & Urpelainen, 2013, Geng & Ji, 2016, Popp et al., 2011), capital accumulation or flow (Ackah & Kizys, 2015, Lin & Omoju, 2017), fossil fuel rents (Baldwin et al., 2017, Bayulgen & Ladewig, 2017, Carley et al., 2017, Lin & Omoju, 2017), resources depletion (Ackah & Kizys, 2015, Zeb et al., 2014), energy or electricity mix concentration (Pfeiffer & Mulder, 2013, Valdés Lucas et al., 2016), power sector reforms (Aguirre & Ibikunle, 2014, Brunnschweiler, 2010), industrial or energy-intensive sector size (Cadoret & Padovano, 2016, Cheon & Urpelainen, 2013, Nyiwul, 2017), previous commitment to RE (Aguirre & Ibikunle, 2014, Cheon & Urpelainen, 2013, Marques & Fuinhas, 2012, Marques et al., 2010).

Table 2.6 Main independent variables considered by at least five authors.

Independent variables	Papers (%)	Countries	Scopes and types of dependent variable	Types of RE sources	Expected sign	Results
Economic variables	98					
Income	96	all	all	all	+	+, - or NC
Fossil fuel prices	48	all	all except absolute level of capacity, and share of consumption	all	+	+ or NC
Local financial sector	21	developing, global	all except *per capita* level and share of consumption, and *per capita* level of capacity	all except non-hydro RE sources for energy	+	+ or NC
Energy/electricity price	19	all	all except *per capita* level of capacity	all except non-hydro RE sources for energy	+/-	+, - or NC
International flows	19	developing, global	absolute and *per capita* level, and share of supply, and absolute level of consumption	all	+	NC
Environmental variable	67					
CO_2 emissions	67	all	all except *per capita* level of capacity	all	+/-	+, - or NC
Energy variables	60					
Energy/electricity consumption	48	all	all except absolute and *per capita* level of consumption and absolute level of capacity	all except non-hydro RE sources for energy	+/-	+, - or NC
Other sources weight in the mix	44	all	all except absolute and *per capita* level of consumption	all except non-hydro RE sources for energy	-	- or NC
Energy security	42	all except developing	all except *per capita* level of supply, absolute and *per capita* level of consumption	all except non-hydro RE sources for energy	+	- or NC
Fossil fuel production	10	all except developed (European)	*per capita* level and share of supply, and *per capita* level of capacity	all except non-hydro RE sources for energy	+/-	NC
Regulatory variables	48					
RE support policies	40	all	all except absolute and *per capita* level of consumption	all except non-hydro RE sources for energy	+	+ or NC

Table 2.6 Main independent variables considered by at least five authors (cont.).

Independent variables	**Papers (%)**	**Countries**	**Scopes and types of dependent variable**	**Types of RE sources**	**Expected sign**	**Results**
Kyoto Protocol	15	all	absolute and *per capita* level and share of supply, and *per capita* level of capacity	all except non-hydro RE sources for energy	+	+ or NC
Political variables	23					
Institutional quality	17	all except developed (global)	all except *per capita* level of consumption, and absolute and *per capita* level of capacity	all except non-hydro RE sources for energy	+	+ or NC
Government ideology (left)	13	all except developing	absolute level and share of supply, share of consumption, and absolute level of capacity	all except non-hydro RE sources for energy	+	+ or NC
Demographic variable	17					
Population size	17	all except developed (global)	all except *per capita* level of supply, and absolute and *per capita* level of capacity	all except non-hydro RE sources for energy	+/-	+, - or NC

Source: author's work.

2.4.2.1 Economic variables

Generally speaking, except for Marques & Fuinhas (2012), every author considered at least one economic variable as a control variable. In their papers, Sadorsky (2009a,b) and Chang et al. (2009) were the first authors to investigate some economic determinants of RE deployment. Following these papers, income (generally taken as GDP *per capita*) is the most frequently used variable. Indeed, authors often assert that an increase in income might lead to a higher energy consumption, including from RE sources (see for instance Omri & Nguyen, 2014, Salim & Rafiq, 2012). Moreover, some authors claim that higher income could foster RE deployment by raising the (financial) resources that can be dedicated to investment in capital intensive RE projects, or to fund regulatory RE supportive incentives (see for instance Aguirre & Ibikunle, 2014, Pfeiffer & Mulder, 2013). Income appears to have a positive influence on RE development in the papers focusing on developing countries. The positive influence is documented with dependent variables representing *per capita* consumption of RE sources and also when considering RE sources for electricity. However, a negative influence is found for European countries, and there is no consensus for samples of developing and developed countries taken together and for samples of developed countries at a global scale. An explanation given by Cadoret & Padovano (2016) is that a high energy demand, resulting from high economic activity, may offset the income effect meaning that after a certain threshold, income has a negative influence on RE deployment because RE sources might not be able to immediately meet this increase in demand.

The (international) price of fossil energy was introduced by Sadorsky (2009b), provided RE and fossil energy sources (particularly oil) are possible substitutes. A little less than half of the papers follow this insight (i.e., introducing the price of oil and occasionally of gas and coal) expecting that an increase in the price of fossil fuel should *ceteris paribus* lead to a decrease (resp. increase) in fossil fuel (resp. RE sources) consumption (substitution effect). However, overall no clear consensus is observed. Nonetheless, a positive influence is found when authors are taking *per capita* level of RE sources consumption as the dependent variable. On the other hand, if no price of fossil fuel is introduced, 19% of the papers consider another price variable for energy or electricity.[9] The expected influence is not clear for authors. In an early study, Chang et al. (2009) observe a threshold effect regarding the pace of economic growth, measuring a positive influence of energy price on the share of RE in energy supply for countries with high economic growth in the previous period. However, in the majority of papers, there is

[9] Only Aguirre & Ibikunle (2014) have both fossil fuel prices and electricity price in their model.

no clear consensus regarding the existence of an influence of energy or electricity price on RE development.

Moreover, for Brunnschweiler (2010), RE deployment is expected to be supported by developed local financial sectors, particularly the banking sector. 21% of the papers reviewed investigate the influence of the development of the local financial sector on RE deployment with diverse variables for developing countries and samples of international countries, or consider a few ones as control variables (see the full list in Table A.6 in Appendix A.4). When more than two indicators are taken together, there is evidence of a positive influence on RE deployment. However, when only one or two indicators related to financial development are taken, the authors generally have no significant findings. Besides this, if overall there is no consensus based on papers count, when considering estimation results, a positive influence is documented.

Finally, 19% of the reviewed papers also control for the size of international flows (i.e., trade openness, and/or foreign direct investment) only for samples of developing countries and at the global scale. A positive influence on RE sources is expected mainly in relation to technology and knowledge transfers, even though it may depend on the country specifics, e.g., physical and human capital, environmental regulations (Pfeiffer & Mulder, 2013). Indeed, globally authors find no clear proof of the existence of a significant relationship.

2.4.2.2 Environmental variable

Following the early contribution of Sadorsky (2009b), 67% of the reviewed papers introduce an environmental indicator (related to CO_2 emissions) as a proxy for environmental concerns and degradation in relation to global warming. Overall, authors expect an increase in CO_2 emissions to lead to a higher use of low-carbon RE sources. Nevertheless, for Marques & Fuinhas (2011, p.353), a negative influence could also reflect the apathy of societies towards environmental issues because it "creates political conditions to maintain the commitment with fossil fuels". Moreover, for Valdés Lucas et al. (2016), the dependency on fossil fuels and the power of lobbies might balance out environmentally friendly (and thus pro RE) policies. These conflicting mechanisms might explain why, different conclusions are documented. Indeed, a positive influence is found when considering the *per capita* level of RE consumption. However, a negative influence is observed when taking the overall estimation results (but not based on papers count), for samples of European countries, and when authors consider a share of RE in total supply as dependent variable.

2.4.2.3 Energy variables

The impact of energy indicators has been extensively addressed in the literature (60% of the reviewed papers), partly to control for countries characteristics. In particular, about half of the papers, state that an increase in energy (or electricity) consumption (or intensity) could be satisfied with both RE and conventional energy sources thus having an unclear expected influence on RE deployment. Indeed, there is no clear consensus on the existence and direction of a relationship between energy (electricity) demand and RE deployment. It should be noted that a positive influence is found if one considers all RE sources for energy.

In addition, most of the authors, particularly those investigating European countries, control for the weight of other sources in the electricity or energy mix. This is done because of the potential lobby effect of existing energy technologies (fossil fuels, nuclear, and hydro energies), due to their past and present relative prevalence on investments, employment and economies in general (Marques et al., 2010). Moreover, due to their low carbon intensity, a large development of nuclear and/or hydro power is expected to have a negative influence on RE deployment (Pfeiffer & Mulder, 2013). Whatever the level of economic development, a higher level of energy produced from fossil fuels and nuclear power plants (and also of hydro power, which is included in a small number of papers) is indeed likely to have a negative impact on RE deployment. It is well documented for global samples of countries and European countries. The impact is particularly clear when the dependent variable taken by authors is specified as a share in total energy generated.

The energy security issue is specifically addressed in two papers (Narbel, 2013, Valdés Lucas et al., 2016). 42% of the reviewed papers include one or more related variables such as energy import dependency or electricity imports. Indeed, the attempt to reach energy self-sufficiency, i.e., reducing imports, is expected to have a positive influence on the development of RE sources (Marques et al., 2010). However, there is no consensus for samples at a global scale. Restricting to European countries, a counter-intuitive negative influence of energy security emerges, supporting the lobby effect of traditional sources mentioned earlier (Marques & Fuinhas, 2012). In addition, surprisingly this variable was never considered for a sample of developing countries only.

Finally, 10% of the authors control for the level of fossil fuel production. They also note that a lobby effect of traditional energy sources, i.e., a local production of fossil fuels, could reduce the price of fossil fuels and diminish energy security and global warming concerns (Pfeiffer & Mulder, 2013), thus negatively impacting RE development. However, in their study of oil producing countries, Romano

& Scandurra (2014), argue that increasing oil extraction could encourage RE investments to cope with a more rapid depletion of this resource. Nevertheless, there is no consensus in the authors' results.

2.4.2.4 Regulatory variables

About half of the papers include a variable related to countries' regulatory context. Following the early papers of Menz & Vachon (2006) and Carley (2009), RE support policies were considered by 40% of the reviewed papers. For Marques & Fuinhas (2012, p.110) "[there] is broad consensus in the literature concerning the need for public intervention to promote RE use". As a result, the existence of support policies is expected to have a global positive influence on RE development. Authors use either diverse categories of support policies, or support measures at a disaggregated level (e.g., feed-in tariffs). A few authors combine national and supranational policies (e.g., RE development targets assigned by the EU). Despite the fact that there is no clear consensus for samples of global developed countries and of developing and developed countries taken together, overall support policies are found to have a positive influence on RE deployment (particularly when measured as a share in energy supply). Some authors insist on the fact that there are different impacts associated with diverse policies. For instance, voluntary instruments are found to have a rather negative influence (Aguirre & Ibikunle, 2014, Zhao et al., 2013).

To control for the influence of other energy or green policies, some papers include one or several related variables. The most commonly used (in 15% of the papers) addresses the implementation or the ratification of the Kyoto Protocol. Indeed, the Kyoto Protocol is viewed as a change in the commitment of countries towards global warming, and more specifically towards RE sources (Brunnschweiler, 2010). Overall, authors find a positive influence of the Kyoto Protocol on RE deployment with less clear results when looking at the diverse types of country samples.

2.4.2.5 Political variables

The political environment complements the regulatory environment, and is a dimension investigated by a few papers (23%). The main indicators selected encompass institutional quality (e.g., democracy, governance; see the full list in Table A.7 in Appendix A.4) and government ideology (e.g., left or right wing ruling party). For Brunnschweiler (2010, p.251), "[it] is in fact likely that RE projects, like other types of investment projects, benefit from general political stability, sound

regulatory frameworks, effective governance and secure property rights.". Indeed, institutional quality is expected to have a positive influence on RE development (Wu & Broadstock, 2015). No clear consensus about the impact of this factor emerges from the literature based on the number of papers. However, overall the result associated with the inclusion of such independent variables in estimations suggests a positive relationship. In addition, regarding government orientation, leftist parties are generally viewed as more environmentally conscious and thus more likely to favour RE deployment (Nicolini & Tavoni, 2017). However, there is no clear consensus in the reviewed papers. It is to be noted that this type of independent variable was never investigated with a sample of developing countries only.

2.4.2.6 Demographic variable

Few of the reviewed papers (17%), control for population size or growth dynamic. Indeed, for Aguirre & Ibikunle (2014) the sign of a potential influence is not clear. An increase in population is expected to increase energy demand. If the latter increase is too high, it may discourage RE deployment in favor of conventional sources. Overall, it seems that population size is found to have a positive influence on RE deployment, even if this is less clear when looking at the different types of samples of countries.

2.5 Discussion of the results

This section builds on the overview of the frameworks and determinants described in Section 2.3 and 2.4 to provide a synthesis of the main results of the empirical literature on RE deployment and discuss them to formulate some recommendations for future research.

2.5.1 Synthesis of the main results

Economic, environmental, energy, regulatory, and to a lesser extent political, and demographic determinants have been discussed by the reviewed literature. A consensus emerges on a few mechanisms: (i) RE support policies and Kyoto Protocol (positive effect), (ii) a lobby effect from traditional (or preexisting) energy sources (negative effect), and (iii) population size (positive effect). In addition, several results are counter-intuitive or worth discussing. Contrary to what is found by Şener et al. (2018), the reviewed papers do not find that income has a systematic positive influence. Indeed, overall, there is no consensus but an ambiguous impact of income when considering the different types of samples of countries based on economic development level (positive effect for developing

countries, negative effect for European countries). Additionally, when counted as the number of papers, there is no consensus regarding the influence of CO_2 emissions on RE deployment. However, when taking the number of estimation results, it appears that there is a rather negative influence of CO_2 emissions and this is also found by authors looking at samples of European countries and considering the deployment of RE sources with a dependent variable representing a share in the mix. A positive influence of CO_2 emissions is documented for a dependent variable representing *per capita* level of energy or electricity consumption. While a positive influence of energy security is expected, there is no global consensus and even a negative influence for European countries. Moreover, when taking the number of papers, there is no consensus regarding the influence of the local financial sector development and institutional quality levels. Nevertheless, these two types of independent variables appear to have a positive influence when considering all estimation results.

Hence, the seemingly fragile consensus regarding the influence of the determinants of RE deployment investigated by the literature (presented in Table A.8 in Appendix A.5) should be tempered by the variety of frameworks, samples, and specifications used by authors. The differences can lead to misinterpretations, especially whenever a unique mechanism is assessed through different (and non-comparable) specifications of the dependent variables. Table A.9 in Appendix A.5 details this decomposition and suggests that this contradiction partly disappears with each choice of specification. Furthermore, the databases considered by the authors vary, as can be seen in Table A.5 in Appendix A.4.[10] Lastly, as illustrated by Table A.10 in Appendix A.5, commonalities are also documented within similar samples of countries.

2.5.2 Discussion and recommendations

The relative lack of consensus that appears at first glance regarding the influence of the determinants considered on RE deployment can be partly explained by the different methodologies and frameworks of the papers. Therefore, this final section provides some elements to guide future research and to structure the policy recommendations that can be derived from this literature.

[10] Overall, data from the United States Energy Information Administration are mainly used for the dependent variables but other sources are also found (e.g., the International Energy Agency). There is the same diversity of data sources for independent variables (income is an interesting example with eight different data sources).

2.5.2.1 RE deployment measurement

The literature reviewed lacks a clear and motivated definition of the indicator chosen to measure RE deployment, despite the critical impact the indicator can have on the results.[11] Moreover, coherent policy recommendations can only be formulated based on a common approach. As a result, misspecification issues and particularities related to RE sources need to be addressed by the literature.

Indeed, the indicators used to measure RE deployment fall into three categories: absolute, or *per capita* levels, and share (of the mix). To investigate the determinants of RE deployment, a simple absolute level measure is not completely applicable due to the differences in population, economic development, and energy market conditions across countries. It is thus crucial to standardize the dependent variable used to account for the deployment dynamic of RE sources. Moreover, one should distinguish an *absolute* and a *relative* definition of the RE deployment. The first one refers to an absolute increase, while the second one captures the substitution potential of RE sources. The second definition seems more appropriate because: (i) governments generally set share targets for RE development, and (ii) to mitigate climate change, a substitution of fossil by RE sources is a mean to reduce GHG emissions (Aguirre & Ibikunle, 2014, Marques & Fuinhas, 2012). From this perspective, normalizing by population size still corresponds to an absolute definition of deployment (an increase in *per capita* level of RE sources does not necessarily imply that its relative share in total energy is increasing). Besides this, no author has considered measuring RE deployment as a share in total installed capacity.

Moreover, the scope of the dependent variable matters. RE production and installed capacity correspond to the energy and industrial policy choices of a given country, whereas RE consumption represents the actual use of RE sources of a country, provided RE consumption encompasses net imports. For instance, a high national deployment of intermittent RE sources, might increase electricity imports resulting in a (relatively) lower rise in RE consumption. As a result, the commitment of a country (materialized by its energy policy orientations) is better evaluated by the supply or installed capacity of RE sources.

Last but not least, only considering RE sources for electricity is too restricting in the sense that RE sources can also be used for heat and for the transport sector.[12] Furthermore, hydro power has specific technical characteristics (Omri & Nguyen, 2014) and can thus potentially have different determinants compared

[11] For instance, as shown in Table A.9 in Appendix A.5, the results for CO_2 emissions depends on the scope considered (i.e., RE supplied, consumed or installed capacity) and the type of indicator (absolute or *per capita* levels, or share).

[12] As per the REN21 (2018) report, the power sector represents about 20% of the total final energy consumption in the world with about 25% from RE sources. RE sources are also used for

to other RE sources. Moreover, hydroelectricity has potential negative social and environmental consequences (Pfeiffer & Mulder, 2013) and is already highly exploited in many countries (Lin & Omoju, 2017). That is why separating hydro from non-hydro RE sources might be relevant.

The choice of another dependent variable can be coherent if, and only if, it is motivated. For instance, Brunnschweiler (2010) justifies the choice of *per capita* values given that total energy supply might be highly correlated with some independent variables integrated in the model (financial sector development variables). In addition, as Kim & Park (2016) want to reflect investment decisions, they decide to select a measure of RE development with installed capacity because electricity generated with RE sources is influenced by factors difficult to control for investors, e.g., meteorology. Moreover, considering diverse dependent variables to account for the particularities of different RE sources (e.g, distinguishing between hydro and non-hydro sources) could be of significant interest to identify the existence of specific dynamics and preclude bias in the assessment.

2.5.2.2 Determinants considered and to be investigated

Several categories of determinants have been considered. Economic and energy variables have received particular attention with the main control variables being: income, fossil fuel prices (mainly oil), and energy or electricity consumption. CO_2 emissions, the only environmental variable used, and regulatory variables (in particular RE support policies) are also control variables taken by more or about half of the papers. Among other possible control variables, few authors have tried to diversify the possible variables that could reflect the existence of a lobby effect from traditional energy sources. Examples of possible control variables (subject to data availability) are: the size of the (conventional) energy sector in the economy, the size of brown public subsidies, or else local fossil fuel reserves. This analysis could be particularly interesting in the case of European countries. Furthermore, very few papers control for the potential of RE sources associated with natural resources, while "[the] feasibility of renewable energy options depends to a large extent on geophysical characteristics of the area where the option is implemented" (IPCC, 2018, Chap.4, p.18).

Regarding the independent variables of interest, it could be interesting to consider other environmental performance measures, especially because it is not certain that CO_2 emissions capture the entire relationship between environmental consideration and the choice of RE sources. Indeed, "[in] addition to reducing

heat (close to 50% of the world consumption with about 30% from RE sources) and transportation (around 30% of the world consumption with roughly 3% from RE sources).

GHG emissions, RE technologies can also offer benefits with respect to air pollution and health compared to fossil fuels" (IPCC, 2012, p.43). Moreover, more research is necessary to assess the impact of diverse national energy or green policies that are not directly related to RE sources, such as local energy market regulation or the existence of a carbon tax. Additionally, the socio-demographic dynamics have been rarely explored by the authors. The characteristics of the population and the attitudes towards RE technologies could influence the deployment of RE sources including at the country level (IPCC, 2018, Sovacool et al., 2015). Finally, authors looking only at samples of developed countries have not considered financial variables. As suggested by Mignon & Bergek (2016), some financial challenges can exist in developed countries for instance because RE technologies require a high upfront investment.

More generally, several specifications of a determinant are found in the reviewed papers.[13] The data sources might also be different. That is why, for comprehension, repeatability, and public policy orientation, it is essential that authors describe the mechanism being investigated, the data sources, and the precise specification of independent variables chosen, notably by referring to previous papers.

2.5.2.3 Methodological framework

In addition to the two aspects previously discussed, it is key to mention that the specification of the econometric model (and the related estimation techniques) are likely to influence the results obtained by the reviewed papers. For instance, focusing on the set of papers that define their indicator of RE deployment as a share in the total energy production (9 papers), which is advocated in this chapter to be a more accurate definition, most of the authors use static panel estimation techniques including: quantile regressions, fixed effects vector decomposition models, and/or panel corrected standard errors estimation methods (see Table A.2 in Appendix A.2 for more details).

Country-specific characteristics and the temporal dimension are two aspects that seem to be relevant in the inference and shall be considered by authors. For one thing, it is very likely that country-specific characteristics (meteorological conditions, natural resources endowment, existing policies, citizens' views on the RE sector, preexisting level of RE development *etc.*) do influence RE development patterns. For another, country might be hit by weather, climate, and economic shocks that could interact with RE deployment. Both of these aspects

[13] For instance, energy consumption is taken in absolute terms, or in relative ones divided by population or GDP.

shall thus be controlled for in estimations. Moreover, RE development, especially when measured as a share in production, is very likely to exhibit a path dependency, previous levels of installed capacities influencing new ones. Dynamic panel methods could capture the latter aspect. Besides this, as suggested by Marques & Fuinhas (2012, p.111), "heteroskedasticity, panel autocorrelation, and contemporaneous correlation phenomena must be adequately addressed" by authors. A complete set of specification and robustness checks is required to ensure the validity of the methodology used (this is not systematically done as of today).

If a more precise discussion of econometric specifications falls beyond the scope of this chapter, an additional methodological recommendation is to systematically justify the choice of econometric models and estimations techniques with regard to the research question addressed. Such a justification is central for the comprehension and the repeatability of the papers.

2.6 Conclusion

Understanding the determinants of RE deployment is essential because developing these low-carbon sources could be a way to reduce GHG emissions and thus mitigate global warming. To gain insight on the dynamics behind the development of RE sources, both for public policy recommendations and for structuring future research, this chapter aims at surveying the existing literature on related empirical determinants. It follows a systematic review methodology to describe and discuss the variety of measures of RE deployment considered and to detail the framework of the reviewed papers.

Indeed, different types of RE deployment metrics have been used in terms of: (i) scope (supply, consumption, or installed capacity), (ii) types of indicator (absolute, or *per capita* levels, or share), and (iii) energy sources (energy, electricity, or excluding hydroelectricity). Among the diverse specifications, a specification with a share of supply (or capacity) seems to better represent the commitment of countries towards RE deployment. Moreover, the authors have considered a variety of determinants, in particular economic and energy-related. The other main categories of determinants investigated are environmental, regulatory, political, and demographic. The main control variables are: income, fossil fuel prices, electricity or energy consumption, CO_2 emissions, and regulatory variables (in particular RE support policies). Even though, there is little consensus overall, in classifying the papers based on the types of dependent variables and samples of countries some significant results emerge. Indeed, a consensus exists on a few mechanisms: (i) RE support policies and Kyoto Protocol (overall positive effect), (ii) lobby effect from traditional (or preexisting) energy sources (overall negative

effect), (iii) population size (overall positive effect), (iv) ambiguous income effect (positive effect for developing countries, negative effect for European countries), (v) unclear effect of CO_2 emissions (negative effect for European countries and dependent variable specified as a share in total energy or electricity supply, but positive when specified as a *per capita* level of consumption), (vi) counter-intuitive effect of energy security for European countries (negative effect), and (vii) local financial sector development and institutional quality levels (overall no consensus based on papers count but positive effect when considering estimation results). In addition, some dimensions have been only rarely or partly explored, yet could shed new light on the RE deployment process after 1980. They include socio-demographic, environmental, or public policy aspects.

To conclude, the strand of literature to which the reviewed papers contribute is relatively new and fragmented. That is why, after mapping the existing literature, this chapter also formulates some recommendations to structure future research. It aims at favouring comparability between the papers and repeatability that are keys for relevant public policy guidance. More specifically, they target the choice of RE deployment measurements, the determinants investigated, and the methodologies considered. Finally, a meta-analysis could be the next step in order to go further in the analysis of the reviewed papers' results and methodologies.

2.7 Bibliography

Ackah, I. & Kizys, R. (2015). Green growth in oil producing african countries: A panel data analysis of renewable energy demand. *Renewable and Sustainable Energy Reviews*, *50*, 1157–1166.

Aguirre, M. & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy*, *69*, 374–384.

Alcayde, A., G. Montoya, F., Baños, R., Perea-Moreno, A.-J., & Manzano-Agugliaro, F. (2018). Analysis of research topics and scientific collaborations in renewable energy using community detection. *Sustainability*, *10*(12).

Apergis, N. & Eleftheriou, S. (2015). Renewable energy consumption, political and institutional factors: Evidence from a group of european, asian and latin american countries. *The Singapore Economic Review*, *60*(01), 1–19.

Baldwin, E., Carley, S., Brass, J. N., & MacLean, L. M. (2017). Global renewable electricity policy: A comparative policy analysis of countries by income status. *Journal of Comparative Policy Analysis: Research and Practice*, *19*(3), 277–298.

Bayulgen, O. & Ladewig, J. W. (2017). Vetoing the future: political constraints and renewable energy. *Environmental Politics*, *26*(1), 49–70.

Bengochea, A. & Faet, O. (2012). Renewable energies and co2 emissions in the european union. *Energy Sources, Part B: Economics, Planning, and Policy*, *7*(2), 121–130.

Best, R. (2017). Switching towards coal or renewable energy? the effects of financial capital on energy transitions. *Energy Economics*, *63*, 75–83.

Biresselioglu, M. E. & Karaibrahimoglu, Y. Z. (2012). The government orientation and use of renewable energy: Case of europe. *Renewable Energy*, *47*, 29–37.

Boulton, C., Dedekorkut-Howes, A., & Byrne, J. (2018). Factors shaping urban greenspace provision: A systematic review of the literature. *Landscape and Urban Planning*, *178*, 82–101.

BP (2019). *Statistical Review of World Energy*.

Brunnschweiler, C. N. (2010). Finance for renewable energy: an empirical analysis of developing and transition economies. *Environment and Development Economics*, *15*(3), 241–274.

Cadoret, I. & Padovano, F. (2016). The political drivers of renewable energies policies. *Energy Economics*, *56*, 261–269.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081.

Carley, S., Baldwin, E., MacLean, L. M., & Brass, J. N. (2017). Global expansion of renewable energy generation: An analysis of policy instruments. *Environmental and Resource Economics*, *68*(2), 397–440.

Chang, T.-H., Huang, C.-M., & Lee, M.-C. (2009). Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from oecd countries. *Energy Policy*, *37*(12), 5796–5802.

Cheon, A. & Urpelainen, J. (2013). How do competing interest groups influence environmental policy? the case of renewable electricity in industrialized democracies, 1989–2007. *Political Studies*, *61*(4), 874–897.

Collaboration for Environmental Evidence (2018). *Guidelines and Standards for Evidence synthesis in Environmental Management*. Number Version 5.0 (AS Pullin, GK Frampton, B Livoreil and G Petrokofsky, Eds).

Darmani, A., Arvidsson, N., Hidalgo, A., & Albors, J. (2014). What drives the development of renewable energy technologies? toward a typology for the systemic drivers. *Renewable and Sustainable Energy Reviews*, *38*, 834–847.

Fouquet, R. (2016). Historical energy transitions: Speed, prices and system transformation. *Energy Research & Social Science*, *22*, 7–12.

Geng, J.-B. & Ji, Q. (2016). Technological innovation and renewable energy development: evidence based on patent counts. *International Journal of Global Environmental Issues*, *15*(3), 217–234.

IEA (2018). *CO2 Emissions from Fuel Combustion 2018 Highlights*.

IPCC (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. Technical Summary.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC (2018). *Global Warming of* $+1.5^{\circ}C$*. Summary for Policymakers. An IPCC Special Report on the impacts of global warming of* $+1.5^{\circ}C$ *above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

Kalimeris, P., Richardson, C., & Bithas, K. (2014). A meta-analysis investigation of the direction of the energy-gdp causal relationship: implications for the growth-degrowth dialogue. *Journal of Cleaner Production*, *67*, 1–13.

Kim, J. & Park, K. (2016). Financial development and deployment of renewable energy technologies. *Energy Economics*, *59*, 238–250.

Lin, B. & Omoju, O. E. (2017). Focusing on the right targets: Economic factors driving non-hydro renewable energy transition. *Renewable Energy*, *113*, 52–63.

Marques, A. C. & Fuinhas, J. A. (2011). Drivers promoting renewable energy: A dynamic panel approach. *Renewable and Sustainable Energy Reviews*, *15*(3), 1601–1608.

Marques, A. C. & Fuinhas, J. A. (2012). Are public policies towards renewables successful? evidence from european countries. *Renewable Energy*, *44*, 109–118.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2010). Motivations driving renewable energy in european countries: A panel data approach. *Energy Policy*, *38*(11), 6877–6885.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2011). A quantile approach to identify factors promoting renewable energy in european countries. *Environmental and Resource Economics*, *49*(3), 351–366.

Menz, F. C. & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796.

Mignon, I. & Bergek, A. (2016). System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. *Journal of Cleaner Production*, *128*, 105–115.

Narbel, P. A. (2013). What is really behind the adoption of new renewable electricity generating technologies? *Energy for Sustainable Development*, *17*(4), 386–390.

Nicolini, M. & Tavoni, M. (2017). Are renewable energy subsidies effective? evidence from europe. *Renewable and Sustainable Energy Reviews*, *74*, 412–423.

Nicolosi, E. & Corbett, J. B. (2018). Engagement with climate change and the environment: a review of the role of relationships to place. *Local Environment*, *23*(1), 77–99.

Nyiwul, L. (2017). Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in sub-sahara africa. *Clean Technologies and Environmental Policy*, *19*(2), 437–450.

Omri, A. & Nguyen, D. K. (2014). On the determinants of renewable energy consumption: International evidence. *Energy*, *72*, 554–560.

Painuly, J. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, *24*(1), 73–89.

Perea-Moreno, M.-A., Hernandez-Escobedo, Q., & Perea-Moreno, A.-J. (2018). Renewable energy in urban areas: Worldwide research trends. *Energies*, *11*(3).

Pfeiffer, B. & Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics*, *40*, 285–296.

Pickering, C. & Byrne, J. (2014). The benefits of publishing systematic quantitative literature reviews for phd candidates and other early-career researchers. *Higher Education Research & Development*, *33*(3), 534–548.

Pickering, C., Grignon, J., Steven, R., Guitart, D., & Byrne, J. (2015). Publishing not perishing: how research students transition from novice to knowledgeable using systematic quantitative literature reviews. *Studies in Higher Education*, *40*(10), 1756–1769.

Popp, D., Hascic, I., & Medhi, N. (2011). Technology and the diffusion of renewable energy. *Energy Economics*, *33*(4), 648–662.

Reboredo, J. C. (2015). Renewable energy contribution to the energy supply: Is there convergence across countries? *Renewable and Sustainable Energy Reviews*, *45*, 290–295.

REN21 (2018). *Renewables 2018 Global Status Report*.

Riebe, L., Girardi, A., & Whitsed, C. (2016). A systematic literature review of teamwork pedagogy in higher education. *Small Group Research*, *47*(6), 619–664.

Romano, A. & Scandurra, G. (2014). Investments in renewable energy sources in opec members: A dynamic panel approach. *Metodoloski Zvezki*, *11*(2), 93–106.

Romano, A. A. & Scandurra, G. (2011). The investments in renewable energy sources: do low carbon economies better invest in green technologies? *International Journal of Energy Economics and Policy*, *1*(4), 107–115.

Romano, A. A. & Scandurra, G. (2016). "Nuclear" and "nonnuclear" countries: Divergences on investment decisions in renewable energy sources. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(6), 518–525.

Romano, A. A., Scandurra, G., Carfora, A., & Fodor, M. (2017). Renewable investments: The impact of green policies in developing and developed countries. *Renewable and Sustainable Energy Reviews*, *68*, 738–747.

Sadorsky, P. (2009a). Renewable energy consumption and income in emerging economies. *Energy Policy*, *37*(10), 4021–4028.

Sadorsky, P. (2009b). Renewable energy consumption, co2 emissions and oil prices in the g7 countries. *Energy Economics*, *31*(3), 456–462.

Salim, R. & Rafiq, S. (2012). Why do some emerging economies proactively accelerate the adoption of renewable energy? *Energy Economics*, *34*(4), 1051–1057.

Sovacool, B., Ryan, S., C Stern, P., Janda, K., Rochlin, G., Spreng, D., Pasqualetti, M., Wilhite, H., & Lutzenhiser, L. (2015). Integrating social science in energy research. *Energy Research & Social Science*, *6*, 95–99.

Valdés Lucas, J. N., Escribano Francés, G., & San Martín González, E. (2016). Energy security and renewable energy deployment in the eu: Liaisons dangereuses or virtuous circle? *Renewable and Sustainable Energy Reviews*, *62*, 1032–1046.

Vieira, L. C., Serrao-Neumann, S., Howes, M., & Mackey, B. (2018). Unpacking components of sustainable and resilient urban food systems. *Journal of Cleaner Production*, *200*, 318–330.

Wu, L. & Broadstock, D. (2015). Does economic, financial and institutional development matter for renewable energy consumption? evidence from emerging economies. *International Journal of Economic Policy in Emerging Economies*, *8*, 20–39.

Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected saarc countries: Progress towards green economy. *Renewable Energy*, *71*, 123–132.

Zhao, Y., Tang, K. K., & li Wang, L. (2013). Do renewable electricity policies promote renewable electricity generation? evidence from panel data. *Energy Policy*, *62*, 887–897.

Şener, S. C., Sharp, J., & Anctil, A. (2018). Factors impacting diverging paths of renewable energy: A review. *Renewable and Sustainable Energy Reviews*, *81*, 2335–2342.

Chapter 3

BUSINESS MODEL AND RISKS OF A RENEWABLE ENERGY CROWDFUNDING PLATFORM

This chapter has been published as
Bourcet, C., Cézanne, C., Rigot, S., & Saglietto, L. (2019). Le financement participatif de projets d'énergies renouvelables (EnR) : éclairages sur le modèle économique et les risques d'une plateforme française. *Innovations*, 59(2), 151-177. Link

Abstract *Crowdfunding platforms appear as a new popular form of financial intermediation able to raise funds for renewable energy (RE) projects. In particular, in France, RE crowdfunding has developed significantly in recent years. In this context, better understanding the business model of RE crowdfunding platforms is relevant. This chapter analyses the French RE crowdfunding platform: Enerfip. Building on the Business Model Canvas of Osterwalder (2004) and Osterwalder & Pigneur (2011), the chapter develops a representation of the platform's business model, a matrix of its risks and the strategies implemented to face them. Finally, this chapter identifies shortfalls in its strategies and discusses diverse means of action to address them.*

Résumé *Les plateformes de financement participatif interviennent comme une nouvelle forme d'intermédiation financière plébiscitée pour contribuer au financement de projets d'énergies renouvelables (EnR). Plus spécifiquement, le crowdfunding d'EnR a connu un développement important ces dernières années. Dans ce contexte, il est intéressant de mieux comprendre le modèle économique des plateformes de financement participatif d'EnR. Ce chapitre analyse la plateforme française d'investissement participatif dédiée aux projets d'EnR : Enerfip. Au regard du Business Model Canvas d'Osterwalder (2004) et Osterwalder & Pigneur (2011), il propose une représentation du modèle économique de la plateforme, de sa matrice de risques et des stratégies qu'elle met en place pour les gérer. Enfin, ce chapitre identifie les insuffisances de ces stratégies et discute différents leviers d'action pour y remédier.*

Contents

3.1 Introduction

The financial crisis that started in 2007 revealed the limits of the traditional financing channels of the economy and the relevance of new forms of financial intermediation to finance investment projects and in particular risky ones (Wehinger, 2012). Crowdfunding platforms are among the new intermediation means. They have been supported by the digital revolution and the development of the collaborative economy and thus illustrate a financing trend oriented towards citizen participation. Crowdfunding is still a niche market in terms of the volume of funds collected (Belleflamme et al., 2015), but the sector has experienced rapid growth rates. This is the case in particular in France. In the country, there was a growth of 330% between 2014 and 2017 according to data from CompinnoV & FPF (2015) and KPMG & FPF (2018). As a result, crowdfunding appears as a significant tool in the context of entrepreneurial finance.

Since the late 2000s, crowdfunding has been attracting growing interest in the academic and business worlds (Bessière & Stéphany, 2015, Girard & Deffains-Crapsky, 2016, Mollick, 2014). It is generally defined as: "an open call, mostly through the Internet, for the provision of financial resources either in the form of donation or in exchange for the future product or some form of reward to support initiatives for specific purpose" (Belleflamme et al., 2014, p.588). The digital crowdfunding platforms use existing instruments, i.e., donation, lending (crowdlending), or else investment (crowdinvesting), as new financing channels for innovative projects (Agrawal et al., 2014, Bruton et al., 2015), cultural projects (Bannerman, 2013, Boeuf et al., 2014), but also environmental projects (Hörisch, 2015, Lam & Law, 2016).

The recent interest of crowdfunding platforms in environmental issues echoes the States and other stakeholders call to develop innovative financing means for the energy transition towards low-carbon sources. More specifically, in France,

the Energy transition for green growth law (LTECV, 2015) supported crowdfunding of renewable energy (RE) projects. In a favorable regulatory context, crowdfunding platforms have offered an increasing number of RE projects since the 2010s (de Broeck, 2018, Nigam et al., 2018). EUR 11.5 million were collected in 2016 by French crowdfunding platforms for RE projects, only through debt instruments (GreenUnivers & FPF, 2017). This represented 4.92% of the total amount collected by crowdfunding platforms and 11.9% of the debt-based amount collected by crowdfunding platforms in France (KPMG & FPF, 2017). This amount was still marginal, but it seems that the growth potential is significant especially since RE crowdfunding could be a way to limit local opposition to the installation of RE technologies (Bonzanini et al., 2016). The total volume collected could reach EUR 250 to 400 million over the next five years, notably encouraged by the incentives of the *Commission de régulation de l'énergie* (French Energy regulatory commission, CRE) (Ponchel & Bordier, 2017). This expected growth calls for a better understanding of the business model adopted by the platforms to achieve it. However, authors investigating crowdfunding only gave a fragmented representation of the operations of crowdfunding platforms by focusing on the profile of their clients and the relationships they have with them (Ahlers et al., 2015, Belleflamme et al., 2014, Vismara, 2018), studying the value creation insisting for instance on the factors and trajectories of campaigns' success (Belleflamme et al., 2013, Corbel et al., 2018, Sannajust et al., 2014), or else looking at specific financing instruments (donation, lending, shares, *etc.*) and associated contributors' motivations (Allison et al., 2015, Cholakova & Clarysse, 2015). The literature focusing on crowdfunding in the specific case of RE projects is also characterized by a limited description of the operations of the crowdfunding platforms. Indeed, some authors studied the success factors of RE crowdfunding campaigns (Bonzanini et al., 2016), the development potential of the sector in a country (Vasileiadou et al., 2016), and the general operations of the platforms and the diversity of projects (de Broeck, 2018, Lam & Law, 2016, Nigam et al., 2018). Finally, when the authors described the business model adopted by RE crowdfunding platforms, they mostly presented the financing instruments offered by these platforms.

One possible way to complement this limited vision is to build on the pioneer framework of Osterwalder (2004) and Osterwalder & Pigneur (2011) called the Business Model Canvas. The aim is to give a global representation of the activities of a crowdfunding platform dedicated to the funding of RE projects in a risky context. The Business Model Canvas details the core of any company's operations. It was recently used to describe the business model of donation and equity-based crowdfunding platforms (see for instance Bessière & Stéphany, 2017). However, to the best of our knowledge, it was never used to present the business model of

crowdfunding platforms offering investments in RE projects. This is thus the objective of this chapter. More specifically, the analysis will be based on a case study of the RE crowdfunding platform called Enerfip (*Energies Renouvelables par le Financement Participatif*, RE through crowdfunding in English). We aim to present and analyze the business model of Enerfip by identifying the indicators associated with its development strategy and that allow the platform to face the risks related to its activity as an intermediation actor. Although the risks and the two customer segments are sometimes mentioned by the authors (de Broeck, 2018, Nigam et al., 2018), they are rarely detailed. Besides this, the choice to focus on France is motivated by the existence of a favorable regulatory environment that is expected to support the development of the sector (Ponchel & Bordier, 2017). This case study is expected to contribute to the in depth and comprehensive understanding of a phenomenon (Easton, 2010). It serves as a preliminary step (Flyvbjerg, 2006) towards a study of all the platforms dedicated to RE projects and aims at enriching the debate on the design and management of RE crowdfunding campaigns in France.

This chapter is organized as follows. Section 3.2 gives the theoretical framework considered that is the Business Model Canvas. Section 3.3 presents the data and methodology used. Then, Section 3.4 details the results of the empirical study. The discussion of these results leads to the formulation of recommendations in Section 3.5. Finally, Section 3.6 concludes this chapter and gives some perspectives for future research.

3.2 Theoretical framework: the Business Model Canvas

The investigation of the operations of RE crowdfunding platforms requires an analysis of their business model and of the associated characteristics. In general, business models "refer to the logic of the firm, the way it operates and how it creates value for its stakeholders" (Casadesus-Masanell & Ricart, 2010, p.196). They correspond to strategic analysis tools that "allow to embrace in the same reflection elements that are generally separated by the functional divisions operated by academic research in management or by the companies themselves" (Lecocq et al., 2006, p.109).[1] If the significance of the concept and its links with other concepts studied by economists or researchers in management have been questioned sometimes, the business model can be analyzed as the link between the strategy of an organization, i.e., its long-term orientation, and its operational implementation (Wirtz et al., 2016).

[1] The original quote in French is: *"permettent d'embrasser dans une même réflexion des éléments qui sont généralement disjoints par les découpages fonctionnels opérés par la recherche académique en gestion ou par les entreprises elles-mêmes"*.

Pillars	Blocks	Definition	Examples and possible indicators
Products/ services	1. Value propositions	Provides an overview of the bundle of products and services that create value for a given company in response to the needs of a given customer segment.	Performance, customization, brand, price, risks reduction, accessibility, usability...
Customer interface	2. Customer segments	Defines the customer segments (individuals or organizations) targeted by the company and to which it wishes to offer value.	Mass market, niche market, segmented market, diversified market, and multi-sided markets.
	3. Channels	Describes the various communication channels between the company and its customers in the different phases of the relationship (awareness, evaluation, purchase, delivery, and after sales) to provide them with a value proposition.	Communication channels, distribution channels, and indirect (in connection with wholesalers or stores) and/or direct (internally in connection with the sales force and online sales) sales channels.
	4. Customer relationships	Explains the types of relationship the company establishes with its different customer segments.	Continuum from interpersonal relationship to automated relationship: personal or dedicated personal assistance, self-service, automated services, community, co-creation...
Infrastructure management	5. Key resources	Describes the assets that are key to the company's activity and the proper functioning of its business model.	Physical, intellectual, human, or else financial resources.
	6. Key activities	Describes the most important things a company must do to make its business model work.	Operations and work performed at the production, problem solving, or platform/network level.
	7. Key partners	Defines the network of separate agreements with other companies critical to the value propositions.	Alliances for optimization, risk reduction, or resource acquisition purposes.
Financial aspects	8. Cost structure	Specifies all costs related to the implementation of the business model.	Fixed costs, variable costs, economies of scale, economies of scope.
	9. Revenue streams	Represents the cash generated by the company's business with each customer segment.	Several sources: sale of goods, right of use, subscription, rental/loan, licensing, brokerage fees, advertising... with different pricing mechanisms (fixed or dynamic).

Table 3.1 Architecture and building blocks of the Business Model Canvas.

Adapted from: Osterwalder (2004), Osterwalder & Pigneur (2011), Osterwalder et al. (2005).

The elements that make up a business model are diverse. According to Lecocq et al. (2006), the business model represents the choices made by a company with the objective to generate revenues. These choices concern the resources and skills used by the company, the offer to its customers, its internal organization (value chain), and its external organization in relation to its partners (value network). Such a concept can be used both in a static and a dynamic approach to describe the operations of a company and analyze changes, particularly in relation to the innovation dynamics (Demil & Lecocq, 2010). The recent literature reviews in the field of business model research (Massa et al., 2017, Wirtz et al., 2016) suggest that the framework proposed by Osterwalder and his co-authors (Osterwalder, 2004, Osterwalder & Pigneur, 2011, Osterwalder et al., 2005) is among the most complete and operational representations. Indeed, the Business Model Canvas enables to present in a synthetic way the characteristics associated with the business model of any organization. More specifically, it is composed of four pillars that represent the main aspects of a company's activity: the product or service offered on the market, the characteristics of the relationships between the company and its customers, the management of its infrastructure, and the financial elements (revenues, costs, and sustainability) of its business model. These four pillars are decomposed into nine blocks as presented in Table 3.1.

This analytical framework is used by both practitioners (Chambre de Commerce et d'Industrie de France, 2019, Deloitte, 2019, SAP, 2017, *etc.*) and researchers (Burger & Luke, 2017, Gabriel & Kirkwood, 2016, Perboli et al., 2018). Regarding academic papers specifically focusing on crowdfunding platforms, several authors have used the Business Model Canvas. This is for instance the case of Boyer et al. (2016) and Attuel-Mendès et al. (2018) that rely on the Business Model Canvas to study equity crowdfunding platforms. Bessière & Stéphany (2017) also use this framework to present the business model of crowdfunding platforms that offer donation and lending-based projects. As the Business Model Canvas has also been considered by authors looking at the actors with a significant role in the development of RE sources (Okkonen & Suhonen, 2010, Richter, 2013), we believe that it is a relevant framework to build on to study crowdfunding platforms specialized in RE projects. Indeed, this theoretical framework enables to represent globally and synthetically the operations of platforms offering RE projects funded *via* equity or debt (bonds, *minibons*[2]).

To conclude, the Business Model Canvas allows to investigate the business model of any organization. Thus, it is a very interesting framework to better understand the RE crowdfunding platforms' operations that cannot be separated from the economic and institutional environment of these platforms. Regarding

[2] *Minibons* are similar to bonds with constant repayment installments that cannot exceed a quarterly frequency (Legifrance, 2016).

crowdfunding platforms that offer investment possibilities in RE projects, their intermediation activity raises questions concerning the risks faced by these platforms and the means developed to deal with them. This is why, in addition to the static analysis that is allowed by the Business Model Canvas framework, and as done by other authors (see for instance Moussavou & Branellec, 2018), we propose a dynamic analysis of the risks that arise during the crowdfunding campaigns and of the strategies developed by the platform in relation to them.

3.3 Methodology

We use a five-step methodology to conduct a single case study of the business model of the crowdfunding platform Enerfip that offers investment possibilities in RE projects (see Appendix B.1 for a detailed presentation of Enerfip). We aim at presenting the Business Model Canvas of the platform and the strategies implemented to face the risks associated with such a business model. This analysis builds on previous papers, such as Lam & Law (2016) and Vasileiadou et al. (2016), that focused on foreign platforms.

3.3.1 Choice of the case to study

According to the professional association of the French crowdfunding sector (Financement Participatif France, 2017), there are eight French crowdfunding platforms interested in "sustainable development and RE sources". Enerfip is one of the four platforms specialized in RE projects (with Lumo, Lendosphere, and Akuocoop, see Appendix B.2 for more details). The choice of Enerfip was motivated by its large financing offer. Indeed, at the begining of the analysis, Enerfip was the only platform to offer four investment instruments: equity, bonds, *minibons*, and partners' current accounts. The platform also already had the two regulated statutes: *Conseiller en investissement participatif* (Crowdfunding investment advisor, CIP) and *Intermédiaire en financement participatif* (Intermediary in crowdfunding, IFP).[3]

[3] In France, two new regulated statutes were created for crowdfunding platforms: CIP and IFP. These statutes and legal authorizations provide guarantees regarding the control exercised by platform managers on the different actors involved in the transaction. The platforms that adopt these statutes also have to be registered in the single register of the *ORIAS* (Body for the register of insurance intermediaries that is a register of insurance, banking, and finance intermediaries). With platforms being registered, any internet user is able to check if a platform indeed has all required authorizations and provides sufficient guarantees.

3.3.2 Construction of the case study

Our theoretical starting point is the Business Model Canvas developed by Osterwalder (2004) and Osterwalder & Pigneur (2011). It is composed of nine blocks to study the business model of a company. These nine blocks constitute both our levels of analysis and the themes mobilized for data collection. In addition to this, we consider the work of Osterwalder et al. (2015) for a more specific analysis of value proposition design, its creation, improvement, and capture. Thus, we aim to obtain a detailed description of the business model of the Enerfip platform. We complement this analysis by identifying the platform's risks and its strategies to manage these risks. To achieve our objectives, we have used a qualitative study. This choice was directly motivated by the nature of our central research question (Yin, 1981). The objective is to obtain selective, high quality, and very detailed information (Cavaye, 1996).

3.3.3 Data collection

Several data sources are mobilized in this chapter.

3.3.3.1 Public information

We collected data from the company's website (enerfip.fr): profile of the employees and co-founders, characteristics of the platform (partners, headquarters, *etc.*), projects funded, project promoters, financing conditions... We also collected information based on a review of press articles extracted from the database Factiva.

3.3.3.2 Individual interviews

We conducted interviews with three of the platform's co-founders who hold the positions of President (PR), Chief Executive Officer (CEO), and Chief Financial Officer (CFO). They represent about 25% of the platform's workforce composed of 12 employees. Unlike other employees, the respondents are experts in their field of activity in terms of their function, position, and training, as well as their experience. Over a period of 3 months (from September to November 2017) with an average duration of 2 hours, these semi-directive interviews were conducted using an interview guide that alternates direct and indirect questions.

3.3.4 Data treatment

To analyze the interviews, we use the classic tools: summary sheet, recording, transcription, and double coding of the interviews. The coding consisted of a transformation of the transcripts of the interviews using the NVivo software. We carried out two different codings: 1) a coding for each theme falling within the

nine blocks of the Business Model Canvas, and 2) a coding for the risks of the platform.

The respect of the interpretation validity is obtained by the saturation threshold, the triangulation of the data, and the variety of the questioning. The respect of the validity of explanation, was obtained by going back and forth between the field and the analysis.

3.3.5 Presentation of the results

Based on the analysis of the collected materials, we provide evidence of our demonstration through the presentation of synthetic tables, narrative examples, and descriptive statistics. They allow us to establish the Business Model Canvas of the Enerfip platform. We then discuss it with regard to the protection mechanisms against risks implemented by the platform.

3.4 Results

The Enerfip crowdfunding platform is specialized in investment possibilities in RE projects. Since its creation in 2014, it has raised about EUR 6 million, of which nearly 5 million were raised in 2017. According to its President and co-founder, Enerfip mainly competes with platforms specialized in RE (Lendosphere, Lumo, Akuocoop) and generalist platforms "who are interested in this market, to diversify, because their initial market is not doing very well" (WiSEED, Lendopolis, Tudigo, LITA.co).

The platform's main purpose is to provide information on "the energy transition, its necessity, possibility, and viability" (PR) and to promote the development of RE sources by bringing together two groups of individuals: on the one hand, project promoters (around 15 in 2017) interested in using crowdfunding and, on the other hand, individual investors that are crowdfunders (5,000 in 2017). The platform creates value by enabling interactions between distinct but interdependent customer groups (Osterwalder & Pigneur, 2011). Such a platform is emblematic of two-sided market structures (Armstrong, 2006, Rochet & Tirole, 2003, 2006). The platform creates value as an intermediary and at the same time faces many risks. Brand image, notoriety, and trust are the platform's main value for both customer segments (all 3 interviewees). For project promoters, the value of the platform is also a function of the number of individual investors, and for individual investors, it depends on the number, type, quality, and potential success of the projects presented.

As stated by Osterwalder & Pigneur (2010, p.78), "[h]ence multi-sided platforms often face a "chicken and egg" dilemma. One way multi-sided platforms

solve this problem is by subsidizing a Customer Segment.". Enerfip is no exception to this principle and must find a way to attract enough customers from both customer segments. The platform has thus set up a subsidized rate for one of its customer segments and hopes to offset the costs incurred by the fees paid by the other customer segment. Indeed, Enerfip seeks to attract individual investors with a free value proposition and project promoters with a paid value proposition.

The crowdfunders are individual investors from all socio-professional categories. Their investments are occasional or regular (with small or large amounts). According to Enerfip, they have three main motivations: (i) to participate in the energy transition to address climate change, (ii) to invest savings directly in a local project, and (iii) to invest in a specific project with an attractive return.

Since its creation, Enerfip has proposed a free accessibility of the platform to all citizens so that they can contribute to the financing of the energy transition. "There is no cost for investors, so it is a significant change compared to [...] conventional solutions" (CEO). Once administratively registered on the platform, they are informed of the campaigns stages and project risks. Thus, the platform maintains a relationship of trust and interaction with the individual investors segment, which is translated into various elements:

- Advice in investment choices. "I think we provide more services to investors. We give them a savings solution" (PR). The platform claims to offer "much higher interest rates than the vast majority of instruments, with very limited risk" (CEO).

- Loyalty savings account. Enerfip offers a loyalty savings account with an annual interest rate of 1% (in the form of gift vouchers (capped at EUR 50,000) that can be used to invest in future projects at least every 6 months). At the same time, funds invested in an ongoing campaign are remunerated at 1.25% per year until the end of the campaign (in the form of gift vouchers that can be used to encourage them to invest in other projects).

- A presentation of the investment process and risks. In a pedagogical form, the platform communicates on the evolution of the invested savings. "The precise world for that is gamification" (PR). Enerfip tries to identify performance indicators of an investor's portfolio, such as the tons of CO_2 saved thanks to its investment. It also works on the visual aspect to show what the contribution of individual investors corresponds to.

- Finally, to contact and communicate with individual investors, Enerfip uses a variety of media (as stated by all interviewees) for each of the five phases of its relationship with this customer segment (see Table 3.2).

Awareness	Evaluation	Purchase	Delivery	After sales
To make the platform's projects and services better known, Enerfip relies on: i) a website, ii) direct relations to inform and prospect (door-to-door, markets, local conferences, sponsorship, word-of-mouth, local authorities and trade fairs...), iii) scientific events, traditional communication media (press releases, fliers), and iv) social networks not directly for communication purposes but for credibility reasons.	Enerfip helps individual investors to evaluate its value proposition through: i) communication means: a highly developed phone customer relations service, on questions/answers web places, on project webpages, *via* email exchanges, and ii) a fun presentation of performance indicators.	Enerfip gives individual investors the opportunity to invest in projects directly on the platform *via* a free accessibility.	Enerfip offers a free value proposition to individual investors that includes assistance in investment choices, a loyalty savings account, a presentation of the investment process and risks.	In the post-campaign phase, Enerfip provides individual investors with different supports in order to allow an informational assessment: internal messaging, emails, and various notifications.

Table 3.2 Relationship between Enerfip and individual investors.

Source: authors' work.

Enerfip has chosen a fee paying value proposition for project promoters and a win-win relationship. The latter are subject to an audit and then selected by a committee composed of co-founders and project managers according to various criteria (technical and administrative qualities, ecological impact, financial strength, local social and economic benefits) (website). "There is a relationship of trust in both directions" (CEO). It manifests itself in a mutual selection. This selection guarantees a certain notoriety to the platform which can then attract more project promoters and individual investors. Once selected, Enerfip offers project promoters various services to facilitate their approach and increase their visibility such as:

- Administrative services. Enerfip carries out certain formalities in order to simplify the organization and the follow-up of the crowdfunding campaigns for project promoters. "The platform fills in the tax declaration of the project promoters and takes care of the payment of the coupons. It can also create and manage an investor register" (PR).

- A good quality website. Enerfip has a website with carefully designed interfaces that can disseminate sufficient information from a qualitative and quantitative point of view (website).

- A complete crowdfunding campaign. By offering a wide range of financial instruments (equity, bonds, *minibons*, and partners' current accounts), Enerfip is able to adapt to the demands and constraints of project promoters

(CFO) and thus improves the probability of success of each crowdfunding campaign (website).

- Support for project promoters. The platform offers them dedicated assistance and personalized advice. The platform thus creates the basis for a value co-creation: the needs of project promoters are specific and can evolve over time. This is why the co-construction and the adaptability of the platform are crucial (CEO and CFO). This support is translated into facts by:
  - The joint drafting of the project description published on the platform's website. "We write everything down and in general, the project promoter then makes his comments" (CFO). Depending on the regulatory obligations imposed by the *Autorité des marchés financiers* (AMF, French financial markets regulator), Enerfip and the project promoter agree on the final presentation of the project.
  - Advice, monitoring, and pedagogy concerning the modalities of the campaign (threshold of success, objective, ceiling, and duration of the campaign...). "We have a big need to reassure them, to orient them on the type of products, what rate, what duration *etc.*, before the campaign" (PR).
- A professional network that comes primarily from the personal network of the co-founders in the energy sector. "We had a network of contacts in this field, which allowed us to get started fairly quickly and to be credible" (PR). It can also rely on a banking network to prevent campaign failure from happening. "If we don't succeed, we can always distribute the project within the X or Y banking network, and there, the project promoter is immediately reassured, and he is willing to sign contracts". These partnerships with banks allow Enerfip to improve its image and notoriety.

Finally, to contact and communicate with project promoters, Enerfip uses a variety of media (as highlighted in all interviews) for each of the five phases of its relationship with this customer segment (see Table 3.3).

Moreover, Enerfip bases its activity on two key resources: the platform and the human resources that enable its operations and sustainability. "Human resources are really the key" (CFO). For example, Enerfip's founders have experience in designing hydroelectric dams, managing photovoltaic projects, and financing hydraulic and biomass projects. "We are in this business because we have expertise and skills in technical, regulatory, financial, and administrative aspects [...] but also because we are enthusiastic" (CEO). To conclude, the human capital specific to the company is a key resource for Enerfip.

Awareness	Evaluation	Purchase	Delivery	After sales
To make the platform better known by project promoters, Enerfip relies mainly on: (i) its website, (ii) trade and local authorities fairs, scientific events, the specialized press, (iii) calls for proposals from project promoters themselves, (iv) calls for tenders from the CRE, and (v) social networks not directly for communication purposes but for credibility reasons.	Enerfip helps project promoters to evaluate their value proposition by setting up information exchange channels (emails, internal messaging, meetings, project management tools, FAQ...).	Enerfip gives project promoters the opportunity to promote their projects directly on the platform *via* a fee paying accessibility.	Enerfip offers a fee-based value proposition to project promoters that includes administrative services, a good quality website, a complete crowdfunding campaign, personalized support before and during the campaign, and a professional network.	In the post-collection phase, Enerfip provides project promoters with different supports in order to allow an informational assessment: internal messaging and emails.

Table 3.3 Relationship between Enerfip and project promoters.

Source: authors' work.

With its resources, Enerfip develops key activities that support its mission and value proposition. These activities correspond to:

– The development of acceptability and the improvement of projects' image and also of the image of their promoters. Promoters are either developing a national crowdfunding approach in order to increase their capital base or a territorial crowdfunding approach in order to involve the local population. "There are those who want to promote the local acceptability of their project and there are those who are really looking for funds because they lack the equity to be able to finance their project, so either as a complement to the debt, or even sometimes 100% through us. And there are those who are obliged to do so, within the framework of the CRE's calls for tenders" (CFO).

– A strong pedagogy on RE sources, to try to raise awareness among the population regarding savings, climate change, and RE development. "One of Enerfip's missions is to teach about energy transition solutions" (PR). "We do a lot of pedagogy through our infographics, our videos, to explain to people what RE is, and what financial products we propose" (CFO).

Enerfip also develops many partnerships based on which its business model works. These key partnerships are aimed at optimizing and reducing risks. For financial optimization, the platform uses a payment service provider S-Money "because we are not a bank, [...] so we have this provider who acts as a channel between individual investors and the projects" (CEO). Regarding legal and

tax optimization, the platform outsources complex arrangements to law firms and legal consulting firms (in particular for drafting the legal documentation for bond issues). In addition, the platform has a contract with one of its shareholders, an investment fund subsidiary of a bank. This is to improve the distribution of its offers, to make itself known to both project promoters and individual investors, and thus contribute to strengthen its reputation and reduce the risk for both customer segments (the 3 interviewees).

Regarding Enerfip's revenue streams, they come exclusively from the project promoters segment in the event of a successful campaign. These revenue flows are based on a fixed price mechanism that depends on the type and characteristics of the projects. Concerning the fee paid by project promoters, "it can always be expressed as a percentage of the amount collected, but in practice it is more like a lump-sum payement" (PR). "Overall, it may be 5 or 6% depending on the options they choose, but in reality, it's a 4% success fee, plus additional expenses (travel expenses or additional meetings fees)" (CFO).

Finally, Enerfip has a relatively traditional cost structure with respect to its key resources and activities. It is mainly composed of costs related to its payroll (which represents, according to the PR, 80 to 85% of the costs) since the company has, for example, its own developers. Compared to its competitors, it is one of the few platforms that have not outsourced this function. It also has costs related to the search for legal optimization, for example when it calls on a law firm to draft a shareholders' agreements for certain projects. "If we take into account both the legal aspects of the campaigns and the compliance with the AMF, it amounts to about 10% of our annual costs" (PR). It also incurs costs due to the outsourcing, to a press agency, of all its press releases (between 5 and 10% according to the PR). Finally, among current expenses (some of which are re-invoiced to project promoters), the platform pays bank transaction fees, travel expenses, and rent (CFO).

These results enable us to present the Business Model Canvas of Enerfip as shown in Figure 3.1. The essence of Enerfip's business model lies in its value propositions, which differ across the to customer segments. As a two-sided platform, Enerfip has a particular revenue structure. The revenue streams from project promoters allow Enerfip to grant a free access to individual investors. In order for this mechanism to work and be sustainable, Enerfip identifies the risks associated with its activity and implements strategies to manage these risks. As a result, the company is able to meet the needs of both customer segments and offers them a value proposition centered on its brand image, its notoriety, and mutual trust. The choice of a (static) building blocks approach reveals that all of these risks are transverse to the blocks of the matrix, as highlighted in Figure 3.2.

<table>
<tr>
<td rowspan="2">Key partners
• Financial optimization: payment service provider
• Legal and tax optimization: law firms, legal consulting firms
• Contractual relationship: investment fund subsidiary of a bank</td>
<td>Key resources
• Platform
• Specific human resources</td>
<td rowspan="2">Value propositions
• Free accessibility to the platform for individual investors
• Fee paying accessibility for project promoters
• Brand image, notoriety and trust</td>
<td>Customer relationships
• Relationship with individual investors: trust and interactions
• Relationship with project promoters: win-win relationship and mutual trust</td>
<td rowspan="2">Customer segments
Two-sided market:
• Individual investors
• Project promoters</td>
</tr>
<tr>
<td>Key activities
• Development of accessibility and improvement of projects image
• Active pedagogy regarding RE sources</td>
<td>Channels
• Direct: face to face (fairs, conferences...)
• Indirect: website and word-of-mouth</td>
</tr>
<tr>
<td colspan="2">Cost structure
• Payroll
• Costs related to partnerships
• Running costs</td>
<td colspan="3">Revenue streams
• Intermediation revenues from the project promoters segment (between 3 and 7% of the amount collected per campaign)</td>
</tr>
</table>

Fig. 3.1 Enerfip's Business Model Canvas.

Source: authors' work.

The risks may be associated with failures of key partners, key resources, one or both customer segments, one or more transmission channels, or else customer relationships. They may also be related to revenue streams and cost structure. However, insofar as these risks are of a different nature (image and/or financial risk), can be transmitted directly or indirectly (*via* the two customer segments), and are more or less significant depending on the nature of the projects (more or less local aspects), they should be apprehended during the three phases of the campaigns (see Figure 3.3). Thus, it is first of all necessary to clarify their nature and their propagation mode during the different phases of the campaigns. In a second step, our approach allows us to highlight the risk management strategies developed by the platform.

During the campaign's preparation phase, the platform may be subject to an image risk. This risk of adverse selection is linked to the asymmetry of information between the project promoter and the platform. It is higher when the project is in an early phase compared to a project in the development or growth phase.

<table>
<tr><td rowspan="2">Key partners
• Partners default risk</td><td>Key resources
• Recruitment risk
• Cash flow/ revenues risk</td><td rowspan="2">Value propositions</td><td>Customer relationships
• Risk of inadequate marketing strategy due to the diversity of customers</td><td rowspan="2">Customer segments
• Adverse selection risk
• Regulatory risk</td></tr>
<tr><td>Key activities</td><td>Channels
• Risk of miscommunication in customer relationship management</td></tr>
<tr><td colspan="2">Cost structure
• Cash flow/revenues risk</td><td colspan="3">Revenue streams
• Risk of campaign failure</td></tr>
</table>

Fig. 3.2 Representation of Enerfip's risk categorization based on the Business Model Canvas blocks.

Source: authors' work.

"If the project is in the development phase, there is much more risk than if the project is in the construction phase, and much less risk if it is in the operation phase" (CEO). To reduce the risk of adverse selection, the platform's due diligence activity, carried out exclusively in-house and building on the co-founders' expertise in the RE sector, is crucial. "Because if you let a bad project go through, you organize the campaign, and the project goes bad a few months or years later, you will be held responsible for advising people to invest in that project. And so, for us, it's absolutely vital to reduce this risk to zero" (PR). This image risk can turn into a financial risk in the next phase (during the campaign) in case of campaign failure (impacting the revenue streams block). The individual investor does not take any risk and the project promoter only incurs the risk of not being selected and not obtaining financing for his project.

During a campaign, the platform may be exposed to direct financial risk related to campaign failure, which can affect revenues. Campaign failure can be attributed to the project promoters (selection of the wrong project), the platform (ineffective communication), and the insufficient number of individual investors (poor design of the campaign). This number of individual investors is all the more crucial in the case of projects with a strong local aspect. The risk of failure therefore influences the image of the platform. "A project promoter who does not succeed in his campaign, it is not a good sign in terms of image" (PR). To reduce the risk of campaign failure and attract a sufficient number of individual

	Phases of the campaign	Project promoters	Platform	Individual investors
Direct risks	Before the campaign	• Risk of not being selected for a project	• Adverse selection risk	
	During the campaign	• Campaign failure risk	• Campaign failure risk • Regulatory risk • Risk of miscommunication in customer relationship management	
	After the campaign	• Risk of project promoter bankruptcy • Moral hazard risk		• Liquidity risk • Risk of non-repayment
Indirect risks	All phases	• Image risk → customer mistrust → financial risk (future campaigns)	• Image risk → recruitment risk • Partners default risk → financial risk (cash flow/revenues risk)	• Image risk → customer mistrust → financial risk (future campaigns)

Fig. 3.3 Categorization of risks during the three phases of campaign.

Source: authors' work.

investors, the platform gets closer to its partners, including banking actors. "The banking partner that is linked to a local investor base, [...] it has a big value for this type of project.". "We have signed a partnership to distribute our offers in the private bank. And the objective is, in the long term, to distribute our offers also in retail banking" (PR). Enerfip also relies on local actors to increase its notoriety and trust capital. "As soon as there is some involvement of the town, it is a success" (CFO).

During a campaign, the platform also faces legal and regulatory risks related to non-compliance with the rules of the AMF and/or *Autorité de contrôle prudentiel et de résolution* (ACPR, French regulator for the banking and insurance sectors), which are the regulatory authorities for financial markets, banks and insurers. "We have required information from the AMF, we will not compromise on this, of course" (CEO). The platform manages these risks with the help of law firms and legal consulting firms (CFO). The platform also ensures that "if the campaign does not reach its success threshold, each person is reimbursed in full" (CEO).

After the campaign, the platform does not incur any direct financial risk as it is no longer expected to receive any revenues associated with the crowdfunded project. However, it may be subject to indirect image risks, *via* its two customer segments, which may have financial consequences. On the individual investors side, there is a liquidity risk because to date no secondary market allows them to

resell their crowdfunding securities. They also incur a non-repayment risk if the project promoter goes bankrupt (for various reasons : "risks of deterioration as a result of natural disasters" and "regulatory or tax risks" (CEO)). To reduce the liquidity risk, the platform is considering the implementation of a solution that would resemble a secondary market for the securities invested in *via* the platform.

To reduce the risk of default, the platform ensures that the promoter has sufficient guarantees, and is committed to undertake the insolvency or liquidation proceedings on the behalf of the individual investors. Enerfip "ensures that the project promoter has taken out an insurance that covers operating losses, machinery breakdown, *etc.*" (CEO). The platform can also ask for additional guarantees from the project promoters. For example, "on a very early development stage project, in general we manage to put in place a financial guarantee from the parent company that develops the project in question, so that the investors benefit from a guarantee on their capital" (CEO). A situation of moral hazard can also arise if a promoter conceals information regarding the implementation of the project or does not use all the funds invested in the project for which the campaign was carried out. "They often want to give the minimum amount of information" (CFO). On the promoter side, the major risk is not being able to meet the commitments set out during the campaign. This risk of default, particularly in the event of bankruptcy of the company promoting the project, then leads to the disappointment of its investors and affects the reputation of the platform. "If the company that controls the projects goes bankrupt, there are always assets that can be sold for scrap, to collect theoretically enough cash to pay off all creditors, or at least part of them" (PR). To prevent the platform's image risk in case of default or bankruptcy, Enerfip "warns at all stages from registration to investment, that there are risks in the projects, that a partial or total capital loss is possible, and that one should only invest money that is not really needed immediately" (PR).

3.5 Discussion and recommendations

Our results allow us to give an overview and to present the elements of Enerfip's business model. Moreover, we extend the static approach of the Business Model Canvas of Osterwalder (2004) and Osterwalder & Pigneur (2011) based on an analysis of the risks and the practices that the Enerfip crowdfunding platform continuously develops to limit them. If they are necessary to sustain Enerfip's business model, these practices seem however still insufficient with regard to the mechanisms recommended by the authors and developed by other platforms (see for example Agrawal et al., 2014, Bessière & Stéphany, 2017), and the key

resources available to the platform. As a result, we make recommendations to enable Enerfip to improve the strategic management of its various risks.

Regarding the risks related to information asymmetry, while the literature indicates that they rather concern the relationship between project promoters and individual investors (Moussavou & Branellec, 2018), our results show that they also affect the platform itself. Based on this observation, we propose several avenues aimed at limiting the situations of adverse selection and moral hazard that Enerfip may face. Firstly, the platform could set up, in addition to the traditional internal mechanisms (selection and due diligence process by the platform), complementary selection procedures based on interactions between the crowd and the project promoters (Belleflamme et al., 2015, Girard & Deffains-Crapsky, 2016). This solution materializes notably through the launch of a pre-campaign (before the actual crowdfunding one) or the evaluation of projects through an online vote from the crowd. Potential contributors could participate in the selection of projects, encouraging at the same time their loyalty to the platform. The collective intelligence of the crowd is sometimes superior for projects selection, with the possible consequence of involving all types of contributors (not only those extrinsically motivated by a financial reward), thus creating large communities of specialized contributors (Belleflamme et al., 2014, Duran, 2018, Vismara, 2018). Secondly, Enerfip could improve its selection process by including regular individual investors and experts in the RE sector as members of its selection committee (Dardour, 2015). These two avenues would enable the platform not to select "bad" projects, in particular fraudulent projects (fake projects, projects used to aggregate financing from fraudulent sources for money laundering (Bessière & Stéphany, 2017)). Thirdly, after the campaign, Enerfip could set up a regular and systematic communication with individual investors, in order to inform them of the project progress or to report on the use of the funds collected by the project promoter.

Regarding the risk of campaign failure, we identify at least three possible ways of resizing crowdfunding campaigns. First of all, the platform has a powerful tool for encouraging investment - the offer of project promoters (green electricity production) - which it does not mobilize in a satisfactory manner. Highlighting contracts that guarantee the long-term electricity feed-in-tariffs is an additional guarantee of a project's success. Indeed, reassuring individual investors about the ability of project promoters to repay the capital invested and pay interests is a way for Enerfip to broaden its investor base. Then, Enerfip could reconsider its communication strategy by actively using online social networks (LinkedIn, Facebook, *etc.*) as other platforms do (Babyloan, Lumo, *etc.*). An amplified and targeted communication through social media would increase the

platform's ability to promote its activity and value proposition (Bessière & Stéphany, 2017, Onnée & Renault, 2013). For projects with a territorial issue, local communication (regional daily press, local radio...) is an essential tool. Finally, the motivation of contributors should be reconsidered as a crucial axis for the development of the investor base. By better targeting individual investors wishing to be major players in the fight against climate change, the platform could initiate the emergence of an "Enerfip community" of individual investors. The platform could federate this community around common values related to the energy transition (mutual aid, environmental protection, *etc.*) and its business model (clean value proposition, territorial approach, *etc.*). The community nature of the contributor groups is recognized as one of the guarantees of successful crowdfunding campaigns for entrepreneurial projects (Allison et al., 2015, Belleflamme et al., 2014, Josefy et al., 2017).

Concerning the cash flow/revenues risk, Enerfip could diversify its crowdfunding financing activity by offering innovation projects in green technologies (energy efficiency, *etc.*). Furthermore, like Lendosphere, Enerfip could adopt an international expansion strategy in order to reach the critical size in terms of number of funded projects.

With regard to regulatory risks, Enerfip must meet the regulatory authorities' requirements for transparency of information within a legal and institutional framework that we consider relatively flexible. The obligations dictated by the ACPR and AMF are not very restrictive on the quantity and quality of the information that the platform have to present on its website. Nevertheless, at the time of the analysis, Enerfip does not seem to comply with the regulatory requirements (in particular Article 325 of the AMF's General Regulation) concerning for example: i) its statutory information, ii) appropriate technical means and secure archiving tools[4], and iii) mandatory information on projects and their risks. Of all the RE projects successfully funded as of early November 2017, several project webpages do not mention the risk of capital loss. In addition, legal and tax risks are not reported for all projects. Regarding mandatory information displayed, Enerfip presents the minimum by communicating simplified information. As a result, the information may be considered either unreliable or overly positive and may encourage individual investors to finance projects where the risk is actually higher than presented. In the end, the flexibility of the regulatory framework leaves the platform significant flexibility. However, "the future of capital-based crowdfunding will depend on the platforms' ability to communicate about their

[4]This requirement is however fundamental in a context where the risks related to cybersecurity are significant in the crowdfunding sector (Bessière & Stéphany, 2017, Moussavou & Branellec, 2018, Tracfin, 2016).

activities, particularly in terms of financial risk assessment before, during, and after investment transactions. In order to gain and strengthen investors trust, platforms would be well advised to seek accreditation of their fundraising processes" (Dardour, 2015, p.63).[5] In this context, it is necessary to consider the relevant individual investors protection solutions in relation to their ability to understand the risks of the investments they choose (Deffains-Crapsky, 2016). A first avenue of both a legal and voluntary nature has recently emerged. As a continuation of the concrete measures resulting from the law of August 17, 2015 relating to the energy transition for green growth, the French Ministry for the Ecological and Inclusive Transition launched in late 2016 the "Crowdfunding for green growth" label co-constructed with the FPF association. As a mobilizing tool for the financing of projects related to the green transition, it aims to improve the transparency of information during and after crowdfunding campaigns. More particularly, this is through the transmission of specific documents and the active participation of contributors in the development of the projects (places dedicated to comments on the platform's website, meetings with the project promoter, *etc.*). It also aims to ensure the environmental quality of the projects through reporting requirements based on impact indicators (water consumption, circular economy, biodiversity, *etc.*). A complementary approach to the latter would be to impose on crowdfunding platforms specialized in RE projects financing a standardized presentation of projects and related risks (common risk indicators and measures). In this way, platforms that strictly comply with this presentation standards would preserve their image and reputation while at the same time allowing individual investors to compare projects on the basis of identical criteria, thus facilitating their investment choice.

3.6 Conclusion

By studying a French RE crowdfunding platform, this chapter has shed new light on crowdfunding platforms' operations. They are generally considered as an innovative but risky method of financing. So far, the literature focused mainly on customer profiles, contributors' motivations, or the success factors of campaigns. This chapter therefore proposes, based on the Business Model Canvas of Osterwalder (2004) and Osterwalder & Pigneur (2011) and a qualitative study, a complete and operational representation of the business model, risks, and risk

[5]The original quote in French is: *"l'avenir du crowdfunding en capital dépendra de la capacité des plateformes à communiquer sur leurs activités, notamment en matière d'évaluation du risque financier avant, pendant et après les opérations d'investissement. Pour gagner et renforcer la confiance des épargnants, les plateformes auraient tout intérêt à solliciter l'accréditation de leurs processus de levée de fonds"*.

management strategies of the Enerfip platform. The analysis reveals that Enerfip's business model is built on a differentiated value proposition according to the customer segments. More specifically, the two-sided platform creates value by promoting, on the basis of relationships of trust, interactions between individual investors and project promoters. In addition, the analysis identifies the multiple risks of this business model. Enerfip's operations create image and financial risks (linked to the existence of information asymmetry and/or regulatory requirements), which may be transmitted directly or indirectly (*via* the two customer segments) during the different phases of the crowdfunding campaigns. Our analysis highlights the inadequacy of the risk management strategies developed by Enerfip and proposes complementary elements in a logic to sustain its business model. Our proposals focus on selection, communication, and information dissemination practices. They aim at increasing the trust of individual investors, thus contributing indirectly to the platform's value creation (through additional revenue flows). Such recommendations deserve to be compared with the study of other RE crowdfunding platforms at the national or even European level. A major avenue for future research will therefore be to propose a meta-analysis of energy transition financing in a favorable context of political and citizen support.

3.7 Bibliography

Agrawal, A., Catalini, C., & Goldfarb, A. (2014). Some simple economics of crowdfunding. *Innovation Policy and the Economy*, *14*, 63–97.

Ahlers, G. K., Cumming, D., Günther, C., & Schweizer, D. (2015). Signaling in equity crowdfunding. *Entrepreneurship Theory and Practice*, *39*(4), 955–980.

Allison, T. H., Davis, B. C., Short, J. C., & Webb, J. W. (2015). Crowdfunding in a prosocial microlending environment: Examining the role of intrinsic versus extrinsic cues. *Entrepreneurship Theory and Practice*, *39*(1), 53–73.

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics*, *37*(3), 668–691.

Attuel-Mendès, L., Bonescu, M., & Raymond, S. (2018). Modèle d'affaires de l'equity crowdfunding en france en 2016 : un état des lieux. *Innovations*, *56*(2), 89–116.

Bannerman, S. (2013). Crowdfunding culture. *Journal of Mobile Media*, *7*(01), 1–30.

Belleflamme, P., Lambert, T., & Schwienbacher, A. (2013). Individual crowdfunding practices. *Venture Capital*, *15*(4), 313–333.

Belleflamme, P., Lambert, T., & Schwienbacher, A. (2014). Crowdfunding: Tapping the right crowd. *Journal of Business Venturing*, *29*, 585–609.

Belleflamme, P., Omrani, N., & Peitz, M. (2015). The economics of crowdfunding platforms. *Information Economics and Policy*, *33*, 11–28.

Bessière, V. & Stéphany, E. (2017). *Le Crowdfunding*. De Boeck supérieur.

Bessière, V. & Stéphany, E. (2015). Financement et gouvernance des start-ups en equitycrowdfunding. *Finance Contrôle Stratégie*, *18*(4).

Boeuf, B., Darveau, J., & Legoux, R. (2014). Financing creativity: Crowdfunding as a new approach for theatre projects. *International Journal of Arts Management*, *16*, 33–48.

Bonzanini, D., Giudici, G., & Patrucco, A. (2016). The crowdfunding of renewable energy projects. In V. Ramiah & G. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 429–444). Elsevier.

Boyer, K., Chevalier, A., Léger, J., & Sannajust, A. (2016). *Le crowdfunding*. La Découverte.

Bruton, G., Khavul, S., Siegel, D., & Wright, M. (2015). New financial alternatives in seeding entrepreneurship: Microfinance, crowdfunding, and peer–to–peer innovations. *Entrepreneurship Theory and Practice*, *39*(1), 9–26.

Burger, S. P. & Luke, M. (2017). Business models for distributed energy resources: A review and empirical analysis. *Energy Policy*, *109*, 230–248.

Casadesus-Masanell, R. & Ricart, J. E. (2010). From strategy to business models and onto tactics. *Long Range Planning*, *43*(2), 195–215.

Cavaye, A. (1996). Case study research: a multi-faceted research approach for is. *Information Systems Journal*, *6*(3), 227–242.

Chambre de Commerce et d'Industrie de France (2019). D'une idée à un business model cohérent.

Cholakova, M. & Clarysse, B. (2015). Does the possibility to make equity investments in crowdfunding projects crowd out reward–based investments? *Entrepreneurship Theory and Practice*, *39*(1), 145–172.

CompinnoV & FPF (2015). Baromètre de l'année 2014 crowdfunding france.

Corbel, P., Charreire Petit, S., & Emmanuelle, D. (2018). Crowdfunding : Les trajectoires du succès… ou de l'échec. *Innovations*, *56*, 239–266.

Dardour, A. (2015). La gestion du risque par les opérateurs de « crowdfunding » d'entreprise. *Recherches en Sciences de Gestion*, *107*, 45–65.

de Broeck, W. (2018). Crowdfunding platforms for renewable energy investments: an overview of best practices in the EU. *International Journal of Sustainable Energy Planning and Management*, *15*, 3–10.

Deffains-Crapsky, C. (2016). Financer la transition énergétique par le crowdfunding : atouts et modalités de mise en oeuvre. In *XIII-ième conférence annuelle TEPP Evaluation des Politiques Publiques*.

Deloitte (2019). Services innovation projects.

Demil, B. & Lecocq, X. (2010). Business model evolution: In search of dynamic consistency. *Long Range Planning*, *43*(2), 227–246.

Duran, N. (2018). Les rôles des acteurs dans la formation et le développement du crowdlending : analyse des liens et échanges sociaux. *Innovations*, *56*(2), 141–160.

Easton, G. (2010). *One case study is enough*. Marketing Working Paper Series. The Department of Marketing.

Financement Participatif France (2017). Panorama des plateformes de crowdfunding en date du 01/11/2017.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245.

Gabriel, C.-A. & Kirkwood, J. (2016). Business models for model businesses: Lessons from renewable energy entrepreneurs in developing countries. *Energy Policy*, *95*(C), 336–349.

Girard, C. & Deffains-Crapsky, C. (2016). Les mécanismes de gouvernance disciplinaires et cognitifs en equity crowdfunding : Le cas de la france. *Finance Contrôle Stratégie*.

GreenUnivers & FPF (2017). Baromètre 2016 du crowdfunding EnR.

Hörisch, J. (2015). Crowdfunding for environmental ventures: an empirical analysis of the influence of environmental orientation on the success of crowdfunding initiatives. *Journal of Cleaner Production*, *107*, 636–645.

Josefy, M., Dean, T. J., Albert, L. S., & Fitza, M. A. (2017). The role of community in crowdfunding success: Evidence on cultural attributes in funding campaigns to "save the local theater". *Entrepreneurship Theory and Practice*, *41*(2), 161–182.

KPMG & FPF (2017). Baromètre du crowdfunding en france 2016.

KPMG & FPF (2018). Baromètre du crowdfunding en france 2017.

Lam, P. T. & Law, A. O. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Lecocq, X., Demil, B., & Warnier, V. (2006). Le business model, un outil d'analyse stratégique. *L'Expansion Management Review*, *4*(123), 96–109.

Legifrance (2016). Décret n2016-1453 du 28 octobre 2016 relatif aux titres et aux prêts proposés dans le cadre du financement participatif.

Massa, L., Tucci, C. L., & Afuah, A. (2017). A critical assessment of business model research. *Academy of Management Annals*, *11*(1), 73–104.

Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, *29*(1), 1–16.

Moussavou, J. & Branellec, G. (2018). La problématique du risque dans le financement de projets innovants : une analyse juridique et managériale du crowdfunding base sur le rendement financier. *Innovations*, *56*(2), 217–238.

Nigam, N., Mbarek, S., & Benetti, C. (2018). Crowdfunding to finance eco-innovation: Case studies from leading renewable energy platforms. *Journal of Innovation Economics and Management*, *2*(26), 195–219.

Okkonen, L. & Suhonen, N. (2010). Business models of heat entrepreneurship in finland. *Energy Policy*, *38*(7), 3443–3452.

Onnée, S. & Renault, S. (2013). Le financement participatif: atouts, risques et conditions de succès. *Gestion Revue Internationale de Gestion*, *38*, 54–65.

Osterwalder, A. (2004). *The Business Model Ontology: a proposition in a design science approach*. Ph.d. dissertation, Université de Lausanne, Ecole des Hautes Etudes Commerciales.

Osterwalder, A. & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons.

Osterwalder, A. & Pigneur, Y. (2011). *Business Model nouvelle génération - Un guide pour visionnaires, révolutionnaires et challengers*. Pearson.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2015). *Value Proposition Design*. Pearson.

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems*, *16*, 1–25.

Perboli, G., Ferrero, F., Musso, S., & Vesco, A. (2018). Business models and tariff simulation in car-sharing services. *Transportation Research Part A: Policy and Practice*, *115*, 32–48.

Ponchel, T. & Bordier, C. (2017). Orienter l'épargne des ménages vers le financement des énergies renouvelables : quelle contribution du bonus au financement participatif ? *I4CE Point Climat number 48*.

Richter, M. (2013). Business model innovation for sustainable energy: German utilities and renewable energy. *Energy Policy*, *62*, 1226–1237.

Rochet, J.-C. & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Rochet, J.-C. & Tirole, J. (2006). Two-sided markets: a progress report. *The RAND Journal of Economics*, *37*(3), 645–667.

Sannajust, A., Roux, F., & Chaibi, A. (2014). Crowdfunding in france: A new revolution? *Journal of Applied Business Research*, *30*, 1909–1918.

SAP (2017). Designing business models for the digital economy.

Tracfin (2016). Le crowdfunding et ses risques. *Annales des Mines - Réalités industrielles*, (1), 61–64.

Vasileiadou, E., Huijben, J., & Raven, R. (2016). Three is a crowd? exploring the potential of crowdfunding for renewable energy in the netherlands. *Journal of Cleaner Production*, *128*, 142–155.

Vismara, S. (2018). Information cascades among investors in equity crowdfunding. *Entrepreneurship Theory and Practice*, *42*(3), 467–497.

Wehinger, G. (2012). Bank deleveraging, the move from bank to market-based financing, and sme financing. *OECD Journal: Financial Market Trends*, (1), 65–79.

Wirtz, B. W., Pistoia, A., Ullrich, S., & Göttel, V. (2016). Business models: Origin, development and future research perspectives. *Long Range Planning*, *49*(1), 36–54.

Yin, R. K. (1981). The case study crisis: Some answers. *Administrative Science Quarterly*, *26*(1), 58–65.

Chapter 4

Overview of the French renewable energy crowdfunding sector

Abstract *The renewable energy (RE) crowdfunding sector has expanded rapidly since 2014 in France. This sector benefits from a favorable regulatory environment that has supported its development. Crowdfunding platforms act as an intermediary between crowdfunders that invest in RE projects and project promoters that offer their projects for funding. So far, no author has described precisely the interactions between these different actors, and in particular in the case of France. Thus, the aim of this chapter is to give an overview of the RE crowdfunding sector in France. To do so, data was collected based on a questionnaire sent to French platforms that have a history of organizing crowdfunding campaigns for RE projects. Moreover, survey data from crowdfunders are used to describe their RE investment profile and motivations for RE crowdfunding.*

Résumé *Le secteur du financement participatif d'énergies renouvelables (EnR) s'est développé rapidement à partir de 2014 en France. Le secteur a bénéficié d'un contexte règlementaire favorable qui a soutenu cette croissance. Les plateformes de crowdfunding jouent le rôle d'intermédiaire entre les contributeurs qui investissent dans des projets d'EnR et les porteurs de projet qui proposent leurs projets au financement. Jusqu'à maintenant, aucun auteur n'a décrit précisément les interactions entre ces différents acteurs, y compris dans le cas de la France. C'est pourquoi l'objectif de ce chapitre est de proposer un panorama du secteur du financement participatif d'EnR en France. Pour ce faire, une collecte de données a été réalisée sur la base d'un questionnaire adressé aux plateformes françaises ayant un historique dans l'organisation de collectes de crowdfunding de projets d'EnR. De plus, des données de sondage collectées auprès de contributeurs sont également utilisées pour décrire leurs investissements dans les EnR et leurs motivations pour le financement participatif d'EnR.*

Contents

4.1 Introduction

There are two possible and complementary human responses to climate change. The first one is the implementation of mitigation actions that aim at reducing the physical risk associated with climate change, i.e., reducing greenhouse gas (GHG) emissions. The second is the design of initiatives to adapt current and future climate-related risks (IPCC, 2014, p.76). In this context, developing renewable energy (RE) sources is a way to reduce GHG emissions and thus contribute to climate change mitigation (IPCC, 2012, p.40). Redirecting financial flows towards RE sources is one of the challenges associated with the energy transition towards low-carbon sources (Mazzucato & Semieniuk, 2018). Moreover, RE sources might face a lack of legitimacy or even an active opposition that hinder their development (Mignon & Bergek, 2016). Thus involving citizens in the funding of RE sources is a way to raise funds for such projects and integrate them in the energy transition process (McInerney & Bunn, 2019).

Compared to the large volume of investments made worldwide, crowdfunding remains a niche sector even though it is expanding (Belleflamme et al., 2015). The literature looking at the crowdfunding sector is relatively new and mainly focuses on entrepreneurial finance (Martínez-Climent et al., 2018). Indeed, crowdfunding is an innovative financing means that enables entrepreneurs or project promoters to access funds from a large pool of investors (Mollick, 2014). Crowdfunding can be considered as a two-sided market (Armstrong, 2006, Rochet & Tirole, 2003, 2006) where platforms are key intermediaries between contributors, i.e., citizens and project promoters. In addition, it is likely that the precise sector of the project influences the behavior of the actors involved in crowdfunding. Some authors have specifically looked at crowdfunding for RE projects. So far, the understanding of the precise operations of the platforms offering RE projects and of the different actors involved in the sector is limited and the literature has focused mainly on the success conditions of campaigns, the description of the diversity of platforms and projects funded (e.g., Bento et al., 2019, Bonzanini et al.,

2016, Cumming et al., 2017, de Broeck, 2018, Lam & Law, 2016, Nigam et al., 2018, Vasileiadou et al., 2016).

The case of France is very interesting in order to investigate the crowdfunding sector and in particular in the context of RE projects. Indeed, the RE crowdfunding sector has experienced a fueled development in recent years characterized by an average annual growth rate of the amounts collected between 2016 and 2019 of around 80% based on the data published by GreenUnivers & FPF (2017, 2018, 2019, 2020). A few crowdfunding platforms collected most of the funds for RE projects. As a result, and since to the best of my knowledge it has not been done before, it seems very interesting to give an overview of the RE crowdfunding sector in the case of France. Thus, this chapter aims at presenting the different actors involved in the French RE crowdfunding sector, i.e., the platforms, the projects promoters, and the contributors. To do so, the analysis is based on the answers to a proprietary questionnaire from four platforms, that represented between 74% and 99% of the funds collected annually *via* crowdfunding platforms for RE projects.[1] To complement this approach concerning contributors' profile and motivations, the dataset collected by YouGov France for FPF and the MTES (2019) from an online questionnaire that targeted specifically contributors to RE crowdfunding campaigns from 8 platforms is also analyzed.

This chapter is organized as follows. Section 4.2 presents the recent development of the French RE crowdfunding sector. Section 4.3 details the data used to carry out the analysis done in this chapter. Section 4.4 gives an overview of the operating model and projects funded by the major platforms involved in the RE crowdfunding sector in France, and their two types of clients that are contributors to projects and project promoters. Finally, Section 4.5 concludes this chapter and formulates recommendations for future research.

4.2 The RE crowdfunding sector in France

In France, the crowdfunding sector was formally regulated in 2014. Since 2014, the sector has experienced a strong growth. Two regulated statutes were created for the crowdfunding sector depending on the instruments of funding used by French platforms: *Conseiller en investissement participatif* (CIP) for investment-based models and *Intermédiaire en financement participatif* (IFP) for donation and lending-based models. Another possible authorized statute for crowdfunding platforms offering investment possibility but not specific to the crowdfunding

[1] The calculation is based on the only sector-level data available that is published by GreenUnivers & FPF (2017, 2018, 2019, 2020). See Table 4.1 for more details.

sector is: *Prestataire de services d'investissement* (PSI).[2] In 2019, EUR 629 million were collected by crowdfunding platforms in France (Mazars & FPF, 2020).

Besides this, crowdfunding has a significant development potential in France. Indeed, in 2018, regulated savings represented about EUR 751 billion, that is about 15% of total households' financial assets (Banque de France, 2019, p.14). However, in recent years, regulated savings offered relatively low rates of return with a stable average remuneration rate of 1.5%. In addition, there is a global support for climate or environmentally-friendly behaviors among the French population as illustrated by the fact that the French population massively supports the development of at least one type of RE source (approval rate of 97% in 2019) (OpinionWay for Qualit'EnR, 2019, p.7). According to the results of the same barometer, most of French citizens (67%) rank households in the top 5 legitimate actors to engage in actions in favor of the environment and the energy transition. It even reaches the first place for 17% of the respondents (OpinionWay for Qualit'EnR, 2019, p.7). According to the results of the barometer published by GreenUnivers & FPF (2020), EUR 67 million were collected in 2019 for RE projects *via* crowdfunding platforms specialized or not on this type of projects.

Moreover, RE crowdfunding benefits from a favorable regulatory environment. Indeed, since 2017, the label *Financement participatif pour la croissance verte* (Crowdfunding for green growth) is awarded by authorized platforms to projects that fulfill specific criteria (FPF, 2019). Besides this, a bonus on the purchasing price of electricity is attributed since 2016 to projects partly funded by local citizens or authorities, possibly *via* crowdfunding, following public tenders.[3] In addition, the 2019 *Plan d'action pour la croissance et la transformation des entreprises* (Action plan for business growth and transformation, or *PACTE* law) increased the ceiling of funds that can be raised *via* crowdfunding to EUR 8 million (against EUR 2.5 million in 2016, and EUR 1 million in 2014). The *PACTE* law also introduced fiscal incentives for crowdfunding instruments.[4]

4.3 Data and methodology

The analysis carried out in this chapter builds on data collected based on a proprietary questionnaire sent to French platforms that have a history of organizing crowdfunding campaigns for RE projects. The choice of relying on data from

[2]The regulatory authorities are the *Autorité de contrôle prudentiel et de résolution* (ACPR, bank and insurance regulator) and the *Autorité des marchés financiers* (AMF, financial markets regulator).

[3]See Rüdinger (2019, in French) for more details about the bonus and the evolution of the award criteria.

[4]The *PACTE* law now allows to invest in crowdfunding instruments through favourable tax regime saving plans. In addition to this, it is now compulsory for life insurance products to propose at least one unit of account that is socially responsible or green.

platforms is justified by the central role of intermediary played by the platforms in this two-sided market (Armstrong, 2006, Rochet & Tirole, 2003, 2006). More precisely, in order to describe at best the sector, platforms were asked about the projects funded since there creation, how they operate, the types of projects funded, and the profile of contributors and of project promoters. The data was collected with the support of Financement Participatif France (FPF), the professional association of the crowdfunding sector in France. Four platforms answered the questionnaire between May and September 2020: Enerfip, Lendopolis, Lendosphere and Lumo. These platforms successfully organized RE crowdfunding campaigns for the first time in 2014 or 2015. Three of the platforms are specialized in RE projects and one also offers real estate projects (Lendopolis). From only 2 successful campaigns in 2014 representing about EUR 0.08 million, the platforms closed 211 campaigns in 2019 for a total amount of around EUR 56.9 million. The annual figures are presented in Table 4.1. As it can be seen, the reviewed platforms represented between 74% and 99% of the annual amounts collected by the French platforms that offered RE projects since 2016 according to the sector-level data published by GreenUnivers & FPF (2017, 2018, 2019, 2020).

	2014	2015	2016	2017	2018	2019
Successful campaigns	2	25	52	73	112	211
EUR amount collected	80,000	2,852,283	11,874,900	18,341,640	28,722,795	56,852,172
Share of the sector			99%	89%	74%	85%

Table 4.1 RE crowdfunding campaigns and amounts collected by the platforms under review.

Source: author's work based on questionnaire data collected.
Note: the share of the RE crowdfunding sector is calculated based on the data of total funds collected by crowdfunding platforms for RE projects published by GreenUnivers & FPF (2017, 2018, 2019, 2020).

To complement this approach based on platforms' insights, and in particular concerning contributors' profile and motivations, survey data are also considered in this chapter. More specifically, the dataset collected by YouGov France for FPF and the MTES (2019)[5] from an online questionnaire that targeted specifically contributors to RE crowdfunding campaigns from 8 platforms is also analysed. Data were collected between February and March 2019 at the individual level and from the following crowdfunding platforms that represent more than 90% of the sector: Akuocoop, Enerfip, Lendopolis, Lendosphere, Lita.co, Lumo, Tudigo, and Wiseed. The final size of the contributors' sample is of 2,154 respondents.

[5]YouGov France is a survey institute and the Ministère de la Transition écologique et solidaire (MTES) is the French Ministry for the Ecological and Inclusive Transition.

Regarding the methodology adopted in this chapter, the answers of platforms to the questionnaire and the survey dataset collected by YouGov France for FPF and the MTES (2019) will be analysed with a descriptive approach to precisely describe the different actors involve in the RE crowdfunding sector in France.

4.4 Results

This section presents an overview of the French RE crowdfunding sector. In particular, Section 4.4.1 presents the major platforms involved in the RE crowdfunding sector in France and their operating model. Section 4.4.3 describes project promoters that used RE crowdfunding. Section 4.4.2 details the different types of RE projects financed. Section 4.4.4 gives an overview of the profile of the contributors of RE crowdfunding projects, their motivations to do so and investments in RE sources with other instruments.

4.4.1 Platforms

As seen before, two regulatory statutes were introduced in France for the crowdfunding sector. The studied platforms chose one of the two statutes to start operating and all of them have decided to ask for the other one at some point (see Table 4.2 for more details regarding the expansion of use of each statute).[6] This means that platforms identified the relevance of expending the financing instrument possibilities they offer in order to grow. Regarding platforms' development and as also shown in Table 4.2, the number of employees increased to reach an average of 13 in 2019. The smallest number of staff is 7 (Lendosphere) and the largest is 20 (Lendopolis).

	2014	2015	2016	2017	2018	2019
IFP (lending, donation)	2	2	2	3	3	3
CIP (equity, bonds, and "minibons")	1	2	3	4	4	4
Av. number of employees	4	4	7	11	12	13

Table 4.2 Number of reviewed platforms based on their regulatory statutes and average number of employees per year.

Source: author's work based on questionnaire data collected.
Note: "Av." = "average".

The platforms act as an intermediary between their two types of customers. They are responsible for the diffusion of information regarding the promoters'

[6] Lumo asked for the IFP statute in 2020 to be able to conduct donation-based campaigns.

projects on the dedicated online webpages and of the organization of the associated crowdfunding campaigns. The platforms also stated that they communicate information to contributors regarding the campaigns and the projects after the campaigns, on a more or less regular basis depending on the platform. Regarding the revenue flows and platforms accessibility, all platforms currently have the same model. Contributors, that are mainly individual investors, have a free access to the projects description and do not pay any fee to invest in them. Prior to 2019, Lumo was the only platform that charged contributors a fee when they invested in projects. Moreover, contributors generally have to invest a minimum amount, generally between EUR 10 and 50, to be able to contribute to a RE project through a crowdfunding campaign. There are sometimes also a maximum contribution by investor to the campaign. On the other hand, project promoters pay a fee to offer their projects on the platforms that is proportional to the amount collected (between 3 and 7%).

Among the platforms studied, three out of four have links with the banking sector. Since 2016, the Crédit Agricole group acquired a stake in Enerfip's capital. In 2017, Lendopolis became a subsidiary of La Banque Postale group. Finally, Lumo became a subsidiary of the Société Générale group in 2018. It is interesting to note that each platform has a relation with a different banking group. It is likely that the banking partners contribute to increase the visibility of the platforms, including to attract contributors and project promoters. If this can be considered as a development facilitator, the main risk identified by the platforms that would have a negative influence on the growth of the crowdfunding sector is the regulatory risk. Indeed, since 2014, the RE crowdfunding sector have benefited from a favorable regulatory environment. A change in the regulation of the general crowdfunding sector or the RE sector is expected to hinder their expansion according to all of the reviewed platforms. Moreover, only one of the studied platforms offered some projects in foreign countries. In addition to projects in France, RE projects in Africa and Sweden were financed *via* Lendosphere. All other platforms stated that they are considering to offer projects in other countries than France.

4.4.2 Crowdfunding instruments and RE projects financed

As mentioned before, the platforms under review chose one of the regulatory statutes available in France for crowdfunding platforms and decided to add the other statute to expand the number of instruments available for RE crowdfunding campaigns. As presented in Table 4.3, between 2014 and 2019 the share of amounts collected calculated at platform level using debt-instruments dominated, i.e., bonds, *minibons* and lending-based campaigns. *Minibons* are similar

to bonds with constant repayment installments that cannot exceed a quarterly frequency (Legifrance, 2016). In particular, the largest share of amounts was collected *via* bond campaigns. The annual breakdown of amounts collected by each platform and by instrument types is given in Appendix C.1. Enerfip and Lumo continue to collect a large share of funds *via* bond campaigns. Since 2016, the share of amounts collected by Lendosphere *via* bond campaigns increased while lending-based campaigns decreased. For Lendopolis, bond campaigns became prevalent in 2018 and replaced lending-based campaigns. All platforms studied used *minibons* and particularly Lendosphere for which is was a significant share of the amounts collected between 2015 and 2017. In addition, Enerfip was the first one to organize equity-based campaigns in 2017, followed in 2019 by Lendosphere.

Regarding the return on investment of debt-based instruments since 2014, it is between 3.6 and 6.5% depending on the platforms and the investment instruments. In addition, the reviewed platforms stated that higher interest rates are sometimes offered to local contributors (between 3 and 48% of the projects depending on the platforms). One reason for this is the local contribution criteria, i.e., contributions from investors of the project local area are required, for the bonus on the price of electricity in the context of public tenders. Thus, debt-based RE crowdfunding had a higher rate of return than regulated savings (average remuneration rate of 1.5% in 2018 according to the report of the Banque de France, 2019). However, investing on a crowdfunding platform is not risk-free. Indeed, if platforms conduct due diligence processes before organizing a campaign for a project, there is a risk of total or partial loss of the invested funds. This risk is specifically identified by the reviewed platforms as the main risk for contributors of RE crowdfunding. The average investment duration ranges from 3 to 6 years for bonds and *minibons* and is slightly shorter for lending-based from 1 to 4 years on average. It is to be noted that before 2018, Lumo used to propose longer investment periods up to 13 years.

	Bonds	***Minibons***	**Lending**	**Shares**
Share in total amounts collected since 2014 (av.)	64 to 94% (84%)	2 to 27% (10%)	0 to 8% (5%)	0 to 5% (2%)
Av. investment duration in years	3 to 6 (up to 13 before 2018)	3 to 6 (up to 11 before 2018)	1 to 4	
Av. return on investment	3.6 to 5.5%	3.6 to 6%	4.3 to 6.5%	

Table 4.3 Investment instruments used, average investment duration and return on investment since 2014.

Source: author's work based on questionnaire data collected.
Note: "Av." = "platform average". Shares are calculated at platform level.

Turning now to the energy sources financed using the studied platforms since 2014, the share of each type of RE-related projects at platform level is presented in Table 4.4. Solar received by far the highest share of funding followed by wind projects. The annual breakdown of amounts collected by each platform (except for Lumo) and by project types is given in Appendix C.2. It can be seen that almost all of the funds raised via Lendopolis were dedicated to solar projects. Solar projects were also significant for Enerfip but the platform diversified the RE sources financed with wind, biomass, and other RE-related projects from 2016 onwards. The platform was also the first one to offer hydro projects (1% of the amounts collected in 2019). On Lendosphere, more than half of the amounts collected funded wind projects before 2018 even if the share of solar projects increased. From 2018 onwards, the platform also offered biomass and other RE-related projects.

	Solar	**Wind**	**Biomass**	**Hydro**	**Other RE-related**
Share in total amounts collected since 2014 (av.)	50 to 98% (69%)	2 to 41% (25%)	0 to 6% (3%)	0 to 0.4% (0%)	0.3 to 3% (2%)

Table 4.4 RE sources or other RE-related projects financed since 2014.

Source: author's work based on questionnaire data collected.
Note: "Av." = "platform average". Lumo did not provide detailed information about the projects funded. Shares are calculated at platform level.

Projects that are available online to investment by contributors through crowdfunding platforms are at different stage in their development. The details regarding development status of projects during crowdfunding campaigns is given in Table 4.5. On average based on platform level data between 2014 and 2019, most of the funds were raised for projects under construction. At a global level, projects under development come next followed by projects in operation.

	Under development	**Under construction**	**In operation**
Share in total amounts collected since 2014 (av.)	1 to 50% (24%)	40 to 88% (58%)	10 to 33% (18%)

Table 4.5 Development stage of the projects since 2014.

Source: author's work based on questionnaire data collected.
Note: "Av." = "platform average". Lumo did not provide detailed information about the projects funded. Shares are calculated at platform level.

4.4.3 Presentation of project promoters

As detailed in the overview of past literature on crowdfunding given by Short et al. (2017), crowdfunding is an innovative financing means that has been primarily considered as relevant for entrepreneurs in complement of other forms of entrepreneurial financing, e.g., business angels, venture capital. In addition to being a way to access funds, crowdfunding can also be "used for marketing purposes, creating interest in new projects" but also benefiting the project promoters' image in case of media coverage for instance (Mollick, 2014, p.3). Indeed, according to the reviewed platforms in the case of RE crowdfunding in the French context, the motivations of project promoters in descending order of priority are to: (i) raise local awareness of projects and favor local acceptance, (ii) obtain the bonus on the purchasing price of electricity following public tenders for projects partly funded by local citizens, (iii) raise funds, and (iv) enable citizen participation in the funding of RE sources. Thus, according to the platforms, the local awareness and acceptance of their projects are central to the strategy of project promoters. Moreover, the platforms all identify the regulatory risk (e.g., in relation to the bonus on the purchasing price of electricity) as the main risk for project promoters using crowdfunding platforms for RE projects.

However, regarding the profile of project promoters, it can be seen in Table 4.6 that most of the funds were collected by large French developers, i.e., developers that operate 20 or more RE installations, during the period 2014 to 2019. Lendopolis and Lendosphere organized campaigns for RE-related projects from two types of promoters with only a very minor share of funds collected for local authorities (0.2% for Lendosphere) or small French developers (1,5% for Lendopolis), the rest being large French developers. On the other hand, during the period 2014-2019 Enerfip organized RE-related campaigns for a much more diverse set of promoters. Indeed, as presented in Appendix C.3, large RE developers only represented 51% of the funds raised and local groups accounted for 22%, foreign developers for about 12%, small French developers for 10%, entrepreneurs for 4.5%, and finally local authorities for 0.3%. As a result, the French RE crowdfunding sector is not dedicated to the funding of RE-related entrepreneurs but the promoters that use platforms are mainly RE developers with a sizeable activity. It is also interesting to see that most of the developers that used French crowdfunding platforms are national ones.

	Small French developers	Large French developers	Foreign developers	Local groups or authorities	Entrepreneurs
Share in total amounts collected since 2014 (av.)	0 to 10% (4%)	51 to 99.8% (83%)	0 to 12% (4%)	0.2 to 4% (2%)	0 to 5% (1.5%)

Table 4.6 Types of project promoters since 2014.

Source: author's work based on questionnaire data collected.
Note: "Av." = "platform average". Developers are considered as small if they operate less than 20 RE installations, otherwise they are considered as large developers. Groups of citizens or farmers are considered here as local groups. Lumo did not provide detailed information about project promoters that used the platform. Shares are calculated at platform level.

4.4.4 Profile and motivations of RE projects crowdfunders

In mid-2020, the platforms had between 14,250 and 30,300 members (the average is of about 19,900 members). Lendopolis had a higher number of members. This might be explained by the fact that the latter platform is also offering crowdfunding of real-estate projects. An overview of the profile in terms of age and gender of contributors is given in Table 4.7. More precisely the 2019 platforms' members age and gender information is compared with the profile of respondents to the survey carried out in early 2019 by YouGov France for FPF and the MTES (2019). It can be seen that about 80% of respondents and on average of platforms' members are between 25 and 64 years old. Even if some platforms organize in-person local meeting and can help potential contributors to invest during these meetings or with a phone advice and support service (see the case of Enerfip in Chapter 3 for a more precise description), retired people – that are generally considered to have greater savings and are found to tend to adopt pro-environmental behaviors (López-Mosquera et al., 2015) – represent a relatively small share of members and respondents. Moreover, young people are not a significant share of contributors (only 1% for the 18-24 age group) which might be explained by the fact that even tough they are very connected, they generally do not have large savings. In addition, RE crowdfunding is very dominated by male contributors with an average of three-quarters of the platforms' members being men. The gap between the two genders is even more pronounced for the survey data.

	18-24	25-34	35-44	45-54	55-64	65+	Men	Women
Av. with platform data	1%	18%	23%	20%	21%	17%	75%	25%
Survey data	1%	20%	21%	22%	20%	17%	87%	13%

Table 4.7 Platforms' members age and gender profile in 2019 and respondent of the survey data characteristics.

Source: author's work based on questionnaire data collected and survey data (YouGov France for FPF and the MTES, 2019).
Note: "Av." = "average". Lendosphere did not provide detailed information about the gender of its members so the average is calculated based on data from the other three platforms.

Relying only on a qualitative thematic analysis of online posts of contributors on projects' webpage, Vasileiadou et al. (2016) find that financial and ethical considerations predominate in RE crowdfunding investment decisions. In Chapter 3, my co-authors and I found that according to Enerfip, the three main motivations of contributors of projects were to: (i) contribute to the energy transition to mitigate climate change, (ii) invest their savings directly for a local purpose, and (iii) invest in a specific project with an interesting rate of return.

More generally, according to the reviewed platforms in the case of RE crowdfunding in the French context, the motivation of contributors in descending order of priority are: (i) the expectation of a significant rate or return or seeking portfolio diversification, (ii) the concern for RE deployment and climate change mitigation, (iii) the contribution to the funding of a project with a significant local aspect, and (iv) the investment behavior outside of the banking system.

In the questionnaire used to collect survey data from contributors to RE crowdfunding by YouGov France for FPF and the MTES (2019), respondents were asked to pick and rank their top-3 motivations among the following: (i) the attractive financial return, (ii) the geographical proximity of the project and the place of residence, (iii) the participation in the local territory's economic development, (iv) the sensitivity to environmental causes, (v) the participation in projects decision-making, (vi) the contribution to the development of renewable energy sources in France, and (vii) other reasons. Figure 4.1 presents a synthesis of the motivations ranked. In particular, contributing to RE development, the sensitivity to environmental causes, and the expectation of an interesting financial return are the most picked motivations. In addition, respondents tend to put the environmental and RE development contribution motivations first or second when the financial motivation is often ranked third. The proximity of projects to dwellings' home and the participation in projects' decision-making seem less important motivations compared to the other ones. These results are slightly different from what platforms think of contributors' motivations.

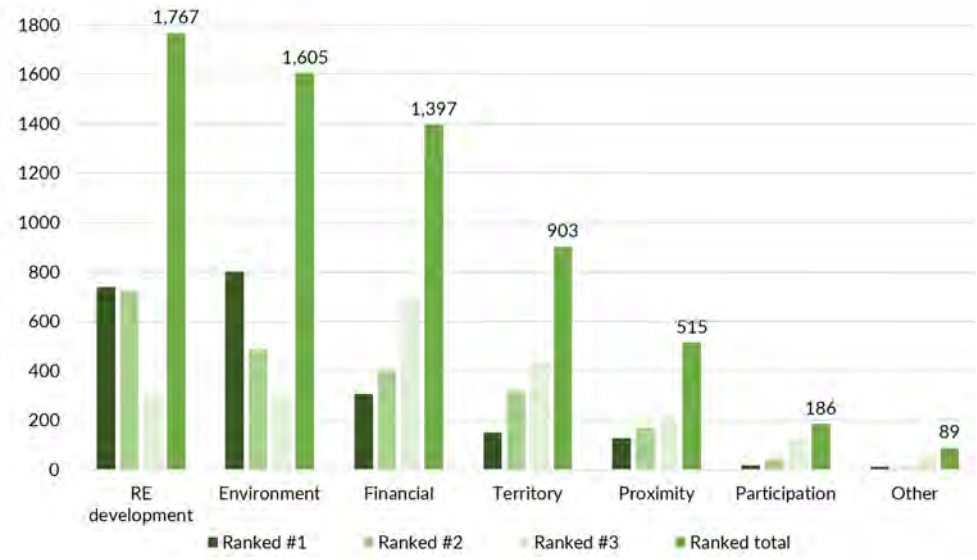


Fig. 4.1 Overview of the motivations ranked by the survey respondents.

Source: author's work based on survey data (YouGov France for FPF and the MTES, 2019).

In addition, in the survey questionnaire, respondents were asked about there existing investments in RE sources using other vehicles. The propositions listed were: (i) an investment fund, (ii) a banking product, (iii) shares on a stock market, or (iv) a community-based initiative. As displayed in Table 4.8, 61% of RE crowdfunders used another instrument to invest in RE sources. In particular, about 50% of the respondents stated that they invested in RE sources *via* a banking product, 18% said they did so through shares on stock markets, about 10% used an investment fund, and also 10% invested *via* a community-based initiative.

Instruments	Number of RE crowdfunders	Frequency associated
Crowdfunding only	841	39.0%
At least one other instrument	1,313	61.0%
- Banking product	1,068	49.6%
- Shares on stock markets	391	18.2%
- Investment fund	224	10.4%
- Community-based initiative	221	10.3%

Table 4.8 Overview of the utilization of RE investment instruments by RE crowdfunders.

Source: author's work based on survey data (YouGov France for FPF and the MTES, 2019).

4.5 Conclusion

Crowdfunding of RE projects is expanding in the world and in particular in France where the sector benefits from a favorable regulatory environment. The literature on RE crowdfunding is relatively scare. To the best of my knowledge,

so far no author has given a very precise overview of the RE crowdfunding sector including regarding the different actors involved in this sector at a country level. This is the aim of this chapter that is based on data collected from the major platforms offering RE projects in France and also on survey data collected by YouGov France for FPF and the MTES (2019).

Regarding platforms business model, since 2014 they have expanded the number of instruments used for RE crowdfunding campaigns and most of them also created links with the banking sector to develop. Between 2014 and 2019, most of the funds were collected through debt-based campaigns, in particular with bonds, with significant rate of returns compared to regulated savings. Moreover, solar energy received the largest share of funds during the same period followed by wind energy. Some platforms diversified the energy sources financed offering biomass or other RE-related projects for instance. During the period studied, the projects that raised the largest share of funds were projects under construction.

Turning now to the profile of project promoters, contrary to what is generally considered in the crowdfunding literature, for RE projects in France they are mostly well-established French developers. According to the platforms, their first motivation when offering their RE projects to citizen funding is to increase local visibility and acceptance. Financial considerations are also significant motivations for them. Interestingly enough, Enerfip is the only platform to have significantly diversified the profile of the project promoters using the platform.

In mid-2020, the platforms studied had on average 19,900 members. About 80% of the platforms' members are between 25 and 64 years old on average. Based on survey data from crowdfunders, it is found that their first three motivations ranked are: the contribution to RE development, the sensitivity to environmental causes, and financial return. In addition to their investment *via* crowdfunding, 61% of the respondents also state that they used other instruments to invest in RE sources, particularly through banking products.

To conclude, this chapter is the first attempt to give an overview of the profile of the different actors involved in the RE crowdfunding sector in the case of France. It enables to shed some new light but more research is necessary to explore the decision-making process of contributors while investing in RE crowdfunding and also to investigate the effective influence of crowdfunding on the local acceptance of projects.

4.6 Bibliography

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics*, *37*(3), 668–691.

Banque de France (2019). *Rapport de l'Observatoire de l'Epargne réglementée 2018*.

Belleflamme, P., Omrani, N., & Peitz, M. (2015). The economics of crowdfunding platforms. *Information Economics and Policy*, *33*, 11–28.

Bento, N., Gianfrate, G., & Groppo, S. V. (2019). Do crowdfunding returns reward risk? evidences from clean-tech projects. *Technological Forecasting and Social Change*, *141*, 107–116.

Bonzanini, D., Giudici, G., & Patrucco, A. (2016). The crowdfunding of renewable energy projects. In V. Ramiah & G. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 429–444). Elsevier.

Cumming, D. J., Leboeuf, G., & Schwienbacher, A. (2017). Crowdfunding cleantech. *Energy Economics*, *65*, 292–303.

de Broeck, W. (2018). Crowdfunding platforms for renewable energy investments: an overview of best practices in the EU. *International Journal of Sustainable Energy Planning and Management*, *15*, 3–10.

FPF (2019). Label croissance verte.

GreenUnivers & FPF (2017). Baromètre 2016 du crowdfunding EnR.

GreenUnivers & FPF (2018). Baromètre 2017 du crowdfunding EnR.

GreenUnivers & FPF (2019). Baromètre 2018 du crowdfunding EnR.

GreenUnivers & FPF (2020). Baromètre 2019 du crowdfunding des EnR.

IPCC (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. Technical Summary.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Lam, P. T. & Law, A. O. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Legifrance (2016). Décret n2016-1453 du 28 octobre 2016 relatif aux titres et aux prêts proposés dans le cadre du financement participatif.

López-Mosquera, N., Lera-López, F., & Sánchez, M. (2015). Key factors to explain recycling, car use and environmentally responsible purchase behaviors: A comparative perspective. *Resources, Conservation and Recycling*, *99*, 29–39.

Martínez-Climent, C., Zorio-Grima, A., & Ribeiro-Soriano, D. (2018). Financial return crowdfunding: literature review and bibliometric analysis. *International Entrepreneurship and Management Journal*, *14*(3), 527–553.

Mazars & FPF (2020). *Baromètre annuel du crowdfunding en France 2019*.

Mazzucato, M. & Semieniuk, G. (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change*, *127*, 8–22.

McInerney, C. & Bunn, D. W. (2019). Expansion of the investor base for the energy transition. *Energy Policy*, *129*, 1240–1244.

Mignon, I. & Bergek, A. (2016). System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. *Journal of Cleaner Production*, *128*, 105–115.

Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, *29*(1), 1–16.

Nigam, N., Mbarek, S., & Benetti, C. (2018). Crowdfunding to finance eco-innovation: Case studies from leading renewable energy platforms. *Journal of Innovation Economics and Management*, *2*(26), 195–219.

OpinionWay for Qualit'EnR (2019). *Les Français et les énergies renouvelables Baromètre Vague 9*. Janvier 2019.

Rochet, J.-C. & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Rochet, J.-C. & Tirole, J. (2006). Two-sided markets: a progress report. *The RAND Journal of Economics*, *37*(3), 645–667.

Rüdinger, A. (2019). *Participatory and citizen renewable energy projects in France - State of play and recommendations (in French)*. Study number 03/19.

Short, J. C., David J. Ketchen, J., McKenny, A. F., Allison, T. H., & Ireland, R. D. (2017). Research on crowdfunding: Reviewing the (very recent) past and celebrating the present. *Entrepreneurship Theory and Practice*, *41*(2), 149–160.

Vasileiadou, E., Huijben, J., & Raven, R. (2016). Three is a crowd? exploring the potential of crowdfunding for renewable energy in the netherlands. *Journal of Cleaner Production*, *128*, 142–155.

YouGov France for FPF and the MTES (2019). Enquête sur le financement participatif des énergies renouvelables.

Chapter 5

French citizens' decision to crowdfund renewable energy projects

This chapter has been published as
Bourcet, C., Bovari, E. (2020). Exploring citizens' decision to crowdfund renewable energy projects: quantitative evidence from France. *Energy Economics*, 88. Link

Abstract *Benefiting from broad citizen and political support, renewable energy (RE) crowdfunding has experienced a strong growth in France. It is a relevant instrument to diversify funding possibilities, commit citizens to the energy transition, and foster local acceptance of RE sources. Thus, and as it was never done before in the literature, it is crucial to better understand the RE crowdfunding investment decision-making process for public policy guidance. Relying on a novel survey dataset, this chapter aims at filling this gap using a probit regression analysis. Among the French population, the main predictors of the decision to invest in RE crowdfunding are: (i) the general opinion about the RE sector, (ii) opinions about the RE sector durability and investment opportunities transparency, (iii) risk perception, and (iv) existing other RE investments. The results suggest that the policy framework recently implemented in France is relevant to foster the development of the sector.*

Résumé *Le financement participatif d'énergies renouvelables (EnR) a connu une forte croissance en France dans un contexte réglementaire favorable et de soutien populaire. Il permet la diversification des sources de financements, l'implication des citoyens dans la transition énergétique et stimule l'acceptabilité locale des EnR. C'est pourquoi, et d'autant plus que cela n'a jamais été étudié auparavant, il est important de mieux cerner le processus d'investissement en crowdfunding d'EnR pour guider les politiques publiques en lien. Ce chapitre s'appuie sur une base de données originale pour conduire une analyse au moyen d'une régression probit. Les principaux prédicteurs de la décision d'investissement en crowdfunding d'EnR des citoyens français sont : (i) l'opinion général du secteur EnR, (ii) les opinions sur la durabilité du secteur EnR et la transparence des opportunités d'investissement, (iii) la perception du risque, et (iv) l'existence d'autres investissements EnR. Les résultats suggèrent que le cadre réglementaire récemment développé en France est à même de soutenir le développement du secteur.*

Contents

5.1 Introduction

There is an international recognition of the existence of a human induced climate change with potential substantial impacts on both economies and ecosystems (IPCC, 2014). Low-carbon renewable energy (RE) sources[1] provide relevant alternatives to fossil fuels to reduce the carbon content of the energy sector, that currently represents more than two-thirds of anthropogenic greenhouse gas emissions (IEA, 2018, p.3). However, the deployment of RE sources is relatively slow and, as noted by Reboredo (2015), substantial differences exist between countries. In the case of France, in 2017, RE sources represented 16.3% of gross final energy consumption, which is below the trajectory projected by the CGDD (2019, p.17) to reach the 23% target by 2020 set by the European Union for France.[2] As pointed out by Painuly (2001) or more recently by Bourcet (2020), different barriers exist that hinder the deployment of RE sources, among which financing and acceptance are prominent.

Besides this, large investments are required to meet climate targets, such as the limitation of global warming to a level below 2°C (or even 1.5°C) with regards to the pre-industrial era, as stated in the Paris Agreement (UNFCCC, 2019). Green investments are especially needed to decarbonize the energy system (IPCC, 2018, p.21-22). To cover these needs, green finance, that is (re)directing significant financial flows towards climate-friendly assets, shall gain momentum, as prompted by international organisations (e.g., NGFS, 2019, OECD, 2017, TCFD, 2017). A nascent literature specifically addresses this issue and has already investigated a

[1] To briefly define RE sources, we follow the list given by the report of the IPCC (2012): bioenergy, direct solar energy, geothermal energy, hydropower, ocean energy, and wind energy.

[2] This target was set by the Directive 2009/28/CE. The CGDD (2019, p.17) has projected that to reach the 2020 objective, the 2017 level of RE in gross final energy consumption should have reached 19.5%. The development delay reported concerns both electricity and heat energy.

panel of investment vehicles and behaviors such as green bonds, impact investing, or carbon pricing (see for instance Clark et al., 2018, Hafner et al., 2020). Renewable energy crowdfunding is another relevant instrument in this regards, because it expands and diversifies the investor base by collecting funds from small retail investors to contribute to the energy transition (McInerney & Bunn, 2019).

Provided citizens are making both consumption and investment choices (Knoefel et al., 2018), crowdfunding has a significant development potential in France. Indeed, in 2018, regulated savings[3] represented about EUR 751 billion, that is about 15% of total households' financial assets (Banque de France, 2019, p.14). However, in recent years, regulated savings have offered relatively low rates of return with a stable average remuneration rate of 1.5%. This might be one reason to explain the tremendous development of crowdfunding. All sectors combined, the funds collected grew from EUR 167 million in 2015 to EUR 402 million in 2018 according to KPMG & FPF (2019), particularly through return-based investment instruments. Indeed, from 2016 to 2018, the funds raised *via* crowdfunding platforms using equities, bonds, or interest-bearing peer-to-peer lending, accounted for about 90% of the increase.

Additionally, RE crowdfunding could be a way to favor projects' local acceptance (Bourcet et al., 2019), and more broadly raise awareness and involve citizens in the energy transition process (Vasileiadou et al., 2016). Indeed, following the seminal work of Elinor Ostrom (e.g., Ostrom, 2012), some scholars have emphasized the useful role of local and collective actions to complement global climate change mitigation policies, and in particular to promote the deployment of RE energy sources (see for instance Bauwens & Eyre, 2017). According to the barometer OpinionWay for Qualit'EnR (2019, p.7), the French population massively supports the development of at least one type of RE source (approval rate of 97% in 2019). Moreover, most of French citizens (67%) rank households in the top 5 legitimate actors to engage in actions in favour of the environment and the energy transition. It even reaches the first place for 17% of the respondents. This growing support for RE sources is echoed by supportive policies targeting crowdfunding, and thus RE crowdfunding, as illustrated by the 2019 *Plan d'action pour la croissance et la transformation des entreprises* (Action plan for business growth and transformation, or *PACTE* law). This law increased the ceiling of funds that can be raised *via* crowdfunding and introduced fiscal incentives for crowdfunding instruments.

All these reasons make France the European leader in RE crowdfunding (Rüdinger, 2019), and thus an ideal case study for this sector. Besides this, in view

[3] In France, regulated savings gather various financial instruments benefiting from specific management, fiscal and/or guarantee rules set by the State.

of this rapid development, it is crucial to pinpoint the very determinants of citizens' decision to invest in RE crowdfunding to build confidence in policy design and evaluation, as emphasized by Bergek et al. (2013). However, and to the best of our knowledge, the existing related literature is relatively scarce on this topic. Moreover, it primarily focuses on crowdfunding platforms and on projects case studies rather than on investors' motivations *per se*. In addition, authors mainly rely on past campaigns' data, which is at best a proxy for investors' decisions. This chapter seeks to contribute to filling this gap by empirically assessing citizens' decision-making process to invest in RE crowdfunding projects. To do so, we use a novel and so far unused dataset provided by YouGov France for FPF and the MTES (2019).[4] This dataset reports survey data collected in 2019 about French RE citizens and investors. It contains several aspects of individuals' attitudes regarding the RE sector (opinions, existing related investments, *etc.*), as well as socio-economic characteristics. We rely on a probit regression model to investigate the factors that influence individuals' decision to invest in RE crowdfunding. We thus complement the green finance and RE crowdfunding literatures by using an empirical methodology based on survey data, that allows us to focus on investors by accessing primary data. In addition, we simultaneously consider several potential determinants of RE crowdfunding investment that are put in perspective with previous research.

Our results suggest that, among the French population, opinions on the RE sector and its characteristics, in particular its durability (i.e., business continuity over time) and the transparency of investment offers, do positively and significantly influence the decision to invest. The risk perception also plays a significant role in the decision-making process. Moreover, positive and significant spillovers arise from existing investments in RE vehicles. The local acceptance of solar power projects, age, education and socio-professional status are also significant predictors of RE crowdfunding. These results are unchanged by additional controls on gender and geography, as well as to various econometric specifications. They are also consistent with previous existing findings in the literature. Consequently, to foster the development of the RE crowdfunding sector, our analysis suggests to promote policies that: (i) strengthen the transparency and reduce the risk perception of the RE crowdfunding sector (independently of RE projects' performance), (ii) promote the durability of the RE sector, and (iii) expand green investment possibilities for retail investors. Policies currently adopted, or to be implemented, in France, are promising steps in this direction.

[4] *Financement Participatif France* (FPF) is the professional association of the crowdfunding sector in France. The *Ministère de la Transition écologique et solidaire* (MTES) is the French Ministry for the Ecological and Inclusive Transition.

The chapter is organized as follows: Section 5.2 presents the literature motivating this chapter, Section 5.3 details the methodology and dataset, Section 5.4 provides and discusses the results of the analysis, and Section 5.5 concludes.

5.2 Related literature

Crowdfunding can be defined as "a method of pooling often small amounts of capital from a potentially large pool of interested funders" (Short et al., 2017, p.149). If this financial innovation is not a new one – this technique was used in 1885 to complete the funding of the Statue of Liberty's pedestal (National Park Service, 2019) – the democratization of the Internet and the emergence of dedicated online platforms resulted in its significant development. This financing mechanism has indeed become widespread over the past 10 years. Additionally, the 2008 financial crisis is likely to have fostered the development of crowdfunding due to increased difficulties for economic agents, and in particular entrepreneurs, to access funds (Bruton et al., 2015). Different instruments can be used – e.g., donation, peer-to-peer lending, other debt-instruments, or shares – to crowdfund a wide range of projects – e.g., business development, artistic creation, or environmental innovations. The literature focusing on crowdfunding through online intermediary platforms (hereafter crowdfunding) is relatively new and mainly focuses on entrepreneurial finance (Martínez-Climent et al., 2018). Such platforms either specialize in particular sectors, or in a specific range of investment instruments. In addition to providing an alternative range of financing instruments, crowdfunding also favors interactions between project founders and investors, possibly resulting in reduced information asymmetries, greater experience sharing, and growing acceptance of funded projects (Robano, 2018).

Due to the specificities of crowdfunding (online platforms, decentralized pool of investors, *etc.*) with regards to traditional financing instruments, it is key to better understand the various factors that shape the decision-making process of crowdfunding contributors (hereafter investors or crowdfunders). Hoegen et al. (2018) survey the recent literature on this topic to classify these factors. They emphasize the role of: (i) the potential benefit and associated financial risk for the investor, (ii) the founder's characteristics in relation to the project and in terms of social capital and interactions, (iii) the investor's characteristics, and (iv) the platform's characteristics. The precise categories and sub-categories identified by Hoegen et al. (2018) are presented in Table 5.1.

Category	Sub-category	Description
Benefits and quality	Outcome and product	Material or non-material benefits promised to the crowdfunders, perceived quality of the product or service financed
	Perceived process quality	Transparency and quality perception of the information regarding the campaign and future steps and plans
Financial risk and campaign statistics	Financial risk	Measurable monetary risk of investment and factors to judge and mitigate it
	Campaign statistics	Platforms' data on the campaign statistics and status
Founder perception and attributes	Founder's characteristics	Measurable and perceived characteristic of the founder in relation to the project (skills, experience, personality, appearance)
	Founder communication	Communication behavior of, and information given by, the founder on the platform and social networks
	Previous behavior	Founder's crowdfunding performance record
	Demographics and physical attributes	Demographics and physical attributes of the founder
Social, relationships, and endorsements	Social capital	Social status and capital, and online social capital of the founder
	Social dynamics	Behavior of others directly linked with the project or the campaign
	Third-party endorsement	Support from other parties than founder or crowdfunders (e.g., media or social media coverage)
Context	Platform context	Aspects of the platform that should not, but do, influence crowdfunders
	Crowdfunder context	Aspects of crowdfunders direct surroundings that should not, but do, influence them
Crowdfunders characteristics (indirect impact on the investment decision)	Affectual reaction	Emotional reaction of crowdfunders
	Motives	General motives of crowdfunders
	Relational fit	Similarity and proximity between the crowdfunders and the founder
	Cognitive features	Cognitive features and aspects of crowdfunders
	Experience	Relevant experience with a type of investment, product, or project

Table 5.1 Overview of general factors influencing crowdfunders' decision making.

Adapted from: Hoegen et al. (2018).
Note: In this table, the term "founder" refers to the project promoters.

However, a limitation of the literature surveyed by Hoegen et al. (2018) is that it relies primarily on secondary data from past campaigns carried out on platforms (see for instance Allison et al., 2015, Hörisch, 2015). Thus, the crowdfunding literature focuses more on the conditions for successful campaigns rather than on investors' behaviors and decisions *per se*.[5] Despite being more suited to the latter analysis, survey methodologies have rarely been considered so far (see for instance Cholakova & Clarysse, 2015). Hoegen et al. (2018) also note that for each category and sub-category, there is no clear consensus on the influence of each factor on the final decision-making process of investors. This is partly due to the various methodologies adopted by authors, but also to the relatively limited number of papers addressing this issue as of today. In addition to this, there is little analysis of the impact of several factors considered simultaneously, rising robustness concerns about existing results.

Furthermore, it is likely that the prominence of the various influencing factors depends on the sector to which the projects belong. For instance, relying on data about past campaigns, Hörisch (2015) investigates the differences in campaigns' success depending on the latter's environmental orientation. This is why a branch of the crowdfunding literature has recently emerged to specifically address the case of RE projects. As of today, this literature remains scarce, despite its potential to contribute to the green finance literature, that aims at investigating the various related investment vehicles and behaviors (e.g., Clark et al., 2018, Hafner et al., 2020). Authors mainly seek to describe the growing RE crowdfunding sector (e.g., business model, investment instruments used, potential development, *etc.*) based on case studies (e.g., online documents review, survey, or interviews of platforms) of projects or platforms (Bourcet et al., 2019, de Broeck, 2018, Lam & Law, 2016, Nigam et al., 2018). As in the broad crowdfunding literature, a few scholars also rely on data from past RE crowdfunding campaigns to investigate the factors that influence the latter's success (Bonzanini et al., 2016, Cumming et al., 2017). Finally, and to the best of our knowledge, Vasileiadou et al. (2016) is the only paper that specifically investigates RE crowdfunding investors' motivation, however relying only on a qualitative thematic analysis of online posts of investors on projects' webpage rather than on quantitative survey data. Their main result is that financial and ethical considerations predominate in investment decisions.

Additionally, an extensive literature also focuses on the determinants of pro-environmental behaviors (Li et al., 2019). According to Kollmuss & Agyeman (2002, p.140), a pro-environmental behavior can be defined as a behavior that

[5] Hoegen et al. (2018) show that past campaigns success could at best be considered as a proxy for crowdfunding investors' decision.

"consciously seeks to minimize the negative impact of one's actions on the natural and built world (e.g., minimize resource and energy consumption, use of non-toxic substances, reduce waste production)". Investing in RE sources can thus be considered as such a behavior. Various types of factors are then investigated for their possible influence. As reported by Li et al. (2019), these factors can be classified into: (i) external variables (e.g., social norms, incentives), (ii) individual socio-economic variables (e.g., gender, age, income), and (iii) individual psychological variables (e.g., attitudes, believes). Regarding socio-economic variables, López-Mosquera et al. (2015) for instance find that elderly people, people with higher education level or high income tend to adopt more frequently at least one of the following pro-environmental behavior: environmentally responsible purchase, recycling, and/or reduced car use frequency. Moreover, Ameli & Brandt (2015) find that the investment in different energy-efficiency technologies is positively related to age. Besides this, regarding gender influence, some authors suggest that women are more concerned about the environment (Li et al., 2019), while other emphasize that they are less likely to invest in risky instruments, as stated by Hervé et al. (2019) for the case of crowdfunding in France. As of today, there is no empirical study suggesting which effect shall prevail for the case of RE crowdfunding. Regarding attitudes, the review of Li et al. (2019) also points out that, on average, authors find that positive environmental attitudes encourage pro-environmental behaviors. For example, the results of Bauwens & Eyre (2017) indicate a positive relation between pro-environmental orientation and membership to a RE cooperative.

To wrap up, bridging the gap between the crowdfunding, green finance, and the pro-environmental behaviors literatures, the emerging literature about RE crowdfunding has already provided key insights to better understand this fast-growing sector and the success factors of campaigns. However, and to the best of our knowledge, it does not quantitatively assess so far the determinants of investors' decision to crowdfund RE projects. This chapter aims at filling this gap relying on a novel survey dataset collected for France. We present our methodology in the next section.

5.3 Methodology

In this section, we present in more detail the French RE crowdfunding sector, the dataset, the variables defined, and finally the methodology considered to carry out the analysis that is presented in the next section.

5.3.1 The RE crowdfunding sector in France

RE crowdfunding enables citizen to participate in the funding of specific RE projects. It corresponds to investments in RE sources *via* online crowdfunding platforms using any available vehicles (debt-based instruments or equity). From the view of RE projects' promoters, crowdfunding is not only a mean to access funds through online platforms, but also to benefit from specific policies such as a bonus on the purchasing price of electricity, and/or to favor local acceptance by involving local retail investors (Bourcet et al., 2019). According to the data published by GreenUnivers & FPF (2019), the amounts collected by the French RE crowdfunding sector have increased from EUR 11.5 million in 2016 to EUR 20.5 million in 2017 and EUR 38.7 million in 2018.[6] This corresponds to 153 projects in 2018 with a net average rate of return of about 5% for investors. Additionally, in 2018 again, the main RE sources financed were solar energy (64%), followed by wind energy (21%). Projects were mainly funded by debt-instruments (loans, minibons, or bonds).

In France, the RE crowdfunding sector benefits from a supportive regulatory environment. The crowdfunding sector was formally regulated in 2014 by a specific act (*Ordonnance n°2014-559 du 30 mai 2014*). Additional regulations or initiatives dedicated to RE crowdfunding followed (Rüdinger, 2019). Since 2017, the label *Financement participatif pour la croissance verte* (Crowdfunding for green growth) is awarded by authorized platforms to projects that fulfill specific criteria (FPF, 2019). Besides this, a bonus on the purchasing price of electricity is attributed since 2016 to projects partly funded by local citizens or authorities, possibly through crowdfunding, following public tenders.[7] This bonus might have shaped the spatial distribution of investments in RE crowdfunding, projects holders seeking to strengthen local financial contributions (Bourcet et al., 2019).

Taking advantage from these favorable policies, crowdfunding platforms started to offer an increasing number of RE projects, or even specialized in this sector. The recent *PACTE* law (2019)[8] is expected to bolster RE crowdfunding by significantly expanding the maximum amount that can be collected by crowdfunded projects to EUR 8 million (against EUR 2.5 million in 2016, and EUR 1 million in

[6]Note that the 2018 figure also includes energy efficiency projects. In 2018, the amount raised by RE related projects represented about 10% of the total funds collected by crowdfunding platforms all sectors combined in France (GreenUnivers & FPF, 2018, KPMG & FPF, 2019).

[7]See Rüdinger (2019, in French) for more details about the bonus and the evolution of the award criteria.

[8]The *Plan d'action pour la croissance et la transformation des entreprises*, now allows to invest in crowdfunding instruments through favourable tax regime saving plans. In addition to this, it is now compulsory for life insurance products to propose at least one unit of account that is socially responsible or green.

2014), and by introducing fiscal and regulatory incentives. Given that RE crowdfunding pursues a rapid expansion, it becomes crucial to better understand the investment decision-making of French RE crowdfunders to shape relevant policy recommendations.

5.3.2 Data

We rely on a novel survey dataset provided by YouGov France for FPF and the MTES (2019).[9] Data were collected between February and March 2019 at the individual level. An online questionnaire was sent to RE crowdfunders, contacted through the platform they use, and French citizens, to build a contrast group.[10] RE crowdfunding investors were surveyed from 8 platforms representing more than 90% of the sector: Akuocoop, Enerfip, Lendopolis, Lendosphere, Lita.co, Lumo, Tudigo, and Wiseed. For each cluster of individuals, opinions and attitudes towards the RE sector were collected as well as socio-economic characteristics. The corresponding variables are hereafter presented in more details. By collecting this type of data for the first time in France, YouGov France, FPF, and the MTES (2019) aimed to: (i) evaluate the perception of the RE crowdfunding sector, (ii) assess if RE funding is perceived as a local or a national issue, (iii) explore the link between RE infrastructures' acceptance and crowdfunding, and (iv) identify the expectations of crowdfunding investors. In this chapter, we investigate individual investors' decision to crowdfund RE projects in France. Therefore, we merge the two groups of respondents for the analysis that follows. After cleaning for incomplete answers, our sample size is of 2,968 individuals.

To improve our sample's representativeness with regards to the French population, we use post-stratification weighting factors (Holt & Smith, 1979) with regards to gender, age, and socio-professional categories, for which the joint distribution is provided by Insee (2017).[11] This adjustment corrects for under or over-representation of strata with regards to these criteria. Intuitively, weighting

[9] A non-disclosure agreement was signed to access these confidential data for research purposes. A public restitution, by YouGov France, FPF, and the MTES (2019), of the survey results (in French) is available online at: https://financeparticipative.org/enquete-sur-le-financement-participatif-des-energies-renouvelables/. These descriptive results were computed relying on undisclosed weighting factors. In this chapter, we only considered the raw data provided by the survey, and have computed relevant weighting factors to adjust the whole sample to the French population.

[10] More specifically, the survey was carried out by YouGov, a professional survey institute, using computer-assisted web interviews. The quota method was applied to build a control group representative of the French population adjusted by weighting factors based on administrative and Insee (French National Institute of Statistics and Economic Studies) data.

[11] The *Enquête Emploi* from Insee (2017) provides the joint distribution of the French population with regards to gender, age (above 15 years old, 13 categories), and socio-professional status (43 categories). These categories were collapsed to match the ones available in the dataset.

factors are computed within each strata such that the joined weighted sample distribution matches the actual French one. We check the robustness of the results by alternatively applying equal weights (unweighted sample), by adopting another weighting where the investors' group is the reference (the results are available upon request, insofar as they are very similar to the equal weighting strategy), and by clustering standards errors according to the data collection groups.

5.3.3 Variables

In this chapter we focus on the factors that drive citizens to invest in RE sources *via* crowdfunding. Consistently with the dataset, variables are defined at the individual level. A description and summary statistics are given in Table 5.2. The dependent variable is a binary variable taking the value 1 if the respondent has invested in RE *via* any available crowdfunding instruments (and 0 otherwise). Similar binary variables are collected regarding RE investments through other vehicles, namely: (i) banking products, (ii) investment funds, (iii) equities, or (iv) community-based initiatives.

Moreover, respondents were asked to give their opinion on the RE sector in general, and on several of the sector's characteristics, namely: (i) transparency of investment offers, (ii) profitability, (iii) inevitability of the energy transition, (iv) appropriateness of the regulation, (v) durability (i.e., a sector that is likely to continue to operate in the next decades), and (vi) impact on the future of the planet. Opinions were also collected regarding the acceptance of the installation of solar and wind power plants within 10 kilometers from the respondent's dwelling. These variables were gathered using 5-point Likert scales, from 1='very positive' to 5='very negative'. To reduce the dimensionality and facilitate the interpretation – the levels of Likert scale variables having little quantitative meaning – these ordinal variables were aggregated into binary variables as suggested by Wooldridge (2013). The value 1 is assigned to a positive opinion (and 0 otherwise), that is a response strictly below the median "neutral" level of the corresponding Likert scale. It is worth mentioning that a sensitivity test on the aggregation process (median level responses also considered as positive opinions) do not qualitatively affect the results obtained in our main specification.

Variable	Description	Mean	SD
Dependent variable			
Inv_RE_CF	=1 if respondent has invested in RE sources *via* a crowdfunding platform	0.57	0.50
Explanatory variables			
RE_Opinion	=1 if opinion on the RE sector < median	0.91	0.29
RE_Transparency	=1 if opinion on the transparency of the investment opportunities offered by the RE sector < median	0.48	0.50
RE_Profitability	=1 if opinion on the profitability of the RE sector < median	0.57	0.49
RE_Inevitability	=1 if opinion on the inevitability of the RE sector development < median	0.85	0.36
RE_Regulation	=1 if opinion on the regulation of the RE sector < median	0.41	0.49
RE_Durability	=1 if opinion on the RE sector development as a durable sector < median	0.75	0.43
RE_Impact	=1 if opinion on the RE sector development as a way to influence the planet's future < median	0.71	0.46
RECF_Risk	=1 if opinion on RE crowdfunding financial risk is medium or high risk	0.77	0.42
Inv_RE_Bank	=1 if respondent has used a banking product to invest in RE sources	0.30	0.46
Inv_RE_Fund	=1 if respondent has used an investment fund to invest in RE sources	0.05	0.23
Inv_RE_Equities	=1 if respondent has used shares on a stock market to invest in RE sources	0.08	0.28
Inv_RE_Community	=1 if respondent has used a community-based initiative to invest in RE sources	0.07	0.25
Accept_Solar	=1 if acceptance (on average) of the installation of solar power plants (ground-based or roof-mounted) within 10 km from respondents' dwelling < median	0.79	0.41
Accept_Wind	=1 if (on average) acceptance of the installation of (onshore or offshore) wind farms within 10 km from respondents' dwelling < median	0.70	0.46
Socio-economic variables			
Age	Age in years	49.44	16.31
Female	=1 if the respondent is a woman	0.52	0.50
Education	Ordinal variable taking the value 1 if secondary education or below, 2 if undergraduate education, and 3 if graduate education	1.87	0.82
SPC	Ordinal variable taking values from 1 to 4 to indicate the socio-professional category from inactive (retirees and people without professional activity), low (farmer-operators, workers, employees), medium (craftsmen, traders, business owners, intermediary professions), to high (executives, higher intellectual professions)	1.97	1.00
Region	Binary variables indicating the region of the respondent (=1 if belonging, 0 otherwise) among a total of 22 regions[12]	–	–

Table 5.2 Descriptive overview of the weighted variables based on 2,968 observations.

Source: authors' work based on survey data (YouGov France for FPF and the MTES, 2019).

Additionally, respondents were also questioned about their perception of the financial risk associated with an investment in RE crowdfunding, rated using a

3-point Likert scale from 1='low risk' to 3='high risk'. Again, this variable was converted into a binary variable, taking the value 1 for a medium or high risk perception (and 0 otherwise). Finally, several socio-economic characteristics were considered to control for gender, age, socio-professional category, education, and region of the respondent.[12]

5.3.4 Econometric approach

To identify the factors that prompt the decision to invest in RE projects, we use a probit model to depict the probability that individual i invests in RE crowdfunding according to:

$$\mathbb{P}(Inv\_RE\_CF_i = 1|\mathbf{X}_i) = \phi\left(\beta_0 + \boldsymbol{\beta} \cdot \mathbf{X}_i\right),$$

where $Inv\_RE\_CF_i$ is a binary variable taking the value 1 if the individual i invests in RE sources using crowdfunding, $\mathbf{X}_i$ is a vector of independent variables listed in Table 5.2 including relevant controls, and $\phi(\cdot)$ is the standard normal cumulative distribution function. As reported in Section 5.4.3, we also compute the average marginal effects (AME) and mean marginal effects (MEM) from our estimated predictors to quantify the impact of each determinant of RE crowdfunding investment decisions.[13]

5.4 Results

In this section, we present our quantitative results about French citizens' decision to crowdfund RE projects successively relying on a mean, a correlation, and an econometric analysis.

5.4.1 Mean analysis

Table 5.3 presents a mean comparison between the groups of RE investors and French citizens (contrast group). Opinions about the RE sector, the perception of the financial risk associated with RE crowdfunding, the use of diverse RE investment instruments, and the local acceptance of solar and wind power plants are

[12]More specifically, the dataset reports the department of each respondent (101 categories) which were aggregated using the territorial grid of former French regions (22 categories) as a compromise between granularity and information criteria metrics (AIC and BIC).

[13]Marginal effects measure the effect in the conditional mean of the covariate for a change in one of the regressor, that is varying from 0 to 1 in the case of our binary categorical variables. Thus, the MEM depicts the change in the probability to invest in RE crowdfunding holding all other variables at their mean, while the AME provides the mean of the marginal effect obtained for each individual in the sample. The AME consequently provide a summary of the marginal impact on the full distribution of the explained variable rather than for an arbitrary "average" individual in the MEM case.

displayed. The obtained means can be interpreted as the shares of each group for which the binary variables are taking the value 1 (e.g., the share of respondents that have a positive opinion on the profitability of the RE sector).

Variable	Crowdfunding group Mean	Contrast group Mean	Test-statistics
RE_Opinion	0.97 (0.01)	0.83 (0.02)	7.07***
RE_Transparency	0.60 (0.02)	0.34 (0.02)	9.37***
RE_Profitability	0.62 (0.02)	0.51 (0.02)	3.73***
RE_Inevitability	0.93 (0.01)	0.75 (0.02)	8.05***
RE_Regulation	0.46 (0.02)	0.36 (0.02)	3.51***
RE_Durability	0.85 (0.01)	0.62 (0.02)	9.10***
RE_Impact	0.79 (0.01)	0.61 (0.02)	6.80***
RECF_Risk	0.70 (0.02)	0.85 (0.02)	-6.25***
Inv_RE_Bank	0.45 (0.02)	0.12 (0.02)	15.07***
Inv_RE_Fund	0.08 (0.01)	0.02 (0.01)	5.65***
Inv_RE_Equity	0.13 (0.01)	0.02 (0.01)	9.84***
Inv_RE_Community	0.10 (0.01)	0.03 (0.01)	5.12***
Accept_Solar	0.92 (0.01)	0.63 (0.02)	11.22***
Accept_Wind	0.78 (0.01)	0.60 (0.02)	6.80***

Table 5.3 Comparison of RE crowdfunding investors to the French population.

Source: authors' work based on survey data (YouGov France for FPF and the MTES, 2019).
Note: Standard errors are in parentheses. Two-sample t-test were performed to compare the means between both groups. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In line with the figures of the OpinionWay for Qualit'EnR's barometer (2019), both groups strongly support the RE sector (mean RE opinions greater than 80%) and largely consider that the RE sector is impacting, that its development is long-lasting, and that the energy transition is inevitable. Besides this, RE crowdfunders have, on average, a better general opinion about the RE sector (97%) compared to the contrast group (83%). This pattern can also be systematically observed for each opinion variable about the RE crowdfunding sector's characteristics: transparency, profitability, inevitability, appropriateness of the regulation, durability, and impact on the future of the planet. The difference is particularly substantial regarding the transparency of investment offers, the durability of the sector, and the inevitability of the energy transition. These results are in line with previous findings in the pro-environmental behavior literature (e.g., Bauwens & Eyre, 2017, Li et al., 2019). As will be discussed, these first two variables appear to be important drivers of the investment decision-making process.

Similarly, regarding investment behaviors, fewer RE crowdfunders perceive on average RE crowdfunding as risky (70%) compared to the contrast group (85%). Additionally, RE crowdfunders tend to have more extensively invested in other RE investment vehicles than the contrast group (the fraction of RE investments is at least 3 times greater in the RE crowdfunders group than in the contrast group). The difference is especially high for banking products, that is

the most widely used RE investment instrument. Moreover, RE crowdfunders are more favorable to the local installation of solar and wind power plants compared to the contrast group. Ultimately, local acceptance is more heterogeneous in the investors group, with about 15 percentage points greater acceptance of local solar power plants. These statistics echo to a certain extent, the literature investigating specifically wind power acceptance in the case of France (see for instance Enevoldsen & Sovacool, 2016).

5.4.2 Correlation analysis

Table 5.4 presents the correlation matrix between the considered variables, from which no significant correlation issue arise. In the following regression analysis, we also compute the Variance Inflation Factor (VIF) that reveals no multicolinearity issue.

Focusing on the correlation structure between the dependent variable, i.e., *Inv_RE_CF*, and the covariates provides some insight about the potential predictors of the investment decision-making process. The highest positive correlations with *Inv_RE_CF* are obtained for *Education* (r = 0.38), *Accept_Solar* (r = 0.36), and *Inv_RE_Bank* (r = 0.35), while the highest negative one is obtained for *Female* (r = -0.39). Moreover, both general and specific opinions about the RE sector, as well as local RE plants acceptance and additional RE investments existence, are intuitively positively correlated with *Inv_RE_CF*. Besides this, *RECF_Risk* is negatively correlated with the dependent variable. Additionally, on average, elderly people, higher educated individuals, and higher socio-professional categories tend to invest in RE crowdfunding. The correlation analysis findings are consistent with the literature surveyed in Section 5.2 (e.g., Bauwens, 2019, Bauwens & Eyre, 2017, López-Mosquera et al., 2015).

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Inv_RE_CF	*1*																			
RE_Opinion	*2*	0.24***																		
RE_Transparency	*3*	0.27***	0.24***																	
RE_Profitability	*4*	0.12***	0.24***	0.35***																
RE_Inevitability	*5*	0.25***	0.44***	0.26***	0.28***															
RE_Regulation	*6*	0.11***	0.17***	0.41***	0.29***	0.16***														
RE_Preserve	*7*	0.05***	0.35***	0.24***	0.28***	0.34***	0.19***													
RE_Durability	*8*	0.26***	0.29***	0.13***	0.2***	0.27***	0.08***	0.18***												
RE_Impact	*9*	0.18***	0.32***	0.16***	0.2***	0.31***	0.06***	0.20***	0.33***											
RECF_Risk	*10*	-0.17***	-0.13***	-0.15***	-0.19***	-0.12***	-0.12***	-0.11***	-0.09***	-0.11***										
Inv_RE_Bank	*11*	0.35***	0.16***	0.16***	0.08***	0.16***	0.05***	0.09***	0.12***	0.12***	-0.01									
Inv_RE_Fund	*12*	0.13***	0.03*	0.06***	0.05***	0.03*	0.05***	0.03*	0.00	0.04**	0.05**	0.18***								
Inv_RE_Stock	*13*	0.20***	0.04**	0.08***	0.03*	0.02	0.05***	0.00	0.01	0.02	0.03	0.21***	0.23***							
Inv_RE_Community	*14*	0.13***	0.07***	0.07***	0.08***	0.01	0.07***	0.00	0.02	0.02	-0.03	0.09***	0.09***	0.04**						
Accept_Solar	*15*	0.36***	0.36***	0.20***	0.19***	0.31***	0.14***	0.21***	0.20***	0.21***	-0.16***	0.19***	0.05***	0.09***	0.08***					
Accept_Wind	*16*	0.21***	0.26***	0.22***	0.27***	0.25***	0.17***	0.21***	0.20***	0.16***	-0.09***	0.15***	0.04**	0.07***	0.06***	0.38***				
Age	*17*	0.07***	-0.07***	-0.04**	-0.14***	0.03	-0.03	-0.01	0.02	-0.07***	0.06***	0.05**	-0.01	-0.02	-0.02	0.01	-0.07***			
Female	*18*	-0.39***	-0.09***	-0.14***	-0.02	-0.09***	-0.04**	0.03	-0.09***	-0.08***	0.04**	-0.17***	-0.11***	-0.22***	-0.10***	-0.20***	-0.14***	0.04**		
Education	*19*	0.38***	0.08***	0.06***	0.07***	0.14***	0.01	0.00	0.12***	0.15***	-0.11***	0.18***	0.06***	0.09***	0.07***	0.20***	0.10***	-0.08***	-0.15***	
SPC	*20*	0.20***	0.09***	0.05**	0.06***	0.07***	0.06***	0.04*	0.07***	0.09***	-0.04**	0.10***	0.08***	0.11***	0.05***	0.09***	0.11***	-0.42***	-0.11***	0.33***

Table 5.4 Correlation matrix.

Source: authors' work based on survey data (YouGov France for FPF and the MTES, 2019).
Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.4.3 Regression analysis

In this section, we assess the factors that predict investors' decision to engage in RE crowdfunding. We successively discuss the coefficients obtained for several econometric models, and then focus on marginal effects (AME and MEM) in our central specification. Table 5.5 reports the estimates, robust standard errors, and significance levels of the regression coefficients. The latter sign can be interpreted in terms of change in the investment probability, $\mathbb{P}(Inv\_RE\_CF_i = 1|\mathbf{X}_i)$. Control variables are gradually introduced, and robustness checks about weighting factors and another econometric specification are implemented. At first, model (1) investigates the relationship between Inv_RE_CF and the main opinion variables about the RE sector. In models (2) to (5), we then successively control for investments in other RE financing instruments, acceptance of local RE plants deployment, socio-economic characteristics, and geography. One can notice that the fit consistently improves, as shown by the increasing Pseudo R-squared, log-likelihood, and percent correctly predicted metrics that respectively reach -1,201, 0.41, and about 82% in model (5), that is our central specification. Moreover, the Brier and AUC scores significantly improve while moving from model (1) to (2), and then from model (3) to (4). The prediction power obtained in model (5) can be considered highly satisfactory with a 0.91 AUC score. We finally provide several robustness checks, considering the unweighted sample[14] in model (6) and introducing an alternate linear probability model in model (7). As previously mentioned, we also compute the VIF for model (7) that reveals no multicolinearity issue with a mean value of 1.88. Finally, we perform a Ramsey RESET test that reveals no misspecification issue at a level of 10%. In addition, a sensitivity test on the aggregation process does not qualitatively affect the results obtained in our main specification.

[14] As previously mentioned, an alternative weighting strategy – adjusting the joint distribution of the French group to match the investors' group one with regards to gender, age (three groups), and socio-professional category (four groups) – does not change the sign and magnitude compared to the equal-weights strategy. The results are available upon request.

Dependent variable: *Inv_RE_CF*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Probit	Probit	Probit	Probit	Probit	Probit	LPM
Independent variable	(MLE)	(MLE)	(MLE)	(MLE)	(MLE)	(MLE)	(OLS)
RE_Opinion	0.44***	0.29*	0.08	0.30$^{\diamond}$	0.36*	0.23*	0.06$^{\diamond}$
	(0.15)	(0.16)	(0.17)	(0.20)	(0.19)	(0.14)	(0.04)
RE_Transparency	0.58***	0.51***	0.49***	0.51***	0.56***	0.54***	0.14***
	(0.09)	(0.09)	(0.09)	(0.11)	(0.10)	(0.08)	(0.03)
RE_Profitability	-0.16**	-0.2**	-0.23***	-0.13	-0.15	-0.07	-0.03
	(0.08)	(0.09)	(0.09)	(0.10)	(0.10)	(0.08)	(0.02)
RE_Inevitability	0.42***	0.42***	0.32**	0.14	0.09	0.19*	0.04
	(0.12)	(0.14)	(0.14)	(0.17)	(0.17)	(0.11)	(0.04)
RE_Regulation	-0.05	-0.07	-0.08	-0.05	-0.05	-0.06	-0.02
	(0.09)	(0.09)	(0.09)	(0.11)	(0.11)	(0.08)	(0.02)
RE_Durability	0.54***	0.58***	0.56***	0.52***	0.52***	0.31***	0.14***
	(0.09)	(0.10)	(0.10)	(0.12)	(0.12)	(0.08)	(0.03)
RE_Impact	0.08	0.05	0.02	-0.06	-0.06	0.20**	-0.01
	(0.09)	(0.09)	(0.10)	(0.11)	(0.11)	(0.08)	(0.03)
RECF_Risk	-0.38***	-0.46***	-0.4***	-0.38***	-0.38***	-0.37***	-0.10***
	(0.10)	(0.10)	(0.10)	(0.11)	(0.12)	(0.08)	(0.03)
Inv_RE_Bank		0.84***	0.79***	0.67***	0.71***	0.78***	0.18***
		(0.10)	(0.10)	(0.11)	(0.11)	(0.08)	(0.02)
Inv_RE_Fund		0.51**	0.52**	0.51**	0.51**	0.48**	0.07*
		(0.22)	(0.22)	(0.23)	(0.24)	(0.19)	(0.04)
Inv_RE_Stock		0.97***	0.9***	0.55***	0.58***	0.66***	0.09***
		(0.16)	(0.17)	(0.16)	(0.17)	(0.15)	(0.03)
Inv_RE_Community		0.61***	0.55***	0.46**	0.48**	0.51***	0.09**
		(0.19)	(0.19)	(0.20)	(0.19)	(0.15)	(0.04)
Accept_Solar			0.73***	0.56***	0.56***	0.48***	0.15***
			(0.12)	(0.13)	(0.13)	(0.10)	(0.03)
Accept_Wind			0.07	0.07	0.03	0.04	0.01
			(0.10)	(0.11)	(0.11)	(0.08)	(0.03)
Age				0.02***	0.02***	0.01***	0.00***
				(0.00)	(0.00)	(0.00)	(0.00)
Female				-0.86***	-0.87***	-0.9***	-0.23***
				(0.09)	(0.09)	(0.07)	(0.02)
Education				0.50***	0.54***	0.6***	0.13***
				(0.06)	(0.06)	(0.05)	(0.02)
SPC				0.21***	0.23***	0.18***	0.05***
				(0.06)	(0.06)	(0.03)	(0.01)
Controls on region	–	–	–	–	Yes	Yes	Yes
Equal weights	–	–	–	–	–	Yes	–
Number of obs.	2,968	2,968	2,968	2,968	2,968	2,968	2,968
Log likelihood	-1,775	-1,576	-1,517	-1,252	-1,201	-909	–
Pseudo *R*-squared	0.13	0.22	0.25	0.38	0.41	0.44	–
Pct. corr. pred.	68.34	73.35	75.60	81.49	81.72	80.50	81.77
Brier score	0.19	0.16	0.15	0.10	0.10	0.10	–
AUC score	0.73	0.82	0.83	0.91	0.91	0.91	–

Table 5.5 Likelihood to invest in renewable energy crowdfunding.

Source: authors' work based on survey data (YouGov France for FPF and the MTES, 2019).
Note: Regression coefficients and robust standard errors (in parentheses) are reported. "Equal weights" refers to the use of unweighted data. "Pct. corr. pred." refers to percent correctly predicted statistics, which are computed using weighting factors assuming a 0.5 classification threshold. $^{\diamond}$ $p < 0.12$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We discuss at first our main econometric specifications from model (1) to (5). To begin with, the general opinion about the RE sector, *RE_Opinion*, is positively correlated with the RE crowdfunding investment decision, *Inv_RE_CF*. However, the significance decreases when control variables are added. This suggests that the investment decision is more tightly related to more specific factors. Indeed, the transparency of investment opportunities and the durability of the RE sector appear to be the main opinion predictors of the investment decision, as shown by the positive and significant coefficients obtained for *RE_Transparency* and *RE_Durability* in models (1) to (5). Opinions about the profitability of the RE sector, *RE_Profitability*, and the inevitability of the energy transition towards RE sources, *RE_Inevitability*, do not appear as significant drivers to crowdfund RE projects. Indeed, the significance of the corresponding estimates vanishes once controlling for socio-economic variables, as from model (4). In addition to this, these variables' impact is smaller compared to the previous variables, as corroborated by the moderate AME and MEM levels reported in Table 5.6 for model (5). Additionally, neither the opinion on the sector's regulation, *RE_Regulation*, nor on the ability of RE projects to have an impact on the planet's future, *RE_Impact*, have a significant influence on the RE crowdfunding investment decision, suggesting that the opinion factors mentioned at first might prevail on the last two factors, even though they sound relevant to the common sense. Finally, the opinion about the perceived risk of RE crowdfunding, *RECF_Risk*, for which negative and significant estimates are obtained, seems to deter the RE crowdfunding investment decision. This is consistent with the basic intuition.

We now turn to the results obtained for the various categories of control variables introduced. Controlling for investments in other instruments (*Inv_RE_Fund*, *Inv_RE_Bank*, *Inv_RE_Equity*, and *Inv_RE_Community*) as from model (2) yields positive and significant estimates. The higher ones are obtained for an investment in a banking product. Thus, an investment in any other RE financing vehicle consistently increases the likelihood to invest in RE crowdfunding. Turning to model (3) and controlling for acceptance of local RE projects, *Accept_Solar* and *Accept_Wind*, reveals that only local solar energy projects' acceptance bears significant and positive coefficients. This may suggest that such projects are more likely to be identified, or appreciated, by RE investors for crowdfunding purposes. Then, controlling as from model (4) for socio-economic variables shows that *Age*, *Education*, and *SPC* are positively and significantly related to RE crowdfunding investment. This is in line with the common sense – assuming older investors might have greater savings, more educated investors greater awareness, and higher SPC investors greater income. Finally, being a woman, *Female*, is negatively correlated with our dependent variable. Controlling for geography has

no impact on the signs of the estimates obtained in model (4) and only improves their significance. This finding substantially supports the robustness of the previous results, geography being likely to affect RE crowdfunding investment patterns. The directions and significance of causalities presented so far hold in all estimated models, except when otherwise discussed. Additionally, the signs obtained for most of the significant estimates are consistent with the pairwise correlations reported in Table 5.4, especially regarding model (5).

We then focus on models (6) and (7) to assess the robustness of the previous results. It turns out that neither the weighting factors, nor the econometric specification crucially affect the sign, magnitude, and significance of the previous findings. The main difference is that the estimates obtained in model (6) for *RE_Inevitability* and *RE_Impact* become significant, with a quite moderate level, with regards to their counterparts in model (5). However, without adjusting the sample with weighting factors, the latter might be more representative of the population of RE crowdfunders than the French one. Such a population might thus be more driven by environmental concerns. Therefore, as we focus on the French population for the purpose of this chapter, we abstract from these changes and emphasize that model (6) confirms the robustness of the previous findings. Ultimately, clustering standard errors in model (5) according to the data collection groups does not significantly change the sign, magnitude and significance of the estimates. The results are available upon request.

We finally focus on model (5), our central specification, to discuss the marginal effects (AME and MEM) reported in Table 5.6. It turns out that, consistently with the previous analysis, the main determinants of the RE crowdfunding investment decision are: (i) the general opinion about the RE sector (AME of $+0.08$), (ii) specific opinions about the transparency of investment offers (AME of $+0.13$) and the durability of the RE sector (AME of $+0.12$), (iii) existing RE investments, especially through banking products (AME of $+0.16$), (iv) acceptance of local solar projects (AME of $+0.13$), (v) gender (AME of -0.20), educational level (AME of $+0.12$), and to a lesser extent the socio-professional category that has a lower marginal impact than education. These results are qualitatively unchanged using MEM metrics.

Lastly, we cannot rule out the possibility of endogeneity issues, for instance regarding existing RE investments in other vehicles. Moreover, a potential selection bias might arise since RE investors could be more informed about the need for RE technologies and accustomed to crowdfunding. However, the observational nature of the obtained dataset and, to the best of our knowledge, the lack of better quality data so far in France, prevent us from being able to unambiguously assess causality, and might limit the external validity of our results. Addressing these

concerns would for instance require to rely on an appropriate instrumental variable, and thus collect more elaborate data. This task is left for further research as it goes far beyond the scope of this chapter, that is essentially exploratory as a first attempt to explore citizens' motivation to invest in RE crowdfunding.

Dependent variable: *Inv_RE_CF* (Probit model)		
Independent variable	AME	MEM
RE_Opinion	0.08* (0.04)	0.14* (0.07)
RE_Transparency	0.13*** (0.02)	0.21*** (0.04)
RE_Profitability	-0.03 (0.02)	-0.06 (0.04)
RE_Inevitability	0.02 (0.04)	0.04 (0.07)
RE_Regulation	-0.01 (0.02)	-0.02 (0.04)
RE_Durability	0.12*** (0.03)	0.20*** (0.05)
RE_Impact	-0.01 (0.02)	-0.02 (0.04)
RECF_Risk	-0.09*** (0.03)	-0.15*** (0.04)
Inv_RE_Bank	0.16*** (0.02)	0.27*** (0.04)
Inv_RE_Fund	0.12** (0.05)	0.19** (0.09)
Inv_RE_Stock	0.13*** (0.04)	0.22*** (0.06)
Inv_RE_Community	0.11** (0.04)	0.18** (0.07)
Accept_Solar	0.13*** (0.03)	0.21*** (0.05)
Accept_Wind	0.01 (0.02)	0.01 (0.04)
Age	0.00*** (0.00)	0.01*** (0.00)
Female	-0.2*** (0.02)	-0.33*** (0.04)
Education	0.12*** (0.01)	0.21*** (0.02)
SPC	0.05*** (0.01)	0.09*** (0.02)
Controls on regions	Yes	Yes

Table 5.6 Mean Marginal Effects (MEM) and Average Marginal Effects (AME) in model (5), Probit model (MLE) with weighting factors.

Source: authors' work based on survey data (YouGov France for FPF and the MTES, 2019).
Note: Standard errors (delta-method) are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.4.4 Discussion

Our analysis reveals that, among the French population, the general opinion about the RE sector is indeed an important driver of RE crowdfunding investment, while opinions about the profitability and the regulation of the RE sector are not. These findings suggest that investors might not be motivated by pure opportunistic behavior or financial prospects, which supports previous findings in the literature, in particular regarding pro-environmental behaviors (e.g., Bauwens & Eyre, 2017, Li et al., 2019). Such a result is not surprising due to the very strong support of the French population for RE deployment (OpinionWay for Qualit'EnR, 2019). Beyond the broad environmental support, our analysis reveals that the main predictors of the RE crowdfunding investment decision are the transparency of the investment offers and the durability of the RE sector, as well as the perceived risk. Surprisingly, the potential impact of RE sources on the

planet's future does not seem to foster RE crowdfunding. However, this observation could be explained by the fact that RE crowdfunders might have internalized that their individual impact remains quite limited with regards to the total amount to be raised to fund RE projects. Indeed, according to GreenUnivers & FPF (2019), about 4.5% of RE projects' cost is met by crowdfunding, with the exception of roof-mounted solar power plants for which RE crowdfunding accounts on average for 25% of the cost. Last but not least, these results suggest that the RE crowdfunding sector might now be perceived as relatively mature, and thus gathering a pool of investors far beyond early-adopters that would only be motivated by pure environmental concerns. Indeed, RE crowdfunders are likely to be older, more educated, and belonging to a higher socio-professional category. They might be thus more aware of climate change issues (López-Mosquera et al., 2015). This claim is comforted by the negative estimate for the risk perception. Indeed, controlling for the perception of the sector's profitability, one would expect a rational investor to be less likely to invest whenever her risk perception is higher. This behavior contrasts with that observed for RE investments involving a higher commitment, such as RE cooperatives, where investors might be willing to accept more risk (Rüdinger, 2019). It is key to specify here that we do not address the objective couple risk-profitability of RE projects *per se*, but rather emphasize the key role of the subjective perceived risk and profitability. From this perspective, communicating and/or strengthening investor's protection independently from projects' profitability might encourage RE crowdfunding.

Our analysis also highlights a robust, positive and significant impact of existing RE investments (through equities, banking products, investment funds, and community-based instruments) on RE crowdfunding investment. Indeed, RE crowdfunding might appear as an additional diversifying vehicle for investors already aware of environmental concerns, hence spillovers from existing RE investments. Besides this, the positive and significant relationship obtained between local acceptance of solar energy projects – and not regarding wind energy projects – and RE crowdfunding is consistent with the observed distribution of RE crowdfunded projects. Indeed, an average of 55% of solar projects were funded in total compared to 37% of wind projects over the past three years (GreenUnivers & FPF, 2017, 2018, 2019).

Moreover, our results provide some insights about which policy should be promoted to support the development of the RE crowdfunding sector. At first, the lack of transparency of investment offers and the risk perceived by crowdfunders might deter the investment decision. Consequently, this chapter calls for reducing information asymmetries and enhancing investor protection. This could

possibly be done for instance through the democratization of labels such as the *Financement participatif pour la croissance verte* label launched in 2016 in France, or by adopting a standardised presentation of risks faced while investing *via* RE crowdfunding. In addition, crowdfunding investors face a high liquidity risk in the absence of a regulated secondary market as of today (Harder & Friggens, 2015, McInerney & Bunn, 2019). This is also an issue for sector specific support policies. Second, strengthening the perception that the RE sector is deemed to promising future is a relevant channel to tilt investors' decision towards RE crowdfunding. Indeed, government policies committed to respect clear and communicated energy objectives might be crucial to anchor expectations and foster coordination. In this respect, the schedule provided by the *Programmation pluriannuelle de l'énergie* (Multi-annual energy plan) initiated in 2015 by the French government (article 176 of the n°2015-992 law) is another important step forward to promote RE sources in general, and might thus benefit to RE crowdfunding.

Last but not least, the diversification of the green investment possibilities that are available to retail investors should be promoted due to the significant spillovers generated. An interpretation provided by the literature is that investing in RE sources is likely to improve the opinion towards the RE sector (see for instance Bauwens & Devine-Wright, 2018, for the case of cooperatives), and might thus foster further involvement. In France, the recent *PACTE* law provides promising support to various green investment possibilities, as well as the initiatives that aim at identifying green or RE-related financing vehicles, such as the *Greenfin* label (created in 2015) dedicated to environmental investment funds (MTES, 2019). From this perspective, an efficient communication to citizens about green investment possibilities remains an important challenge to foster such involvement. Finally, the rapid development of the RE crowdfunding sector calls for further analysis of the social allocation of risk towards citizens, that might potentially be ill-informed about the complex energy markets dynamics and the underlying risks of the associated investment offers. This concern echoes the significant role of the risk and transparency variables emphasized in the analysis. The issue being far beyond the scope of this chapter, it is left for further research on this topic.

5.5 Conclusion

In this chapter, we use a novel survey dataset to shed some light on citizens' decision to crowdfund RE projects in the case of France. To the best of our knowledge, this is the first time that such an analysis has been performed for the RE crowdfunding sector. Our results suggest that, among the French population, opinions

on the RE sector in general, its durability, the transparency of its investment opportunities, and the perception of the risk associated with RE crowdfunding, are the main predictors of the decision to invest in RE crowdfunding. Moreover, positive and significant spillovers arise from existing RE investments in other instruments, in particular through banking products. Additionally, the local acceptance of solar power projects, age, education, and socio-professional status are significant drivers of RE crowdfunding. These results are unaffected by additional controls on gender and geography, as well as other robustness checks.

As a consequence, to foster the development of the RE crowdfunding sector in France, these findings suggest to promote policies aiming at: (i) strengthening the transparency and reducing the perceived risk of RE crowdfunding, (ii) promoting the durability of RE sources development, and (iii) expanding green investment possibilities for retail investors. The policies currently adopted, or to be implemented, in France, such as the *PACTE* law or the *PPE*, are promising steps in this direction. However, a greater emphasis on communication about green investment possibilities and transparency standards should be considered for RE crowdfunding to gain momentum as an instrument for citizens to participate in the energy transition.

Finally, the limitations arising from the methodological choices made in this chapter call for future research. First, due to the observational nature of the data, the issue of behavioral change following RE investment was not addressed. A possible avenue for future research could be to design an empirical strategy to assess the causality of RE financing on greater climate awareness or commitment, perhaps through experimental or quasi-experimental methods. Second, the rapid expansion of the RE crowdfunding sector raises several issues regarding the optimality of the social allocation of risk towards retail investors, in particular in view of their full understanding of the complex energy market dynamics and of related investment offers. Lastly, greater attention could be dedicated to the very RE investment decision-making process. For instance, the factors prompting portfolio allocation (choice of RE-related securities), or the spillovers between different investors' populations (e.g., crowdfunding, cooperative, or banking products investors) could be explored. Discrete choice experimental approaches could constitute promising areas for future research in this regard.

5.6 Bibliography

Allison, T. H., Davis, B. C., Short, J. C., & Webb, J. W. (2015). Crowdfunding in a prosocial microlending environment: Examining the role of intrinsic versus extrinsic cues. *Entrepreneurship Theory and Practice*, *39*(1), 53–73.

Ameli, N. & Brandt, N. (2015). Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes. *Environmental Research Letters*, *10*(4), 044015.

Banque de France (2019). *Rapport de l'Observatoire de l'Epargne réglementée 2018*.

Bauwens, T. (2019). Analyzing the determinants of the size of investments by community renewable energy members: Findings and policy implications from flanders. *Energy Policy*, *129*, 841–852.

Bauwens, T. & Devine-Wright, P. (2018). Positive energies? an empirical study of community energy participation and attitudes to renewable energy. *Energy Policy*, *118*, 612–625.

Bauwens, T. & Eyre, N. (2017). Exploring the links between community-based governance and sustainable energy use: Quantitative evidence from flanders. *Ecological Economics*, *137*, 163–172.

Bergek, A., Mignon, I., & Sundberg, G. (2013). Who invests in renewable electricity production? empirical evidence and suggestions for further research. *Energy Policy*, *56*, 568–581.

Bonzanini, D., Giudici, G., & Patrucco, A. (2016). The crowdfunding of renewable energy projects. In V. Ramiah & G. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 429–444). Elsevier.

Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Economics*, *85*, 104563.

Bourcet, C., Cézanne, C., Rigot, S., & Saglietto, L. (2019). Le financement participatif de projets d'énergies renouvelables (EnR) : éclairages sur le modèle économique et les risques d'une plateforme française. *Innovations*, *2*, 151–177.

Bruton, G., Khavul, S., Siegel, D., & Wright, M. (2015). New financial alternatives in seeding entrepreneurship: Microfinance, crowdfunding, and peer–to–peer innovations. *Entrepreneurship Theory and Practice*, *39*(1), 9–26.

CGDD (2019). Chiffres clés des énergies renouvelables édition 2019. mai 2019.

Cholakova, M. & Clarysse, B. (2015). Does the possibility to make equity investments in crowdfunding projects crowd out reward–based investments? *Entrepreneurship Theory and Practice*, *39*(1), 145–172.

Clark, R., Reed, J., & Sunderland, T. (2018). Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. *Land Use Policy*, *71*, 335–346.

Cumming, D. J., Leboeuf, G., & Schwienbacher, A. (2017). Crowdfunding cleantech. *Energy Economics*, *65*, 292–303.

de Broeck, W. (2018). Crowdfunding platforms for renewable energy investments: an overview of best practices in the EU. *International Journal of Sustainable Energy Planning and Management*, *15*, 3–10.

Enevoldsen, P. & Sovacool, B. K. (2016). Examining the social acceptance of wind energy: Practical guidelines for onshore wind project development in france. *Renewable and Sustainable Energy Reviews*, *53*, 178–184.

FPF (2019). Label croissance verte.

GreenUnivers & FPF (2017). Baromètre 2016 du crowdfunding EnR.

GreenUnivers & FPF (2018). Baromètre 2017 du crowdfunding EnR.

GreenUnivers & FPF (2019). Baromètre 2018 du crowdfunding EnR.

Hafner, S., Jones, A., Anger-Kraavi, A., & Pohl, J. (2020). Closing the green finance gap – a systems perspective. *Environmental Innovation and Societal Transitions*, *34*, 26–60.

Harder, K. & Friggens, S. (2015). Crowdfunding: Ready for the big league? In C. W. Donovan (Ed.), *Renewable Energy Finance: Powering the Future* (pp. 325–340). Imperial College Business School.

Hervé, F., Manthé, E., Sannajust, A., & Schwienbacher, A. (2019). Determinants of individual investment decisions in investment-based crowdfunding. *Journal of Business Finance & Accounting*, *46*(5-6), 762–783.

Hoegen, A., Steininger, D. M., & Veit, D. (2018). How do investors decide? an interdisciplinary review of decision-making in crowdfunding. *Electronic Markets*, *28*(3), 339–365.

Holt, D. & Smith, T. M. F. (1979). Post stratification. *Journal of the Royal Statistical Society. Series A (General)*, *142*(1), 33–46.

Hörisch, J. (2015). Crowdfunding for environmental ventures: an empirical analysis of the influence of environmental orientation on the success of crowdfunding initiatives. *Journal of Cleaner Production*, *107*, 636–645.

IEA (2018). *CO2 Emissions from Fuel Combustion 2018 Highlights*.

Insee (2017). Activité, emploi et chômage en 2016. Enquête emploi en continu - Insee Résultats.

IPCC (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. Technical Summary.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC (2018). *Global Warming of* $+1.5°C$*. Summary for Policymakers. An IPCC Special Report on the impacts of global warming of* $+1.5°C$ *above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

Knoefel, J., Sagebiel, J., Özgür Yildiz, Müller, J. R., & Rommel, J. (2018). A consumer perspective on corporate governance in the energy transition: Evidence from a discrete choice experiment in germany. *Energy Economics*, *75*, 440–448.

Kollmuss, A. & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260.

KPMG & FPF (2019). Baromètre du crowdfunding en france 2018.

Lam, P. T. & Law, A. O. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Li, D., Zhao, L., Ma, S., Shao, S., & Zhang, L. (2019). What influences an individual's pro-environmental behavior? a literature review. *Resources, Conservation and Recycling*, *146*, 28–34.

López-Mosquera, N., Lera-López, F., & Sánchez, M. (2015). Key factors to explain recycling, car use and environmentally responsible purchase behaviors: A comparative perspective. *Resources, Conservation and Recycling*, *99*, 29–39.

Martínez-Climent, C., Zorio-Grima, A., & Ribeiro-Soriano, D. (2018). Financial return crowdfunding: literature review and bibliometric analysis. *International Entrepreneurship and Management Journal*, *14*(3), 527–553.

McInerney, C. & Bunn, D. W. (2019). Expansion of the investor base for the energy transition. *Energy Policy*, *129*, 1240–1244.

MTES (2019). Le label greenfin.

National Park Service (2019). Joseph pulitzer—statue of liberty national monument new york.

NGFS (2019). *A call for action: Climate change as a source of financial risk*.

Nigam, N., Mbarek, S., & Benetti, C. (2018). Crowdfunding to finance eco-innovation: Case studies from leading renewable energy platforms. *Journal of Innovation Economics and Management*, *2*(26), 195–219.

OECD (2017). *Mobilising financing for the transition*.

OpinionWay for Qualit'EnR (2019). *Les Français et les énergies renouvelables Baromètre Vague 9*. Janvier 2019.

Ostrom, E. (2012). Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? *Economic Theory*, *49*(2), 353–369.

Painuly, J. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, *24*(1), 73–89.

Reboredo, J. C. (2015). Renewable energy contribution to the energy supply: Is there convergence across countries? *Renewable and Sustainable Energy Reviews*, *45*, 290–295.

Robano, V. (2018). Case study on crowdfunding. *OECD SME and Entrepreneurship Papers*, (4).

Rüdinger, A. (2019). *Participatory and citizen renewable energy projects in France - State of play and recommendations (in French)*. Study number 03/19.

Short, J. C., David J. Ketchen, J., McKenny, A. F., Allison, T. H., & Ireland, R. D. (2017). Research on crowdfunding: Reviewing the (very recent) past and celebrating the present. *Entrepreneurship Theory and Practice*, *41*(2), 149–160.

TCFD (2017). *Recommendations of the Task Force on Climate related Financial Disclosures*.

UNFCCC (2019). The Paris Agreement.

Vasileiadou, E., Huijben, J., & Raven, R. (2016). Three is a crowd? exploring the potential of crowdfunding for renewable energy in the netherlands. *Journal of Cleaner Production*, *128*, 142–155.

Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach. Fifth Edition*, chapter 7. South-Western, Cengage Learning.

YouGov France for FPF and the MTES (2019). Enquête sur le financement participatif des énergies renouvelables.

YouGov France, FPF, and the MTES (2019). *Restitution de l'enquête sur le financement participatif des énergies renouvelables*.

Chapter 6

Conclusion

This thesis aimed at contributing to the energy economics and green finance branches of literature. To do so, it focused first on empirical determinants of renewable energy (RE) sources deployment at a country level. Then, it studied an innovative financing means for the funding of these low-carbon sources that enables to redirect individual investors' savings and also involve them in the energy transition process. This last section will give an overview of the main conclusions of the different chapters, present some practical implications in terms of policy recommendations, and give some perspectives for future research.

6.1 Synthesis of the main results

The general context of this thesis is the recognition of the human influence on climate and the relevance of climate mitigation actions to reduce global greenhouse gas emissions. In particular, RE sources deployment is relevant to decarbonize the energy-related sector. However, these low-carbon sources have only developed slowly and significant differences exist between countries.

Thus, a strand of literature emerged to specifically investigate the determinants of RE development with econometric methods. To the best of my knowledge no systematic literature review had been conducted on this topic. In Chapter 2, I used a systematic literature review methodology to give an overview of the existing literature that investigated the empirical determinants of RE deployment at a country level and with a multi-country framework. I found that authors contributing to this strand of literature used different metrics to evaluate RE deployment in terms of: (i) scope (supply, consumption, or installed capacity), (ii) types of indicator (absolute or *per capita* levels, or share), and (iii) energy sources (energy, electricity, or excluding hydroelectricity). Following this finding, it appears that measuring RE deployment with a share of supply (or capacity) seems to better represent the commitment of countries towards RE deployment. The main categories of determinants investigated are: economic, energy-related, environmental, regulatory, political, and demographic. Due to the diverse frameworks

adopted by the authors, there is little consensus overall. Nevertheless, when classifying the papers based on the type of dependent variables and sample of countries considered, some significant results emerge. In particular, they are: (i) positive effect of RE support policies and Kyoto Protocol, (ii) negative lobby effect from traditional (or preexisting) energy sources, (iii) positive population size effect, (iv) ambiguous income effect (positive for developing countries, negative for European countries), (v) unclear effect of CO_2 emissions (negative for European countries and dependent variable specified as a share in total energy or electricity supply, but positive when specified as a *per capita* level of consumption), and (vi) counter-intuitive negative effect of energy security for European countries. In this chapter I also formulated some recommendations to favor comparability between papers and repeatability, e.g., systematic justification of the methodology and robustness checks of the results.

In addition to this country-level and econometric approach of the determinants of RE deployment, a large strand of literature has developed to investigate the barriers that reduce the speed of such a deployment at a national or even at a local level. In particular, RE financing and acceptance have been considered as significant factors that can hinder the deployment of RE sources. In order to contribute to the understanding of potential ways to overcome these two barriers, I decided to look at crowdfunding. This innovative financing means enables the participation of citizens in the funding of RE projects, thus mobilizing funds and involving them in the energy transition process towards RE sources. However, the literature that focused on crowdfunding was relatively new and scarce. In particular, very few authors had investigated the crowdfunding of RE projects even though as a result of the characteristics of the energy system it is likely that the RE crowdfunding sector has specific aspects.

More specifically, I chose to focus on the French case because the country set ambitious climate-related targets and thus significant RE deployment objectives. The French authorities also designed a favorable environment for crowdfunding, and in particular in the case of crowdfunding for RE projects. To better understand how platforms specialized on RE projects operate and because to the best of my knowledge it had not been done before, with my co-authors we decided to carry out a case study of a French platform called Enerfip. Indeed, in Chapter 3, the different elements that constitute the business model of Enerfip were presented based on the Business Model Canvas of Osterwalder (2004) and Osterwalder & Pigneur (2011). Based on the analysis of interviews of the platform's co-founders, we gave an overview of the value creation by the platform. It results from the interactions between the platform and its two types of customers and is linked to the communication with them and the organization of the RE

crowdfunding campaigns. In addition, we analyzed the risks associated with the operations of the platform. More specifically, the platform faces image and financial risks. Some recommendations were formulated regarding the strategy of the platform to face these risks, e.g. in connection to information communication.

To complement this perspective that was centered on the case of one platform, and since to the best of my knowledge no author had precisely described the RE crowdfunding sector in the case of France, this was the objective of Chapter 4. More specifically, relying on platforms' answers to a questionnaire designed for this analysis, I described the different actors of the French RE crowdfunding sector. The major French crowdfunding platforms that have offered RE projects since 2014 have expanded the number of instruments used and some links were created with the banking sector for most of them. During the period 2014-2019, most of the funds were collected through debt-based campaigns. Solar energy received the largest share of funds followed by wind projects. In addition, contrary to the general literature on crowdfunding, in the case of the French RE crowdfunding sector most of the promoters that have raised funds since 2014 were well-established developers that wanted primarily to increase the local visibility and acceptance of their projects. Regarding the contributors, i.e., individual investors and mostly French citizens, relying on survey data collected by YouGov France for FPF and the MTES (2019), I found that their top 3 motivations to invest in RE crowdfunding are: the contribution to RE development, the sensitivity to environmental causes, and the financial return. Moreover, 61% of the survey respondents used some other investment vehicles than crowdfunding to invest in RE sources.

This analysis on the RE crowdfunding sector in France shed some light on the interactions of the different actors involved in the sector, i.e., the platforms, project promoters, and contributors. However, little was known regarding the precise decision making-process of contributors to RE crowdfunding campaigns. In the general literature looking at crowdfunding, there had been little use of survey data to investigate this aspect too. This is why in Chapter 5, my co-author and I relied on survey data collected by YouGov France for FPF and the MTES (2019) from contributors to specifically study the influence of opinion variables on the decision to invest in RE crowdfunding. Our results suggested that, among the French population, opinions on the RE sector in general, its durability, and the transparency of its investment opportunities had a positive influence while the perception of the risk associated with RE crowdfunding had a negative influence on the decision to invest in RE crowdfunding. Moreover, positive and significant spillovers arose from existing RE investments in other instruments.

6.2 Practical implications and future lines of research

Practical implications and possible research avenues resulting from the contributions of this thesis are related to the investigation of empirical determinants of RE deployment and RE crowdfunding based on the case study of France.

As presented in Chapter 2, the existing literature on empirical determinants of RE deployment is quite fragmented in relation to the methodologies used. More research is needed to investigate the influence of other determinants and control for relevant variables, e.g., regarding the lobby effect from traditional energy sources. In addition, for relevant analysis of the empirical determinants of RE deployment, the availability of good quality data is key. In particular, there is room for improvement concerning the data available for such an analysis. For instance, the availability of better socio-demographic variables or natural resources endowment variables, including regarding the RE potential, could contribute to a better understanding of the factors that influence the development of RE sources at a country level.

In addition, a substantial part of this thesis focused on the case of the RE crowdfunding sector in France that previously received little attention in the literature. The contributions of this thesis are voluntarily exploratory but nevertheless several practical implications and policy recommendations can be formulated. The analysis carried out in Chapter 3 and Chapter 4 shed some light on the operations of platforms that offer RE projects in France. More research could be conducted to better understand their links with the banking sector including in other countries. Moreover, the regulatory risk was identified by the major French platforms as the main risk for the development of the sector. Thus, in the French context, an evolution of the regulatory environment of the crowdfunding sector or of the regulatory environment of the RE sector are expected to influence the business model of the platforms that offer RE projects.

In France, RE crowdfunding is associated with the funding of projects from well-established developers. Thus, crowdfunding in the case of RE projects cannot be considered as a pure entrepreneurial finance tool. More research is necessary to better understand the identity and motivations of RE project promoters that use crowdfunding, including in other countries than France. In addition to this, it could be very interesting to specifically investigate the influence of crowdfunding on the development of RE projects. In a perspective of public policy recommendations including regarding the RE acceptability issue, this could enable to determine if crowdfunding effectively reduces local opposition and the conditions under which it is the case (stage of development of the project at the time of the crowdfunding campaign, level of local participation required, *etc.*).

In Chapter 5, my co-author and I investigated the influence of opinion variables about the RE sector on the decision of French citizens to invest in RE crowdfunding. More research is necessary to better understand the decision making-process of individual investors regarding RE crowdfunding, including with other country or cross-country case studies. Moreover, in relation to the potential of crowdfunding to influence RE acceptability, it could be interesting to investigate the change of opinion regarding RE sources after an investment in RE projects *via* crowdfunding. In addition, in this thesis, I only focused on the case of crowdfunding in France and did not investigate more broadly citizens' RE investment behaviors. There are other financing means available to citizens to invest in RE sources (e.g., banking products, community-based initiatives, *etc.*). Besides this, in the recent report of the Citizens' Convention on Climate (Convention Citoyenne pour le Climat, 2020b, p.430-431)[1] several proposals were related to a more transparent environment for citizens' climate-related investments in France. More research could be conducted to study portfolio allocation choices, including in relation to investments in RE sources, of individual investors for instance using experimental methods.

If the Citizens' Convention on Climate (Convention Citoyenne pour le Climat, 2020b, p.56 and p.142 to 145), emphasized the positive influence of citizens' involvement to raise awareness regarding climate issues and proposed to increase the participation of citizens in RE projects, with the development of RE crowdfunding in France some concerns have arisen. Indeed, there are some questions regarding the ability of individual investors to understand the risks taken while investing, also in relation to the complexity of the energy sector. Thus, it could be particularly relevant that platforms adopt a standard presentation of the risks that exist for every specific RE project. There is also a liquidity risk associated with the holding of crowdfunding instruments as no secondary market exists. More broadly, crowdfunding for RE projects raises some questions regarding the social aspects of a transition towards RE sources and the impact of their deployment on local territories.

For now, only one French platform, Lendosphere, has offered projects in other countries than France, including in Africa. As RE sources could contribute to develop the access to clean energy in developing countries (REN21, 2019, p.133), crowdfunding could be an interesting funding means (World Bank, 2013, p.73). In particular, funds from developed countries could be mobilized to contribute to the development of these low-carbon sources in developing countries not only

[1] The French Citizen's Convention on Climate gathered a group of 150 randomly selected participants that aimed at defining "a series of measures that will allow to achieve a reduction of at least 40% in greenhouse gas emissions by 2030 (compared to 1990) in a spirit of social justice" (Convention Citoyenne pour le Climat, 2020a). The final report was adopted on June 21st 2020.

through development institutions or international funds. More research on the decision marking process of investors in RE crowdfunding is necessary to investigate the willingness to invest and the specific investment conditions (instruments, energy sources, time period, rate of return, *etc.*) of individual investors in developed countries for RE projects in developing countries. This could for instance build on previous work using experimental methods such as the paper of Chen et al. (2019).

6.3 Bibliography

Chen, J. I., Foster, A., & Putterman, L. (2019). Identity, trust and altruism: An experiment on preferences and microfinance lending. *European Economic Review*, *120*, 103304.

Convention Citoyenne pour le Climat (2020a). The citizens' convention on climate, what is it?

Convention Citoyenne pour le Climat (2020b). Rapport de la convention citoyenne pour le climat.

Osterwalder, A. (2004). *The Business Model Ontology: a proposition in a design science approach*. Ph.d. dissertation, Université de Lausanne, Ecole des Hautes Etudes Commerciales.

Osterwalder, A. & Pigneur, Y. (2011). *Business Model nouvelle génération - Un guide pour visionnaires, révolutionnaires et challengers*. Pearson.

REN21 (2019). *Renewables 2019 Global Status Report*.

World Bank (2013). Crowdfunding's potential for the developing world.

YouGov France for FPF and the MTES (2019). Enquête sur le financement participatif des énergies renouvelables.

Appendix A: Empirical determinants of renewable energy deployment

Contents

A.1 Search strategy

Keywords and refinements	Description and rationale	Scopus results
Search string (search in Article title, Abstract, Keywords)		
(renewable* OR "renewable energ*" OR "renewable electric*")	This enables to precisely identify the type of energy sources considered.	144,577 results
AND (invest* OR source* OR generat* OR technolog* OR consum* OR deploy* OR diffus* OR develop*)	These terms refer to the use of this type of energy sources.	122,139 results
AND (motiv* OR factor* OR driv* OR promot* OR determin* OR influence* OR relation* OR impact* OR potential* OR affect*)	These terms are related to the study of potential determinants.	69,922 results
AND (panel OR estimat* OR regression OR data*)	This enables to capture only econometric analyses.	17,004 results
AND (countries* OR states*)	This terms are used to identify papers conducting an analysis with a with a panel of countries.	3,023 results
Specification of the fields of research		
AND ((EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "MATE") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "PHAR") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "NEUR") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "COMP"))	Due to the focus of this review, the following subject areas are excluded: Materials Science, Earth and Planetary Sciences, Chemistry, Medicine, Biochemistry, Genetics and Molecular Biology, Physics and Astronomy, Pharmacology, Toxicology and Pharmaceutics, Immunology and Microbiology, Health Professions, Nursing, Neuroscience, Veterinary, and Computer Science.	2,399 results
Document type and language specification		
AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO(LANGUAGE, "English"))	This chapter aims at reviewing papers published in English in peer-reviewed journals to ensure that the papers that are reviewed can be found and understood by any reader.	1,725 results

Table A.1 Description of the search strategy in relation to the search string.

Source: author's work.
Note: as the articles search started in early 2018, the articles published after December of 2017 are not considered here.

A.2 Presentation of the reviewed papers

Table A.2 Description of the reviewed papers.

References	Period	Countries	Methodology	Dependent variable	Independent variables
Chang et al. (2009)	1997-2006	30 developed	Static panel model estimation techniques (panel threshold regression model)	Share of all RE in energy supply	Economic (income, prices)
Sadorsky (2009a)	1994-2003	18 developing	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income, prices)
Sadorsky (2009b)	1980-2005	7 developed	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income, prices), Environmental
Brunnschweiler (2010)	1980-2006	119 developing	Static panel model estimation techniques (GLS), dynamic panel model estimation techniques (GMM)	Level of all RE electricity, hydro and non-hydro RE electricity generated per capita	Economic (income, prices, international flows, financial), Energy (fossil fuels), Regulatory and Political
Marques et al. (2010)	1990-2006	24 developed (European)	Static panel model estimation techniques (OLS, RE, FE, FEVD)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Political, RE potential
Gan & Smith (2011)	1994-2003	26 developed	Static panel model estimation techniques (GLS)	Level of all RE and bioenergy supply per capita	Economic (income, prices), Environmental, Regulatory
Marques & Fuinhas (2011b)	1990-2006	24 developed (European)	Static panel model estimation techniques (FE), dynamic panel model estimation techniques (difference and system GMM, LSDVC)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix)
Marques & Fuinhas (2011a)	1990-2006	21 developed (European)	Static panel model estimation techniques (OLS, quantile regression model)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Marques et al. (2011)	1990-2006	24 developed (European)	Static panel model estimation techniques (OLS, quantile regression model)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory, RE potential
Popp et al. (2011)	1991-2004	26 developed	Static panel model estimation techniques (FGLS)	Installed capacity per capita of non-hydro RE electricity	Economic (income), Energy (security, consumption, mix, fossil fuels), Regulatory, RE potential
Romano & Scandurra (2011)	1980-2008	29 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (consumption, mix)
Bengochea & Faet (2012)	1990-2004	15 developed (European)	Static panel model estimation techniques (OLS, FE, RE, PCSE, FGLS)	Level of all RE supply	Economic (prices), Environmental

Table A.2 Description of the reviewed papers (cont.).

References	Period	Countries	Methodology	Dependent variable	Independent variables
Biresselioglu & Karaibrahimoglu (2012)	1999-2009	30 developed (European)	Static panel model estimation techniques (?)	Share of all RE in energy consumption	Economic (income), Energy (security, consumption, mix), Population, Regulatory and Political, RE potential
Marques & Fuinhas (2012)	1990-2007	23 developed (European)	Static panel model estimation techniques (RE, FE, PCSE)	Share of all RE in energy supply	Environmental, Energy (security, consumption, mix), Regulatory, RE potential
Salim & Rafiq (2012)	1980-2006	6 developing	Panel cointegration techniques, Time series analysis (cointegration and Granger causality)	Level of all RE consumption	Economic (income, prices), Environmental
Cheon & Urpelainen (2013)	1989-2007	19 developed	Dynamic panel model estimation techniques (?)	Share of non-hydro RE in electricity generated	Economic (income, prices), Energy (consumption, mix), Regulatory, Political, RE potential
Narbel (2013)	2007-2009	107 developing and developed	Cross-section analysis (OLS)	Share of non-hydro RE in electricity generated	Economic (income), Energy (security, mix)
Pfeiffer & Mulder (2013)	1980-2010	108 developing	Static panel model estimation techniques (Two-part model (probit, OLS) and two-step selection model (probit))	Level of non-hydro RE electricity generated per capita	Economic (income, international flows, financial), Energy (consumption, mix, fossil fuels), Population, Regulatory and Political
Sick et al. (2013)	1991-2009	18 developed	Static panel model estimation techniques (?)	Installed capacity per capita of non-hydro RE electricity	Economic (income, prices), Energy (consumption, mix), Regulatory
Zhao et al. (2013)	1980-2010	122 developing and developed	Static panel model estimation techniques (OLS, Poisson pseudo-maximum likelihood estimation)	Share of non-hydro RE in electricity generated	Economic (income, international flows, financial), Environmental, Energy (security), Population, Regulatory
Aguirre & Ibikunle (2014)	1990-2010	38 developing and developed	Static panel model estimation techniques (GLS, FEVD, PCSE)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix) Population, Regulatory, RE potential
Apergis & Payne (2014a)	1980-2011	25 developed	Panel cointegration techniques, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Apergis & Payne (2014b)	1980-2010	7 developing	Panel cointegration techniques with possible structural breaks, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Omri & Nguyen (2014)	1990-2011	64 developing and developed	Dynamic panel model estimation techniques (GMM)	Level of non-hydro RE consumption	Economic (income, prices, international flows), Environmental
Romano & Scandurra (2014)	1980-2009	6 developing	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, fossil fuels)
Zeb et al. (2014)	1975-2010	5 developing	Panel cointegration techniques, Granger causality	Level of all RE electricity generated	Economic (income), Environmental, Population

Table A.2 Description of the reviewed papers (cont.).

References	Period	Countries	Methodology	Dependent variable	Independent variables
Ackah & Kizys (2015)	1971-2012	11 developing	Static panel model estimation techniques (two-stage EGLS and least squares), dynamic panel model estimation techniques (GMM)	Level of all RE consumption per capita	Economic (income, prices), Environmental, Energy (other), Population, RE potential
Apergis & Eleftheriou (2015)	1995-2011	16 developing and developed	Panel cointegration techniques, Granger causality	Level of all RE consumption	Economic (income), Population, Political
Apergis & Payne (2015)	1980-2010	11 developing	Panel cointegration techniques, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Kehrel & Sick (2015)	1991-2010	18 developed	Time-series cross-section analysis (multivariate linear regression)	Installed capacity of non-hydro RE electricity and production volume of biofuels per capita	Economic (income, prices), Energy (consumption, mix), Regulatory
Wu & Broadstock (2015)	1990-2010	22 developing	Dynamic panel model estimation techniques (GMM)	Level of all RE consumption	Economic (incomre, prices, international flows, financial), Environmental, Population, Political
Cadoret & Padovano (2016)	2004-2011	26 developed (European)	Static panel model estimation techniques (Two-step estimation technique (LSDV, OLS))	Share of all RE in energy consumption	Economic (income, prices), Environmental, Energy (security), Regulatory and Political
Geng & Ji (2016)	1980-2010	6 developed countries	Panel cointegration techniques, Granger causality	Level of non-hydro RE in energy consumption per capita	Economic (income, prices) Environmental, RE potential
Kilinc-Ata (2016)	1990-2008	27 developed	Static panel model estimation techniques (FE)	Share of non-hydro RE in electricity generated	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Kim & Park (2016)	2000-2013	30 developing and developed	Static panel model estimation techniques (OLS, Tobit)	Installed capacity of non-hydro electricity	Economic (income, financial), Regulatory, RE potential
Romano & Scandurra (2016a)	2000-2008	32 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of hydro and non-hydro RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Romano & Scandurra (2016b)	1980-2008	60 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Romano & Scandurra (2016c)	1980-2008	32 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Valdés Lucas et al. (2016)	1990-2013	21 developed (European)	Static panel model estimation techniques (RE, FGLS, PCSE)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Baldwin et al. (2017)	1990-2010	149 developing and developed	Static panel model estimation techniques (FE)	Level of all and non-hydro RE electricity generated	Economic (income, international flows, financial), Energy (security, consumption, fossil fuels), Population, Regulatory and Political

Table A.2 Description of the reviewed papers (cont.).

References	Period	Countries	Methodology	Dependent variable	Independent variables
Bayulgen & Ladewig (2017)	1974-2012	125 developing and developed	Static panel model estimation techniques (mixed-effect)	Share of all, hydro and non-hydro RE in electricity generated	Economic (income, prices, financial), Environmental, Energy (security, fossil fuels), Population, Political, RE potential
Best (2017)	1998-2012	Up to 137 developing and developed	Cross-section analysis (OLS), static panel model estimation techniques (FE)	Share of all RE in energy supply and electricity generated	Economic (income, financial), Energy (consumption, fossil fuels), RE potential
Carley et al. (2017)	1990-2010	164 developing and developed	Dynamic panel model estimation techniques (differences-in-differences estimator)	Level and share of all and non-hydro RE in electricity generated	Economic (income, international flows, financial), Energy (security, consumption, fossil fuels), Population, Regulatory and Political
Lin & Omoju (2017)	1980-2011	46 developing and developed	Panel cointegration techniques, Granger causality	Level and share of non-hydro RE in electricity generated	Economic (income, prices, international flows, financial), Energy (fossil fuels), Regulatory, RE potential
Lu (2017)	1990-2012	24 developing and developed	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income), Environmental
Nicolini & Tavoni (2017)	2000-2010	5 developed (European)	Static panel model estimation techniques (pooled OLS, FE, RE, Hausman Taylor estimator)	Level and installed capacity of all and incentivized RE	Economic (income, prices), Environmental, Energy (security, mix), Regulatory and Political
Nyiwul (2017)	1980-2011	27 developing	Panel cointegration techniques (DOLS, FMOLS, FE)	Level of all RE consumption	Economic (income, prices, other), Environmental, Population
Romano et al. (2017)	2004-2013	56 developing and developed	Static panel model estimation techniques (PCSE)	Share of non-hydro RE in electricity generated	Economic (income, prices, international flows), Environmental, Energy (security, consumption, mix, fossil fuels), Population, Regulatory

A.3 Statistics around the reviewed papers

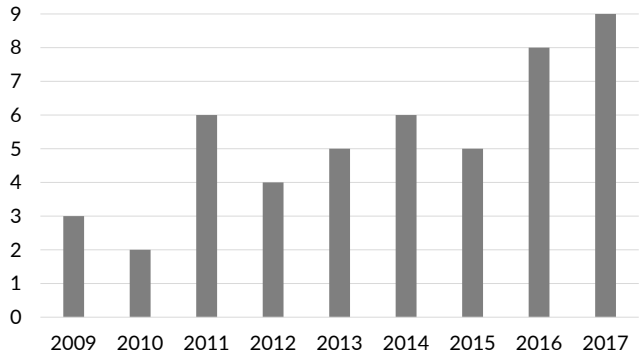


Fig. A.1 Number of papers published per year.

Source: author's work.

Journal	Number of papers
Energy Economics	8
Energy Policy	5
Renewable and Sustainable Energy Reviews	5
Energy Sources, Part B: Economics, Planning and Policy	4
Renewable Energy	4
Energy for Sustainable Development	2
Environmental and Resource Economics	2
Applied Economics	1
Biomass and Bioenergy	1
Clean Technologies and Environmental Policy	1
Energy	1
Environment and Development Economics	1
Environmental Politics	1
Environmental Science and Policy	1
Environmental Science and Pollution Research	1
Foresight	1
International Journal of Economic Policy in Emerging Economies	1
International Journal of Energy Economics and Policy	1
International Journal of Energy Sector Management	1
International Journal of Global Environmental Issues	1
Journal of Applied Statistics	1
Journal of Comparative Policy Analysis: Research and Practice	1
Metodoloski Zvezki	1
Political Studies	1
Singapore Economic Review	1

Table A.3 Journals of the reviewed papers.

Source: author's work.

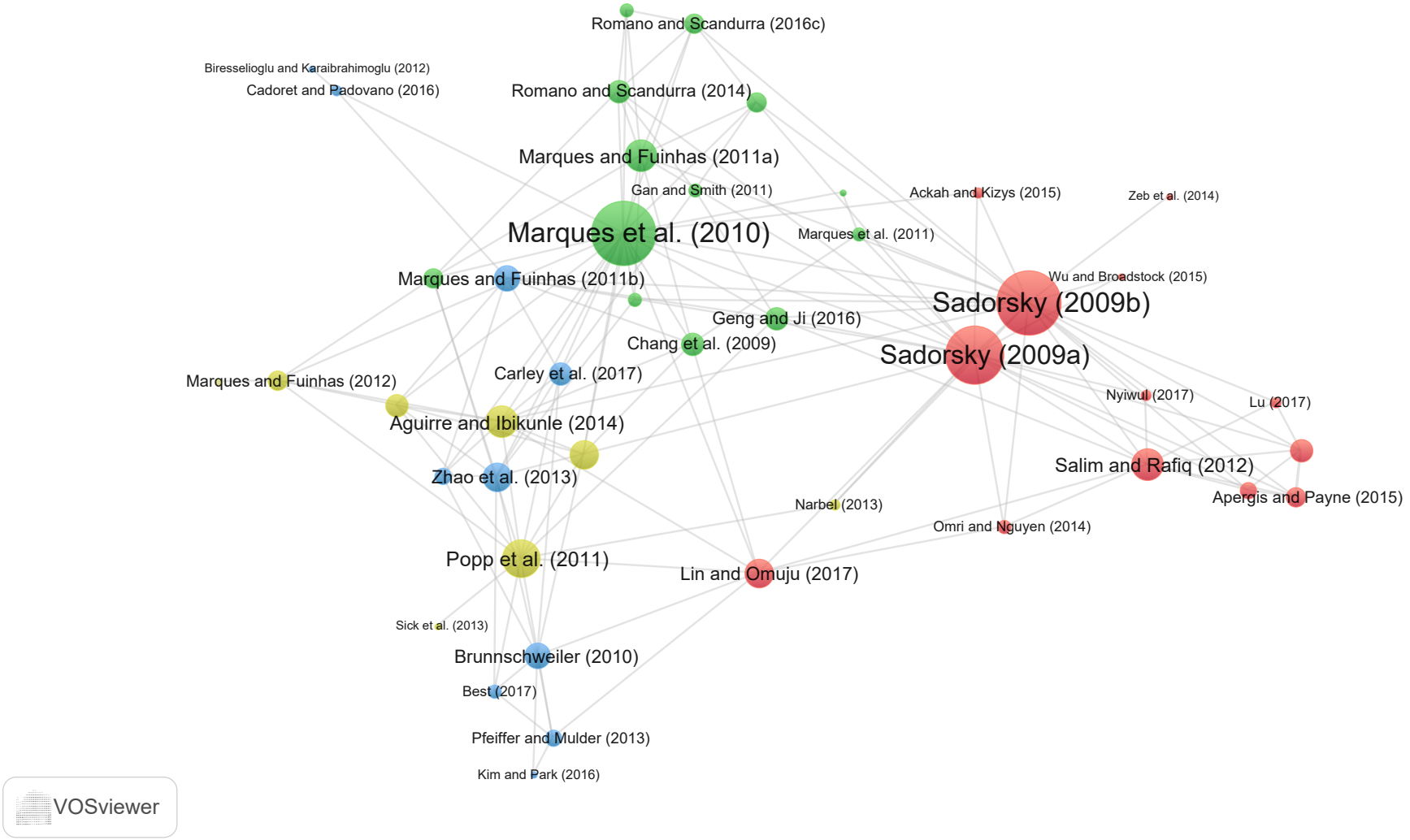


Fig. A.2 Network of citations of and by the reviewed papers.

Source: author's work.

A.4 Details regarding the framework of the reviewed papers

	Absolute level	Per capita level	Share	Absolute level and share	Total
Supply	*Developed (European):* .Static panel model estimation techniques (2.1%) *Developing:* .Panel cointegration techniques and Granger causality tests (2.1%) *Developing and developed:* .Static panel model estimation techniques (2.1%)	*Developed (global):* .Static panel model estimation techniques (2.1%) *Developing:* .Static panel model estimation techniques (2.1%) .Static and dynamic panel model estimation techniques (2.1%)	*Developed (global):* .Dynamic panel model estimation techniques (2.1%) .Static panel model estimation techniques (4.2%) *Developed (European):* .Static panel model estimation techniques (10.4%) .Static and dynamic panel model estimation techniques (2.1%) *Developing:* .Dynamic panel model estimation techniques (2.1%) *Developing and developed:* .Dynamic panel model estimation techniques (8.3%) .Static panel model estimation techniques (8.3%) .Others (4.2%)	*Developing and developed:* .Dynamic panel model estimation techniques (2.1%) .Panel cointegration techniques and Granger causality tests (2.1%)	58.5%
Cons.	*Developing:* .Dynamic panel model estimation techniques (2.1%) .Others (4.2%) *Developing and developed:* .Dynamic panel model estimation techniques (2.1%) .Panel cointegration techniques and Granger causality tests (2.1%)	*Developed (global):* .Panel cointegration techniques and Granger causality tests (6.3%) *Developing:* .Panel cointegration techniques and Granger causality tests (6.3%) .Static and dynamic panel model estimation techniques (2.1%) *Developing and developed:* .Panel cointegration techniques and Granger causality tests (2.1%)	*Developed (European)* .Static panel model estimation techniques (4.2%)		31.5%
Installed capacity	*Developing and developed:* .Static panel model estimation techniques (2.1%)	*Developed (global):* .Static panel model estimation techniques (4.2%) .Others (2.1%)			8.4%
Supply and capacity	*Developed (European):* .Static panel model estimation techniques (2.1%)				2.1%
Total	21.0%	29.4%	45.9%	4.2%	100%

Table A.4 Dependent variables types, sample of countries and methodologies considered by reviewed papers (small differences due to rounding).

Source: author's work.

Variables	Main data sources
Dependent variables	
Supply	U.S. Energy Information Administration, OECD, IEA, Eurostat, national authorities.
Consumption	U.S. Energy Information Administration, OECD, IEA, Eurostat, national authorities.
Capacity	IEA, Bloomberg New Energy Finance, U.S. Energy Information Administration, national authorities.
Independent variables	
Economic variables	
Income	World Bank, U.S. Energy Information, IMF, OECD, Penn World Table, United Nations, Eurostat, IEA, national authorities.
Fossil fuel prices	BP, Thomson Reuters.
Local financial sector	World Bank, Bloomberg New Energy Finance.
International flows	World Bank.
Energy/electricity price	IEA, OECD, IMF, Eurostat.
Environmental variable	
CO_2 emissions	U.S. Energy Information, Eurostat, World Bank, BP, European Commission, OECD, national authorities.
Energy variables	
Energy/electricity consumption	Eurostat, U.S. Energy Information Administration, IEA, European Commission, World Bank.
Other sources weight in the mix	U.S. Energy Information Administration, Eurostat, World Bank, European Commission, IEA.
Energy security	Eurostat, US U.S. Energy Information, World Bank, European Commission, IEA, BP.
Fossil fuel production	U.S. Energy Information Administration, BP.
Regulatory variables	
RE support policies	IEA, Eurostat, REN21, OECD, national authorities.
Kyoto Protocol	IEA, United Nations.
Political variables	
Institutional quality	World Bank, Transparency international, Freedom house, TransResearch Consortium Center for Systemic Peace, Heritage Foundation, Fraser Institute, Center on Democratic Performance, University of Pennsylvania.
Government ideology (left)	World Bank.
Demographic variable	
Population size	World Bank, Eurostat, Penn World Table.

Table A.5 Main data sources considered by the authors in order of importance.

Source: author's work.
Note: "OECD" = "Organisation for Economic Co-operation and Development", "IEA" = "International Energy Agency", "IMF" = "International Monetary Fund".

References	Indicators
Brunnschweiler (2010)	Deposit money bank assets/(deposit money + central) bank assets, Private credit by deposit money banks/GDP, Financial depth (liquid liabilities/GDP).
Pfeiffer & Mulder (2013)	Deposit money bank assets/total bank assets.
Zhao et al. (2013)	Domestic credit to the private sector/GDP.
Wu & Broadstock (2015)	Stock market total value traded/GDP, Bank return on assets, Bank overhead costs/total assets, Bank cost-income ratio, Public bond market capitalisation/GDP, Bank credit/bank deposits, Loans from non-resident banks/GDP, Offshore bank deposits/domestic bank deposits, Bank return on equity.
Kim & Park (2016)	Annual equity market development*Dependence, Annual credit market development*Dependence, Variable composed of the 2 previous variables*Dependence. Dependence measures the dependence on external financing (based on U.S. RE firms, also tested with U.K. RE firms and U.S. LCOE).
Best (2017)	For 10-year change: Private credit from deposit money banks/GDP. For panel data: Private credit from deposit money banks/GDP, Domestic private debt securities, International private debt securities, Public debt securities, Stock market capitalization.
Bayulgen & Ladewig (2017)	Domestic credit to the private sector/GDP.
Lin & Omoju (2017)	Domestic credit to the private sector/GDP.
Baldwin et al. (2017)	Private credit by deposit money banks/GDP, Bank credit/bank deposits.
Carley et al. (2017)	Private credit by deposit money banks/GDP.

Table A.6 Local financial development independent variables considered by the authors.

Source: author's work.
Note: "LCOE" = "levelized cost of energy".

References	Indicators
Brunnschweiler (2010)	Economic freedom index.
Pfeiffer & Mulder (2013)	Polity score.
Wu & Broadstock (2015)	Political stability and absence of violence, Voice and accountability, Regulatory quality.
Apergis & Eleftheriou (2015)	Political (Number of political parties), Institutional (Size of government, Legal system and property rights, Freedom to trade internationally, Regulation level).
Cadoret & Padovano (2016)	Quality of governance (Corruption Perception Idex; Control of Corruption Index).
Baldwin et al. (2017)	Freedom House rating, Government ability to appropriate and collect portions of GDP (proxy for state administrative capability).
Bayulgen & Ladewig (2017)	Political constraint, Polity score.
Carley et al. (2017)	Freedom House rating.

Table A.7 Institutional quality independent variables considered by the authors.

Source: author's work.

A.5 Detailed results

Independent variables	Global results (papers)	Global results (estimations)
Economic variables		
Income	NC	NC
Fossil fuel prices	NC	NC
Local financial sector	NC	+
Energy/electricity price	-	NC
International flows	NC	NC
Environmental variable		
CO_2 emissions	NC	-
Energy variables		
Energy/electricity consumption	NC	NC
Other sources weight in the mix	-	-
Energy security	NC	NC
Fossil fuel production	NC	NC
Regulatory variables		
RE support policies	+	+
Kyoto Protocol	+	+
Political variables		
Institutional quality	NC	+
Government ideology (left)	NC	NC
Demographic variable		
Population size	+	+

Table A.8 Overall results for the main independent variables (considered by at least five authors).

Source: author's work.
Note: "NC" = "no consensus".

Independent variables	Supply			Consumption			Capacity	
	Absolute	Per capita	Share	Absolute	Per capita	Share	Absolute	Per capita
Economic variables								
Income	NC	(+)	NC	NC	+	(-)	(NC)	(NC)
Fossil fuel prices	(NC)	(NC)	NC	(NC)	+			(+)
Local financial sector	(NC)	(NC)	NC	(NC)			(+)	
Energy/electricity price	(-)	(NC)	(NC)	(NC)	(-)	(+)	(-)	
International flows	(NC)	(NC)	(NC)	(NC)				
Environmental variable								
CO_2 emissions	(NC)	(NC)	-	(+)	+	(+)	(NC)	
Energy variables								
Energy/electricity consumption	(NC)	(NC)	NC			(-)		(NC)
Other sources weight in the mix	(NC)	(NC)	-			(-)	(NC)	(NC)
Energy security	(NC)		NC			(NC)	(NC)	(NC)
Fossil fuel production		(NC)	(NC)					(NC)
Regulatory variables								
RE support policies	(NC)	(NC)	+			(+)	(+)	(NC)
Kyoto Protocol	(NC)	(+)	(NC)					(+)
Political variables								
Institutional quality	(NC)	(NC)	(+)	(NC)		(+)		
Government ideology (left)	(NC)		(NC)			(+)	(NC)	
Demographic variable								
Population size	(NC)		(NC)	(NC)	(+)	(-)		

Table A.9 Detailed results by types of dependent variable for the main independent variables (results in parentheses correspond to less than 5 papers).

Source: author's work.
Note: "NC" = "no consensus".

Independent variables	Global	Developing	Developed (European)	Developed (global)
Economic variables				
Income	NC	+	-	NC
Fossil fuel prices	NC	NC	NC	NC
Local financial sector	NC	(NC)		
Energy/electricity price	(NC)	(-)	(NC)	(NC)
International flows	NC	(NC)		
Environmental variable				
CO_2 emissions	NC	NC	-	NC
Energy variables				
Energy/electricity consumption	NC	(NC)	(+)	NC
Other sources weight in the mix	-	(NC)	-	(NC)
Energy security	NC		-	(NC)
Fossil fuel production	(NC)	(NC)		(NC)
Regulatory variables				
RE support policies	NC	(+)	(+)	NC
Kyoto Protocol	(NC)	(+)	(NC)	(NC)
Political variables				
Institutional quality	(NC)	(NC)	(+)	
Government ideology (left)	(NC)		(+)	(NC)
Demographic variable				
Population size	(+)	(+)	(-)	

Table A.10 Detailed results by types of sample of countries for the main independent variables (results in parentheses correspond to less than 5 papers).

Source: author's work.
Note: "NC" = "no consensus".

A.6 Bibliography

Ackah, I. & Kizys, R. (2015). Green growth in oil producing african countries: A panel data analysis of renewable energy demand. *Renewable and Sustainable Energy Reviews*, *50*, 1157–1166.

Aguirre, M. & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy*, *69*, 374–384.

Apergis, N. & Eleftheriou, S. (2015). Renewable energy consumption, political and institutional factors: Evidence from a group of european, asian and latin american countries. *The Singapore Economic Review*, *60*(01), 1–19.

Apergis, N. & Payne, J. E. (2014a). The causal dynamics between renewable energy, real gdp, emissions and oil prices: evidence from oecd countries. *Applied Economics*, *46*(36), 4519–4525.

Apergis, N. & Payne, J. E. (2014b). Renewable energy, output, co2 emissions, and fossil fuel prices in central america: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics*, *42*, 226–232.

Apergis, N. & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: Evidence from south america. *Energy Sources, Part B: Economics, Planning, and Policy*, *10*(3), 281–287.

Baldwin, E., Carley, S., Brass, J. N., & MacLean, L. M. (2017). Global renewable electricity policy: A comparative policy analysis of countries by income status. *Journal of Comparative Policy Analysis: Research and Practice*, *19*(3), 277–298.

Bayulgen, O. & Ladewig, J. W. (2017). Vetoing the future: political constraints and renewable energy. *Environmental Politics*, *26*(1), 49–70.

Bengochea, A. & Faet, O. (2012). Renewable energies and co2 emissions in the european union. *Energy Sources, Part B: Economics, Planning, and Policy*, *7*(2), 121–130.

Best, R. (2017). Switching towards coal or renewable energy? the effects of financial capital on energy transitions. *Energy Economics*, *63*, 75–83.

Biresselioglu, M. E. & Karaibrahimoglu, Y. Z. (2012). The government orientation and use of renewable energy: Case of europe. *Renewable Energy*, *47*, 29–37.

Brunnschweiler, C. N. (2010). Finance for renewable energy: an empirical analysis of developing and transition economies. *Environment and Development Economics*, *15*(3), 241–274.

Cadoret, I. & Padovano, F. (2016). The political drivers of renewable energies policies. *Energy Economics*, *56*, 261–269.

Carley, S., Baldwin, E., MacLean, L. M., & Brass, J. N. (2017). Global expansion of renewable energy generation: An analysis of policy instruments. *Environmental and Resource Economics*, *68*(2), 397–440.

Chang, T.-H., Huang, C.-M., & Lee, M.-C. (2009). Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from oecd countries. *Energy Policy*, *37*(12), 5796–5802.

Cheon, A. & Urpelainen, J. (2013). How do competing interest groups influence environmental policy? the case of renewable electricity in industrialized democracies, 1989–2007. *Political Studies*, *61*(4), 874–897.

Gan, J. & Smith, C. (2011). Drivers for renewable energy: A comparison among oecd countries. *Biomass and Bioenergy*, *35*(11), 4497–4503.

Geng, J.-B. & Ji, Q. (2016). Technological innovation and renewable energy development: evidence based on patent counts. *International Journal of Global Environmental Issues*, *15*(3), 217–234.

Kehrel, U. & Sick, N. (2015). Oil prices as a driving force in the diffusion of renewables? *International Journal of Energy Sector Management*, *9*(2), 227–250.

Kilinc-Ata, N. (2016). The evaluation of renewable energy policies across eu countries and us states: An econometric approach. *Energy for Sustainable Development*, *31*, 83–90.

Kim, J. & Park, K. (2016). Financial development and deployment of renewable energy technologies. *Energy Economics*, *59*, 238–250.

Lin, B. & Omoju, O. E. (2017). Focusing on the right targets: Economic factors driving non-hydro renewable energy transition. *Renewable Energy*, *113*, 52–63.

Lu, W.-C. (2017). Renewable energy, carbon emissions, and economic growth in 24 asian countries: evidence from panel cointegration analysis. *Environmental Science and Pollution Research*, *24*(33), 26006–26015.

Marques, A. C. & Fuinhas, J. A. (2011a). Do energy efficiency measures promote the use of renewable sources? *Environmental Science & Policy*, *14*(4), 471–481.

Marques, A. C. & Fuinhas, J. A. (2011b). Drivers promoting renewable energy: A dynamic panel approach. *Renewable and Sustainable Energy Reviews*, *15*(3), 1601–1608.

Marques, A. C. & Fuinhas, J. A. (2012). Are public policies towards renewables successful? evidence from european countries. *Renewable Energy*, *44*, 109–118.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2010). Motivations driving renewable energy in european countries: A panel data approach. *Energy Policy*, *38*(11), 6877–6885.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2011). A quantile approach to identify factors promoting renewable energy in european countries. *Environmental and Resource Economics*, *49*(3), 351–366.

Narbel, P. A. (2013). What is really behind the adoption of new renewable electricity generating technologies? *Energy for Sustainable Development*, *17*(4), 386–390.

Nicolini, M. & Tavoni, M. (2017). Are renewable energy subsidies effective? evidence from europe. *Renewable and Sustainable Energy Reviews*, *74*, 412–423.

Nyiwul, L. (2017). Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in sub-sahara africa. *Clean Technologies and Environmental Policy*, *19*(2), 437–450.

Omri, A. & Nguyen, D. K. (2014). On the determinants of renewable energy consumption: International evidence. *Energy*, *72*, 554–560.

Pfeiffer, B. & Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics*, *40*, 285–296.

Popp, D., Hascic, I., & Medhi, N. (2011). Technology and the diffusion of renewable energy. *Energy Economics*, *33*(4), 648–662.

Romano, A. & Scandurra, G. (2014). Investments in renewable energy sources in opec members: A dynamic panel approach. *Metodoloski Zvezki*, *11*(2), 93–106.

Romano, A. & Scandurra, G. (2016a). Divergences in the determinants of investments in renewable energy sources: hydroelectric vs. other renewable sources. *Journal of Applied Statistics*, *43*(13), 2363–2376.

Romano, A. A. & Scandurra, G. (2011). The investments in renewable energy sources: do low carbon economies better invest in green technologies? *International Journal of Energy Economics and Policy*, *1*(4), 107–115.

Romano, A. A. & Scandurra, G. (2016b). Investments in renewable energy sources in countries grouped by income level. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(10), 929–935.

Romano, A. A. & Scandurra, G. (2016c). "Nuclear" and "nonnuclear" countries: Divergences on investment decisions in renewable energy sources. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(6), 518–525.

Romano, A. A., Scandurra, G., Carfora, A., & Fodor, M. (2017). Renewable investments: The impact of green policies in developing and developed countries. *Renewable and Sustainable Energy Reviews*, *68*, 738–747.

Sadorsky, P. (2009a). Renewable energy consumption and income in emerging economies. *Energy Policy*, *37*(10), 4021–4028.

Sadorsky, P. (2009b). Renewable energy consumption, co2 emissions and oil prices in the g7 countries. *Energy Economics*, *31*(3), 456–462.

Salim, R. & Rafiq, S. (2012). Why do some emerging economies proactively accelerate the adoption of renewable energy? *Energy Economics*, *34*(4), 1051–1057.

Sick, N., Golembiewski, B., & Leker, J. (2013). The influence of raw material prices on renewables diffusion. *Foresight*, *15*(6), 477–491.

Valdés Lucas, J. N., Escribano Francés, G., & San Martín González, E. (2016). Energy security and renewable energy deployment in the eu: Liaisons dangereuses or virtuous circle? *Renewable and Sustainable Energy Reviews*, *62*, 1032–1046.

Wu, L. & Broadstock, D. (2015). Does economic, financial and institutional development matter for renewable energy consumption? evidence from emerging economies. *International Journal of Economic Policy in Emerging Economies*, *8*, 20–39.

Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected saarc countries: Progress towards green economy. *Renewable Energy*, *71*, 123–132.

Zhao, Y., Tang, K. K., & li Wang, L. (2013). Do renewable electricity policies promote renewable electricity generation? evidence from panel data. *Energy Policy*, *62*, 887–897.

Appendix B: Business model and risks of a renewable energy crowdfunding platform

Contents

B.1 Enerfip fact sheet

- The platform organized its first campaign in 2015 and today has both CIP and IFP statutes. Enerfip has about 5,000 registered members in November 2017.
- The number of projects funded at the beginning of November 2017 is 28. This corresponds to approximately EUR 6 million collected (around EUR 110,000 in 2015 and EUR 1.1 million in 2016) for projects located in France.
- The average investment per contributor is of about EUR 1,500.
- The technologies financed are as follows:

RE technology	Number of campaigns	Average amounts collected (in EUR)	Total amounts collected (in EUR)
Solar energy	16	176,000	2,816,500
Wind energy	9	292,000	2,628,300
Biomass	1	78,600	78,600
RE-related innovation	2	225,500	451,000

– The annual electricity production objectives of the financed projects are 50 to 76,300 MWh with an average of 2,815 MWh for solar energy and 37,920 MWh for wind energy.

– The financing instruments used are as follows:

Financing instrument	Number of campaigns	Average amounts collected (in EUR)	Total amounts collected (in EUR)
Bonds	23	181,100	4,164,400
Minibons	2	150,000	300,000
Equity	3	503,300	1,510,000

– The characteristics of debt-based campaigns (bonds and *minibons*) are as follows:

	Interest rate	Investment period
Minimum	4,5%	1,5 years
Maximum	7%	6 years
Average	5,7%	3,1 years

B.2 Overview of the French platforms specialized in crowdfunding of RE projects

	Enerfip	Lumo	Lendosphere	Akuocoop
First campaign year	2015	2012	2014	2017
Number of projects financed	28	About 30	70	3
Amounts of funds collected in million EUR	About 6	4	19,5	1

Table B.1 Comparative statistics regarding platforms specialized in RE crowdfunding.

Source: platforms' website (November 2017).

B.3 Enerfip's co-founders verbatim comments in French

Table B.2 Verbatim comments as stated by the interviewees and the English translation.

Verbatim quotation in French	**English translation**
"qui s'intéressent à ce marché, pour se diversifier, parce que leur marché initial ne marche pas très bien" (PR)	"who are interested in this market, to diversify, because their initial market is not doing very well"
"la transition énergétique, sa nécessité, sa possibilité et sa viabilité" (PR)	"the energy transition, its necessity, possibility, and viability"
"On n'a pas de frais pour les investisseurs, donc c'est quand même un changement assez significatif par rapport [...] aux solutions conventionnelles" (DG)	"There is no cost for investors, so it is a significant change compared to [...] conventional solutions"
"Je pense qu'on fournit plus de services aux épargnants. On leur donne une solution d'épargne" (PR)	"I think we provide more services to investors. We give them a savings solution"
"des taux d'intérêt beaucoup plus élevés que l'immense majorité des supports, avec un risque très limité" (DG)	"much higher interest rates than the vast majority of instruments, with very limited risk"
"Le terme consacré, c'est *gamification*" (PR)	"The precise world for that is gamification"
"Il y a une relation de confiance dans les deux sens" (DG)	"There is a relationship of trust in both directions"
"La plateforme réalise la déclaration fiscale des porteurs de projet et elle s'occupe du versement des coupons. Elle peut aussi faire la création et la tenue des registres investisseurs" (PR)	"The platform fills in the tax declaration of the project promoters and takes care of the payment of the coupons. It can also create and manage an investor register"
"Nous rédigeons tout et en général, le porteur de projet fait ensuite ses commentaires" (DF)	"We write everything down and in general, the project promoter then makes his comments"
"On a un gros besoin de les rassurer, de les orienter sur le type de produits, quel taux, quelle durée *etc.*, en amont" (PR)	"We have a big need to reassure them, to orient them on the type of products, what rate, what duration *etc.*, before the campaign"
"On avait un réseau de contacts dans ce milieu, qui nous permettait de démarrer assez vite et d'être crédibles" (PR)	"We had a network of contacts in this field, which allowed us to get started fairly quickly and to be credible"

Table B.2 Verbatim comments as stated by the interviewees and the English translation (cont.).

Verbatim quotation in French	**English translation**
"si jamais on n'y arrive pas, on pourra toujours diffuser le projet au sein du réseau bancaire X ou Y, et là, le porteur de projet est tout de suite rassuré, et il veut bien signer des contrats" (PR)	"If we don't succeed, we can always distribute the project within the X or Y banking network, and there, the project promoter is immediately reassured, and he is willing to sign contracts"
"Les moyens humains, c'est vraiment la clé" (DF)	"Human resources are really the key"
"On est dans ce milieu parce qu'on a une expertise et des compétences sur les aspects techniques, réglementaires, financiers, administratifs [...] mais c'est aussi parce qu'on est passionnés" (DG)	"We are in this business because we have expertise and skills in technical, regulatory, financial, and administrative aspects [...] but also because we are enthusiastic"
"Il y a ceux qui veulent favoriser l'acceptabilité locale de leur projet et il y a ceux qui recherchent vraiment des fonds parce qu'ils sont en manque de fonds propres pour pouvoir financer leur projet, donc soit en complément de la dette, soit même des fois à 100% en passant par nous. Et il y a ceux qui sont obligés d'en faire, dans le cadre des appels d'offres de la CRE" (DF)	"There are those who want to promote the local acceptability of their project and there are those who are really looking for funds because they lack the equity to be able to finance their project, so either as a complement to the debt, or even sometimes 100% through us. And there are those who are obliged to do so, within the framework of the CRE's calls for tenders"
"L'une des missions qu'Enerfip s'est donnée, c'est de faire de la pédagogie sur les solutions de la transition énergétique" (PR)	"One of Enerfip's missions is to teach about energy transition solutions"
"On fait beaucoup de pédagogie à travers nos infographies, nos vidéos, pour expliquer aux gens ce que sont les EnR, et ce que sont les produits financiers qu'on propose" (DF)	"We do a lot of pedagogy through our infographics, our videos, to explain to people what RE is, and what financial products we propose"
"parce qu'on n'est pas une banque, [...] donc on a ce prestataire qui joue ce rôle de tuyau entre les épargnants et les projets" (DG)	"because we are not a bank, [...] so we have this provider who acts as a channel between individual investors and the projects"

Table B.2 Verbatim comments as stated by the interviewees and the English translation (cont.).

Verbatim quotation in French	**English translation**
"on peut toujours l'exprimer en pourcentage de la collecte, mais en pratique, c'est plutôt un montant forfaitaire" (PR)	"it can always be expressed as a percentage of the amount collected, but in practice it is more like a lump-sum payement"
"Au global, ça va peut-être faire 5 ou 6% en fonction des options qu'ils vont choisir, mais dans la réalité, c'est du 4% success fee, plus les frais annexes (frais de déplacement ou les frais de permanences supplémentaires)" (DF)	"Overall, it may be 5 or 6% depending on the options they choose, but in reality, it's a 4% success fee, plus additional expenses (travel expenses or additional meetings fees)"
"Si on compte à la fois le juridique des collectes et la *compliance* avec l'AMF, ça revient à peu près à 10% de nos coûts annuels" (PR)	"If we take into account both the legal aspects of the campaigns and the compliance with the AMF, it amounts to about 10% of our annual costs"
"Si le projet est en phase de développement, il y a beaucoup plus de risques que si le projet est en phase de construction, et beaucoup moins de risques s'il est en phase d'exploitation" (DG)	"If the project is in the development phase, there is much more risk than if the project is in the construction phase, and much less risk if it is in the operation phase"
"Parce que, si on laisse passer un projet véreux, qu'on a une collecte et que le projet foire quelques mois ou quelques années plus tard, on sera tenus pour responsables d'avoir conseillé aux gens d'investir dans ce projet-là. Et donc, pour nous, c'est absolument vital de réduire ce risque à zéro" (PR)	"Because if you let a bad project go through, you organize the campaign, and the project goes bad a few months or years later, you will be held responsible for advising people to invest in that project. And so, for us, it's absolutely vital to reduce this risk to zero"
"Un porteur de projet qui ne réussit pas sa collecte, ce n'est pas bon signe, en termes d'image" (PR)	"A project promoter who does not succeed in his campaign, it is not a good sign in terms of image"
"Le partenaire bancaire qui est lié à une base d'investisseurs locale, [...] ça a une grosse valeur pour ce type de projet". "On a signé un partenariat pour diffuser nos offres auprès de la banque privée. Et l'objectif, c'est, à terme, de diffuser nos offres aussi dans la banque de détail" (PR)	"The banking partner that is linked to a local investor base, [...] it has a big value for this type of project.". "We have signed a partnership to distribute our offers in the private bank. And the objective is, in the long term, to distribute our offers also in retail banking"

Table B.2 Verbatim comments as stated by the interviewees and the English translation (cont.).

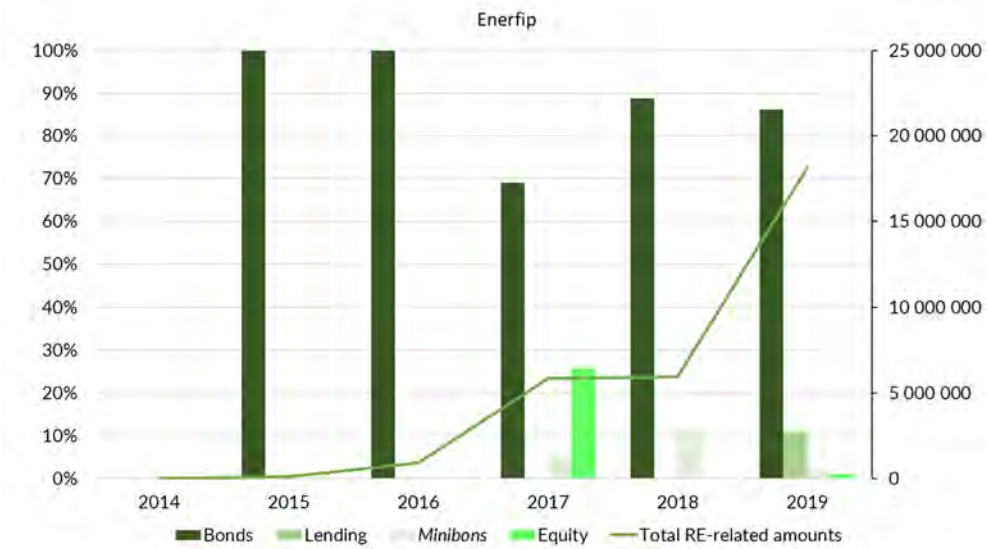
Verbatim quotation in French	**English translation**
"Dès qu'il y a l'implication de la commune, c'est un succès" (DF)	"As soon as there is some involvement of the town, it is a success"
"On a des informations obligatoires, de la part de l'AMF ; on ne transige pas là-dessus, évidemment" (DG)	"We have required information from the AMF; we will not compromise on this, of course"
"si la collecte n'atteint pas ce seuil de réussite, chaque personne est remboursée intégralement" (DG)	"if the campaign does not reach its success threshold, each person is reimbursed in full"
"des risques de dégradation suite à des catastrophes naturelles" et "des risques réglementaires ou fiscaux" (DG)	"risks of deterioration as a result of natural disasters" and "regulatory or tax risks"
"s'assure auprès du porteur de projet qu'il met bien en place les assurances pertes d'exploitation, bris de machines, *etc.*" (DG)	"ensures that the project promoter has taken out an insurance that covers operating losses, machinery breakdown, *etc.*"
"sur un projet très en amont, dans la phase de développement, en général on arrive à mettre en place une garantie financière émanant de la maison mère qui développe le projet en question, de sorte que les investisseurs bénéficient d'une garantie sur leur capital" (DG)	"on a very early development stage project, in general we manage to put in place a financial guarantee from the parent company that develops the project in question, so that the investors benefit from a guarantee on their capital"
"Eux aussi veulent souvent donner le minimum d'informations" (DF)	"They often want to give the minimum amount of information"
"Si la société qui contrôle les projets fait faillite, il y a toujours des actifs qu'il est possible de vendre à la casse, et puis de récupérer, en théorie suffisamment de cash pour payer tous les créanciers, ou au moins une partie" (PR)	"If the company that controls the projects goes bankrupt, there are always assets that can be sold for scrap to collect, theoretically enough cash to pay off all creditors, or at least part of it"
"avertit à toutes les étapes de l'inscription jusqu'à l'investissement, qu'il y a des risques dans les projets, que la perte en capital est possible, partielle ou totale, et qu'il ne faut investir que l'argent dont on n'a pas vraiment immédiatement besoin" (PR)	"warns at all stages from registration to investment, that there are risks in the projects, that a partial or total capital loss is possible, and that one should only invest money that is not really needed immediately"

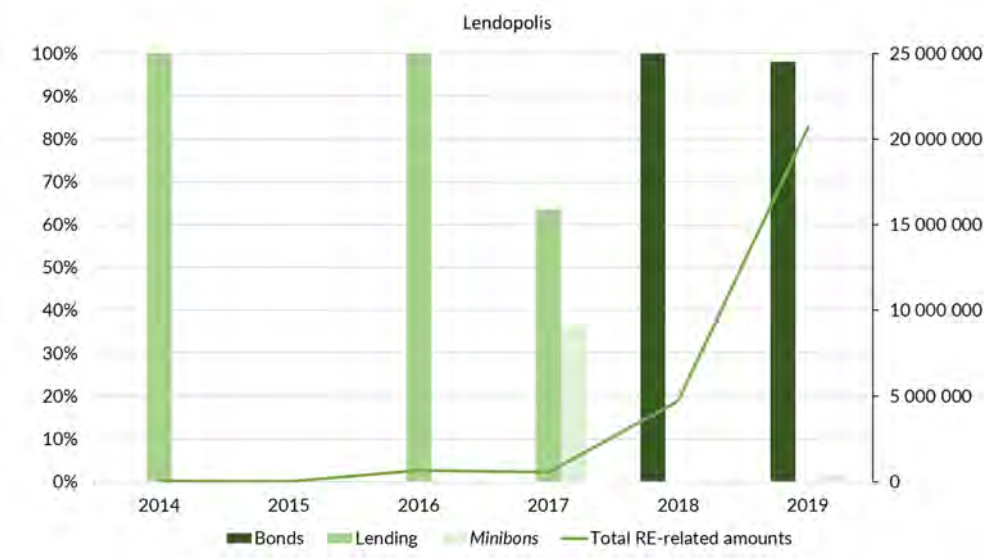
Source: interviews and authors' translation.

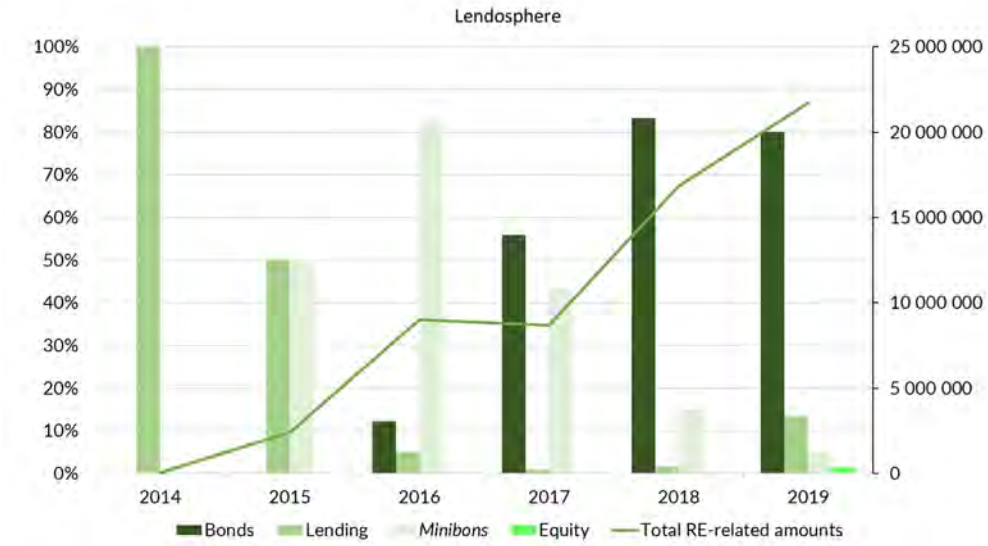
Appendix C: Overview of the French renewable energy crowdfunding sector

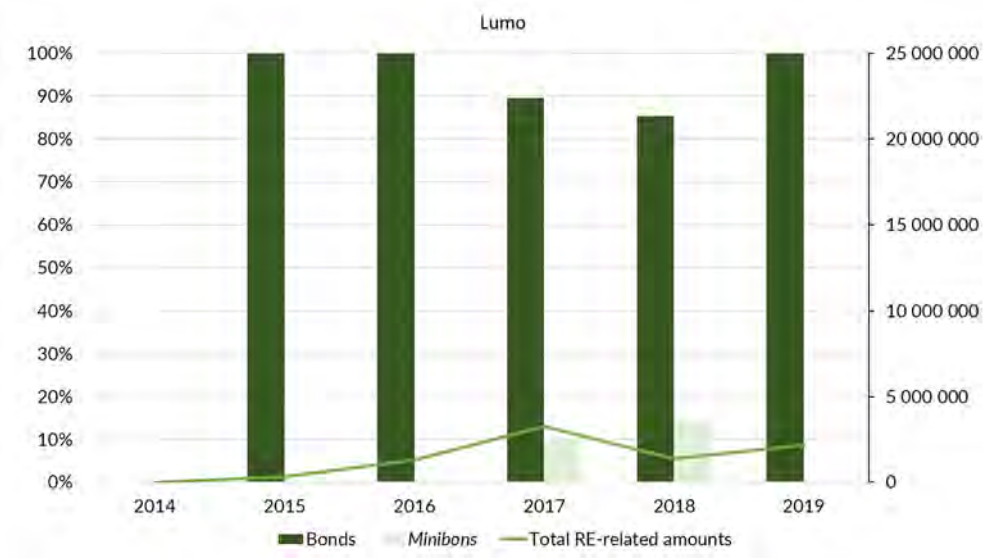
Contents

C.1 Crowdfunding instruments used by the reviewed platforms



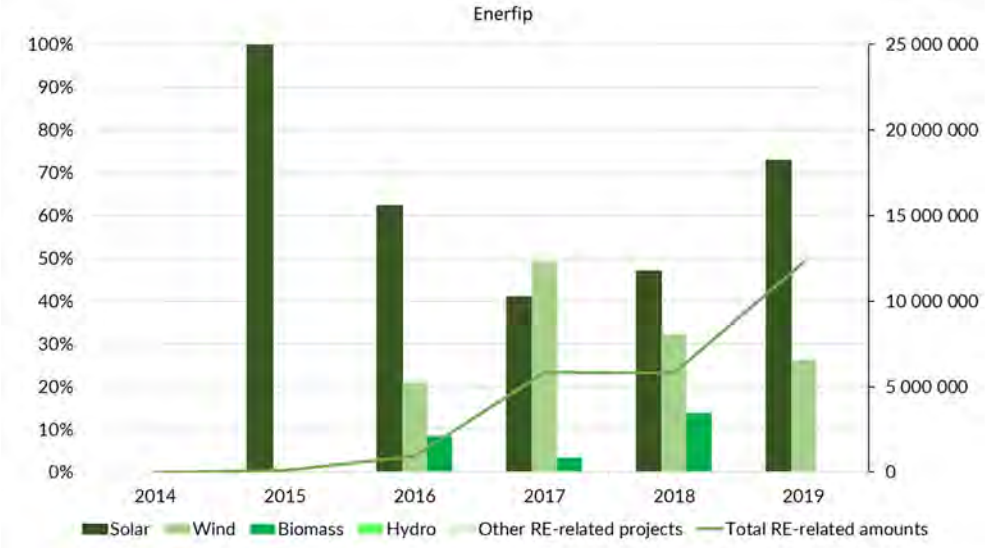

Lendopolis
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25 000 000
20 000 000
15 000 000
10 000 000
5 000 000
0
2014
2015
2016
2017
2018
2019
Bonds
Lending
Minibons
Total RE-related amounts

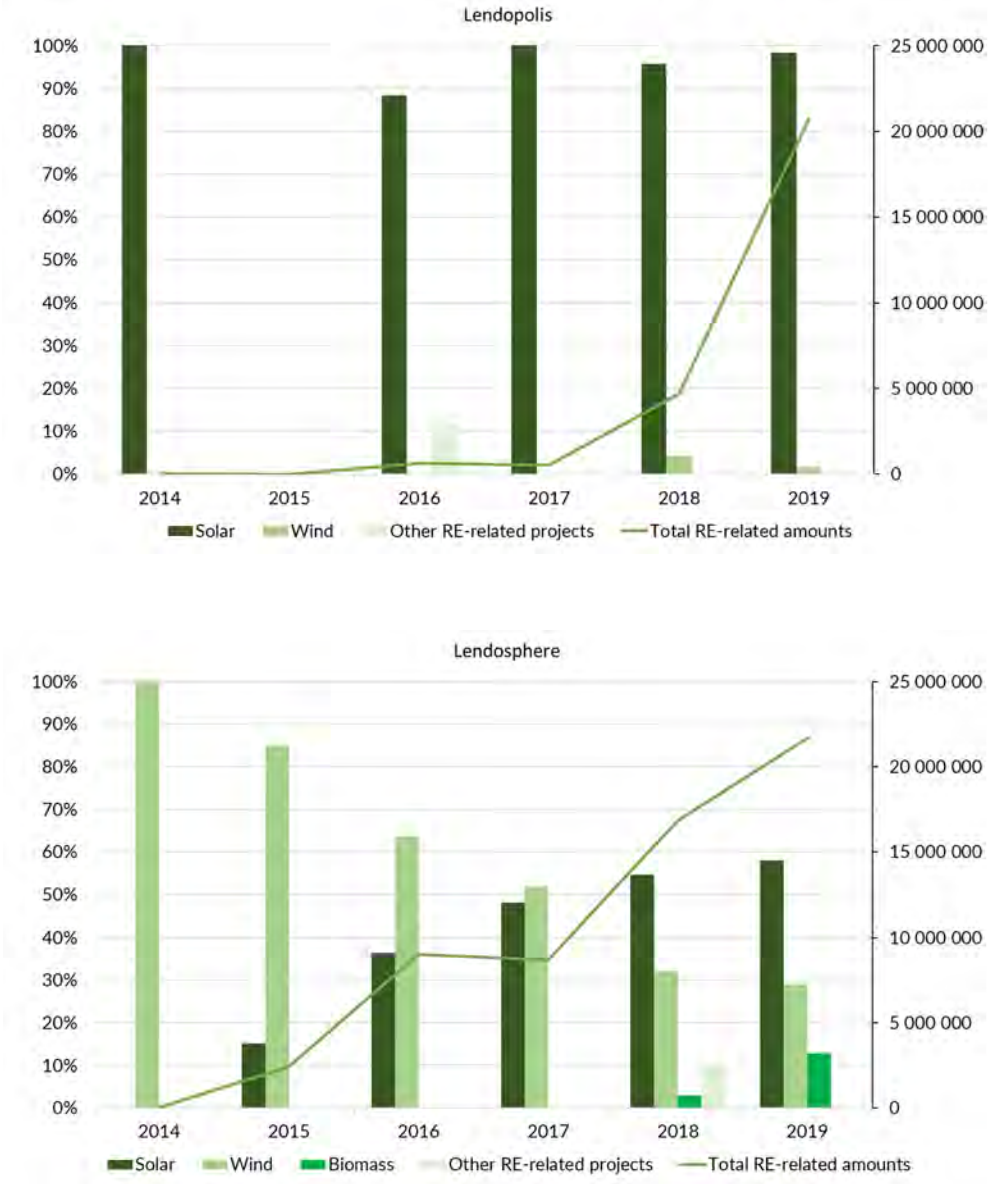

Lendosphere
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25 000 000
20 000 000
15 000 000
10 000 000
5 000 000
0
2014
2015
2016
2017
2018
2019
Bonds
Lending
Minibons
Equity
Total RE-related amounts



Source: author's work based on questionnaire data collected.

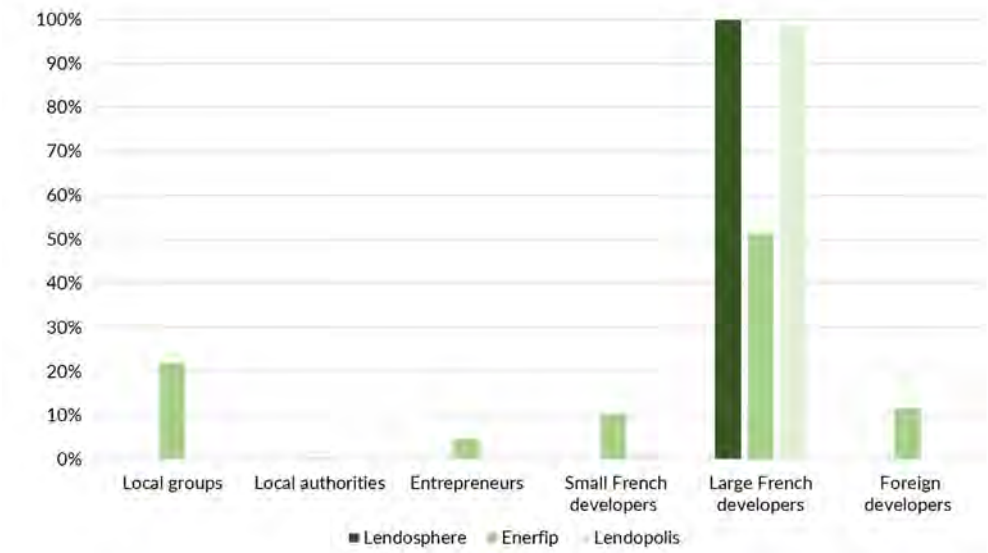
C.2 RE sources financed through the reviewed platforms





Source: author's work based on questionnaire data collected.

C.3 Types of project promoters



Source: author's work based on questionnaire data collected.
Note: developers are considered as small if they operate less than 20 RE installations, otherwise they are considered as large developers. Groups of citizens or farmers are considered here as local groups. Lumo did not provide detailed information about project promoters that have used the platform.

Bibliography

Ackah, I. & Kizys, R. (2015). Green growth in oil producing african countries: A panel data analysis of renewable energy demand. *Renewable and Sustainable Energy Reviews*, *50*, 1157–1166.

Agrawal, A., Catalini, C., & Goldfarb, A. (2014). Some simple economics of crowdfunding. *Innovation Policy and the Economy*, *14*, 63–97.

Aguirre, M. & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy*, *69*, 374–384.

Ahlers, G. K., Cumming, D., Günther, C., & Schweizer, D. (2015). Signaling in equity crowdfunding. *Entrepreneurship Theory and Practice*, *39*(4), 955–980.

Alcayde, A., G. Montoya, F., Baños, R., Perea-Moreno, A.-J., & Manzano-Agugliaro, F. (2018). Analysis of research topics and scientific collaborations in renewable energy using community detection. *Sustainability*, *10*(12).

Allison, T. H., Davis, B. C., Short, J. C., & Webb, J. W. (2015). Crowdfunding in a prosocial microlending environment: Examining the role of intrinsic versus extrinsic cues. *Entrepreneurship Theory and Practice*, *39*(1), 53–73.

Ameli, N. & Brandt, N. (2015). Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes. *Environmental Research Letters*, *10*(4), 044015.

Andriosopoulos, K. & Silvestre, S. (2017). French energy policy: A gradual transition. *Energy Policy*, *106*, 376–381.

Apergis, E. & Apergis, N. (2017). The role of rare earth prices in renewable energy consumption: The actual driver for a renewable energy world. *Energy Economics*, *62*, 33–42.

Apergis, N. & Eleftheriou, S. (2015). Renewable energy consumption, political and institutional factors: Evidence from a group of european, asian and latin american countries. *The Singapore Economic Review*, *60*(01), 1–19.

Apergis, N. & Payne, J. E. (2014a). The causal dynamics between renewable energy, real gdp, emissions and oil prices: evidence from oecd countries. *Applied Economics*, *46*(36), 4519–4525.

Apergis, N. & Payne, J. E. (2014b). Renewable energy, output, co2 emissions, and fossil fuel prices in central america: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics*, *42*, 226–232.

Apergis, N. & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: Evidence from south america. *Energy Sources, Part B: Economics, Planning, and Policy*, *10*(3), 281–287.

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics*, *37*(3), 668–691.

Attuel-Mendès, L., Bonescu, M., & Raymond, S. (2018). Modèle d'affaires de l'equity crowdfunding en france en 2016 : un état des lieux. *Innovations*, *56*(2), 89–116.

Baldwin, E., Carley, S., Brass, J. N., & MacLean, L. M. (2017). Global renewable electricity policy: A comparative policy analysis of countries by income status. *Journal of Comparative Policy Analysis: Research and Practice*, *19*(3), 277–298.

Bannerman, S. (2013). Crowdfunding culture. *Journal of Mobile Media*, *7*(01), 1–30.

Banque de France (2019). *Rapport de l'Observatoire de l'Epargne réglementée 2018*.

Bauwens, T. (2019). Analyzing the determinants of the size of investments by community renewable energy members: Findings and policy implications from flanders. *Energy Policy*, *129*, 841–852.

Bauwens, T. & Devine-Wright, P. (2018). Positive energies? an empirical study of community energy participation and attitudes to renewable energy. *Energy Policy*, *118*, 612–625.

Bauwens, T. & Eyre, N. (2017). Exploring the links between community-based governance and sustainable energy use: Quantitative evidence from flanders. *Ecological Economics*, *137*, 163–172.

Bayulgen, O. & Ladewig, J. W. (2017). Vetoing the future: political constraints and renewable energy. *Environmental Politics*, *26*(1), 49–70.

Belleflamme, P., Lambert, T., & Schwienbacher, A. (2013). Individual crowdfunding practices. *Venture Capital*, *15*(4), 313–333.

Belleflamme, P., Lambert, T., & Schwienbacher, A. (2014). Crowdfunding: Tapping the right crowd. *Journal of Business Venturing*, *29*, 585–609.

Belleflamme, P., Omrani, N., & Peitz, M. (2015). The economics of crowdfunding platforms. *Information Economics and Policy*, *33*, 11–28.

Bengochea, A. & Faet, O. (2012). Renewable energies and co2 emissions in the european union. *Energy Sources, Part B: Economics, Planning, and Policy*, *7*(2), 121–130.

Bento, N., Gianfrate, G., & Groppo, S. V. (2019). Do crowdfunding returns reward risk? evidences from clean-tech projects. *Technological Forecasting and Social Change*, *141*, 107–116.

Bergek, A., Mignon, I., & Sundberg, G. (2013). Who invests in renewable electricity production? empirical evidence and suggestions for further research. *Energy Policy*, *56*, 568–581.

Bessière, V. & Stéphany, E. (2017). *Le Crowdfunding*. De Boeck supérieur.

Bessière, V. & Stéphany, E. (2015). Financement et gouvernance des start-ups en equitycrowdfunding. *Finance Contrôle Stratégie*, *18*(4).

Best, R. (2017). Switching towards coal or renewable energy? the effects of financial capital on energy transitions. *Energy Economics*, *63*, 75–83.

Biresselioglu, M. E. & Karaibrahimoglu, Y. Z. (2012). The government orientation and use of renewable energy: Case of europe. *Renewable Energy*, *47*, 29–37.

Boeuf, B., Darveau, J., & Legoux, R. (2014). Financing creativity: Crowdfunding as a new approach for theatre projects. *International Journal of Arts Management*, *16*, 33–48.

Bonzanini, D., Giudici, G., & Patrucco, A. (2016). The crowdfunding of renewable energy projects. In V. Ramiah & G. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 429–444). Elsevier.

Boulton, C., Dedekorkut-Howes, A., & Byrne, J. (2018). Factors shaping urban greenspace provision: A systematic review of the literature. *Landscape and Urban Planning*, *178*, 82–101.

Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Economics*, *85*, 104563.

Bourcet, C. & Bovari, E. (2020). Exploring citizens' decision to crowdfund renewable energy projects: Quantitative evidence from France. *Energy Economics*, *88*.

Bourcet, C., Cézanne, C., Rigot, S., & Saglietto, L. (2019). Le financement participatif de projets d'énergies renouvelables (EnR) : éclairages sur le modèle économique et les risques d'une plateforme française. *Innovations*, *2*, 151–177.

Boyer, K., Chevalier, A., Léger, J., & Sannajust, A. (2016). *Le crowdfunding*. La Découverte.

BP (2019). *Statistical Review of World Energy*.

Brunnschweiler, C. N. (2010). Finance for renewable energy: an empirical analysis of developing and transition economies. *Environment and Development Economics*, *15*(3), 241–274.

Bruton, G., Khavul, S., Siegel, D., & Wright, M. (2015). New financial alternatives in seeding entrepreneurship: Microfinance, crowdfunding, and peer–to–peer innovations. *Entrepreneurship Theory and Practice*, *39*(1), 9–26.

Burger, S. P. & Luke, M. (2017). Business models for distributed energy resources: A review and empirical analysis. *Energy Policy*, *109*, 230–248.

Cadoret, I. & Padovano, F. (2016). The political drivers of renewable energies policies. *Energy Economics*, *56*, 261–269.

Cany, C., Mansilla, C., Mathonnière, G., & da Costa, P. (2018). Nuclear contribution to the penetration of variable renewable energy sources in a french decarbonised power mix. *Energy*, *150*, 544 – 555.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081.

Carley, S., Baldwin, E., MacLean, L. M., & Brass, J. N. (2017). Global expansion of renewable energy generation: An analysis of policy instruments. *Environmental and Resource Economics*, *68*(2), 397–440.

Carney, M. (2015). Breaking the tragedy of the horizon - climate change and financial stability - speech.

Casadesus-Masanell, R. & Ricart, J. E. (2010). From strategy to business models and onto tactics. *Long Range Planning*, *43*(2), 195–215.

Cavaye, A. (1996). Case study research: a multi-faceted research approach for is. *Information Systems Journal*, *6*(3), 227–242.

CGDD (2019a). Chiffres clés de l'énergie édition 2019. septembre 2019.

CGDD (2019b). Chiffres clés des énergies renouvelables édition 2019. mai 2019.

CGDD and I4CE (2019). Key figures on climate france, europe and worldwide - 2020 edition. november 2019.

Chambre de Commerce et d'Industrie de France (2019). D'une idée à un business model cohérent.

Chang, T.-H., Huang, C.-M., & Lee, M.-C. (2009). Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from oecd countries. *Energy Policy*, *37*(12), 5796–5802.

Chen, J. I., Foster, A., & Putterman, L. (2019). Identity, trust and altruism: An experiment on preferences and microfinance lending. *European Economic Review*, *120*, 103304.

Cheon, A. & Urpelainen, J. (2013). How do competing interest groups influence environmental policy? the case of renewable electricity in industrialized democracies, 1989–2007. *Political Studies*, *61*(4), 874–897.

Cholakova, M. & Clarysse, B. (2015a). Does the possibility to make equity investments in crowdfunding projects crowd out reward–based investments? *Entrepreneurship Theory and Practice*, *39*(1), 145–172.

Cholakova, M. & Clarysse, B. (2015b). Does the possibility to make equity investments in crowdfunding projects crowd out reward–based investments? *Entrepreneurship Theory and Practice*, *39*(1), 145–172.

Clark, R., Reed, J., & Sunderland, T. (2018). Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. *Land Use Policy*, *71*, 335–346.

Collaboration for Environmental Evidence (2018). *Guidelines and Standards for Evidence synthesis in Environmental Management*. Number Version 5.0 (AS Pullin, GK Frampton, B Livoreil and G Petrokofsky, Eds).

CompinnoV & FPF (2015). Baromètre de l'année 2014 crowdfunding france.

Connaissance des énergies (2017). Grenelle environnement.

Convention Citoyenne pour le Climat (2020a). The citizens' convention on climate, what is it?

Convention Citoyenne pour le Climat (2020b). Rapport de la convention citoyenne pour le climat.

Corbel, P., Charreire Petit, S., & Emmanuelle, D. (2018). Crowdfunding : Les trajectoires du succès… ou de l'échec. *Innovations*, *56*, 239–266.

Court, V. (2016). *Energy, EROI, and Economic Growth in a Long-Term Perspective*. Ph.d. dissertation, Université Paris Nanterre.

Crippa et al. (2019). Fossil co2 and ghg emissions of all world countries - 2019 report. Emissions Database for Global Atmospheric Research (EDGAR) - Publications Office of the European Union.

Cumming, D. J., Leboeuf, G., & Schwienbacher, A. (2017). Crowdfunding cleantech. *Energy Economics*, *65*, 292–303.

Dardour, A. (2015). La gestion du risque par les opérateurs de « crowdfunding » d'entreprise. *Recherches en Sciences de Gestion*, *107*, 45–65.

Darmani, A., Arvidsson, N., Hidalgo, A., & Albors, J. (2014). What drives the development of renewable energy technologies? toward a typology for the systemic drivers. *Renewable and Sustainable Energy Reviews*, *38*, 834–847.

de Broeck, W. (2018). Crowdfunding platforms for renewable energy investments: an overview of best practices in the EU. *International Journal of Sustainable Energy Planning and Management*, *15*, 3–10.

Deffains-Crapsky, C. (2016). Financer la transition énergétique par le crowdfunding : atouts et modalités de mise en oeuvre. In *XIII-ième conférence annuelle TEPP Evaluation des Politiques Publiques*.

Deloitte (2019). Services innovation projects.

Demil, B. & Lecocq, X. (2010). Business model evolution: In search of dynamic consistency. *Long Range Planning*, *43*(2), 227–246.

Duran, N. (2018). Les rôles des acteurs dans la formation et le développement du crowdlending : analyse des liens et échanges sociaux. *Innovations*, *56*(2), 141–160.

Easton, G. (2010). *One case study is enough*. Marketing Working Paper Series. The Department of Marketing.

EEA (2019). Country profiles - greenhouse gases and energy 2019.

Enevoldsen, P. & Sovacool, B. K. (2016). Examining the social acceptance of wind energy: Practical guidelines for onshore wind project development in france. *Renewable and Sustainable Energy Reviews*, *53*, 178–184.

European Commission (2020a). 2020 climate & energy package.

European Commission (2020b). 2030 climate & energy framework.

European Commission (2020c). 2050 long-term strategy.

Financement Participatif France (2017). Panorama des plateformes de crowdfunding en date du 01/11/2017.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245.

Fouquet, R. (2016). Historical energy transitions: Speed, prices and system transformation. *Energy Research & Social Science*, *22*, 7–12.

FPF (2019). Label croissance verte.

Frankfurt School-UNEP Centre, Bloomberg NEF (2019). *Global Trends in Renewable Energy Investment 2019*. Full report.

Gabriel, C.-A. & Kirkwood, J. (2016). Business models for model businesses: Lessons from renewable energy entrepreneurs in developing countries. *Energy Policy*, *95*(C), 336–349.

Gan, J. & Smith, C. (2011). Drivers for renewable energy: A comparison among oecd countries. *Biomass and Bioenergy*, *35*(11), 4497–4503.

Geng, J.-B. & Ji, Q. (2016). Technological innovation and renewable energy development: evidence based on patent counts. *International Journal of Global Environmental Issues*, *15*(3), 217–234.

Girard, C. & Deffains-Crapsky, C. (2016). Les mécanismes de gouvernance disciplinaires et cognitifs en equity crowdfunding : Le cas de la france. *Finance Contrôle Stratégie*.

GreenUnivers & FPF (2017). Baromètre 2016 du crowdfunding EnR.

GreenUnivers & FPF (2018). Baromètre 2017 du crowdfunding EnR.

GreenUnivers & FPF (2019). Baromètre 2018 du crowdfunding EnR.

GreenUnivers & FPF (2020). Baromètre 2019 du crowdfunding des EnR.

Hafner, S., Jones, A., Anger-Kraavi, A., & Pohl, J. (2020). Closing the green finance gap – a systems perspective. *Environmental Innovation and Societal Transitions*, *34*, 26–60.

Hainaut, H., Ledez, M., & Cochran, I. (2019). *Panorama des financements climat Edition 2019*.

Harder, K. & Friggens, S. (2015). Crowdfunding: Ready for the big league? In C. W. Donovan (Ed.), *Renewable Energy Finance: Powering the Future* (pp. 325–340). Imperial College Business School.

Hervé, F., Manthé, E., Sannajust, A., & Schwienbacher, A. (2019). Determinants of individual investment decisions in investment-based crowdfunding. *Journal of Business Finance & Accounting*, *46*(5-6), 762–783.

Hoegen, A., Steininger, D. M., & Veit, D. (2018). How do investors decide? an interdisciplinary review of decision-making in crowdfunding. *Electronic Markets*, *28*(3), 339–365.

Holt, D. & Smith, T. M. F. (1979). Post stratification. *Journal of the Royal Statistical Society. Series A (General)*, *142*(1), 33–46.

Hu, J., Harmsen, R., Crijns-Graus, W., & Worrell, E. (2018). Barriers to investment in utility-scale variable renewable electricity (vre) generation projects. *Renewable Energy*, *121*, 730–744.

Hörisch, J. (2015). Crowdfunding for environmental ventures: an empirical analysis of the influence of environmental orientation on the success of crowdfunding initiatives. *Journal of Cleaner Production*, *107*, 636–645.

IEA (2018). *CO2 Emissions from Fuel Combustion 2018 Highlights*.

IEA (2019). *CO2 Emissions from Fuel Combustion 2019 Highlights*.

IEA (2019). Sustainable development goal 7.

IEA (2020). *CO2 Emissions from Fuel Combustion: Overview*.

Insee (2017). Activité, emploi et chômage en 2016. Enquête emploi en continu - Insee Résultats.

IPCC (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. Technical Summary.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC (2018). *Global Warming of $+1.5°C$. Summary for Policymakers. An IPCC Special Report on the impacts of global warming of $+1.5°C$ above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

IRENA (2019). *Renewable Energy and Jobs – Annual Review 2019*.

IRENA, IEA, and REN21 (2018). *Renewable Energy Policies in a Time of Transition*.

Jobert, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: Factors of success identified in french and german case studies. *Energy Policy*, *35*(5), 2751–2760.

Josefy, M., Dean, T. J., Albert, L. S., & Fitza, M. A. (2017). The role of community in crowdfunding success: Evidence on cultural attributes in funding campaigns to "save the local theater". *Entrepreneurship Theory and Practice*, *41*(2), 161–182.

Kalimeris, P., Richardson, C., & Bithas, K. (2014). A meta-analysis investigation of the direction of the energy-gdp causal relationship: implications for the growth-degrowth dialogue. *Journal of Cleaner Production*, *67*, 1–13.

Kehrel, U. & Sick, N. (2015). Oil prices as a driving force in the diffusion of renewables? *International Journal of Energy Sector Management*, *9*(2), 227–250.

Kilinc-Ata, N. (2016). The evaluation of renewable energy policies across eu countries and us states: An econometric approach. *Energy for Sustainable Development*, *31*, 83–90.

Kim, J. & Park, K. (2016). Financial development and deployment of renewable energy technologies. *Energy Economics*, *59*, 238–250.

Knoefel, J., Sagebiel, J., Özgür Yildiz, Müller, J. R., & Rommel, J. (2018). A consumer perspective on corporate governance in the energy transition: Evidence from a discrete choice experiment in germany. *Energy Economics*, *75*, 440–448.

Kollmuss, A. & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260.

KPMG & FPF (2017). Baromètre du crowdfunding en france 2016.

KPMG & FPF (2018). Baromètre du crowdfunding en france 2017.

KPMG & FPF (2019). Baromètre du crowdfunding en france 2018.

Lam, P. T. & Law, A. O. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Lecocq, X., Demil, B., & Warnier, V. (2006). Le business model, un outil d'analyse stratégique. *L'Expansion Management Review*, *4*(123), 96–109.

Legifrance (2005). Loi n2005-781 du 13 juillet 2005 de programme fixant les orientations de la politique énergétique.

Legifrance (2009). Loi n2009-967 du 3 août 2009 de programmation relative à la mise en oeuvre du grenelle de l'environnement (1).

Legifrance (2010). Loi n2010-788 du 12 juillet 2010 portant engagement national pour l'environnement (1).

Legifrance (2016). Décret n2016-1453 du 28 octobre 2016 relatif aux titres et aux prêts proposés dans le cadre du financement participatif.

Li, D., Zhao, L., Ma, S., Shao, S., & Zhang, L. (2019). What influences an individual's pro-environmental behavior? a literature review. *Resources, Conservation and Recycling*, *146*, 28–34.

Lin, B. & Omoju, O. E. (2017). Focusing on the right targets: Economic factors driving non-hydro renewable energy transition. *Renewable Energy*, *113*, 52–63.

Lu, W.-C. (2017). Renewable energy, carbon emissions, and economic growth in 24 asian countries: evidence from panel cointegration analysis. *Environmental Science and Pollution Research*, *24*(33), 26006–26015.

López-Mosquera, N., Lera-López, F., & Sánchez, M. (2015). Key factors to explain recycling, car use and environmentally responsible purchase behaviors: A comparative perspective. *Resources, Conservation and Recycling*, *99*, 29–39.

Marques, A. C. & Fuinhas, J. A. (2011a). Do energy efficiency measures promote the use of renewable sources? *Environmental Science & Policy*, *14*(4), 471–481.

Marques, A. C. & Fuinhas, J. A. (2011b). Drivers promoting renewable energy: A dynamic panel approach. *Renewable and Sustainable Energy Reviews*, *15*(3), 1601–1608.

Marques, A. C. & Fuinhas, J. A. (2012). Are public policies towards renewables successful? evidence from european countries. *Renewable Energy*, *44*, 109–118.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2010). Motivations driving renewable energy in european countries: A panel data approach. *Energy Policy*, *38*(11), 6877–6885.

Marques, A. C., Fuinhas, J. A., & Manso, J. P. (2011). A quantile approach to identify factors promoting renewable energy in european countries. *Environmental and Resource Economics*, *49*(3), 351–366.

Martínez-Climent, C., Zorio-Grima, A., & Ribeiro-Soriano, D. (2018). Financial return crowdfunding: literature review and bibliometric analysis. *International Entrepreneurship and Management Journal*, *14*(3), 527–553.

Massa, L., Tucci, C. L., & Afuah, A. (2017). A critical assessment of business model research. *Academy of Management Annals*, *11*(1), 73–104.

Mazars & FPF (2020). *Baromètre annuel du crowdfunding en France 2019*.

Mazzucato, M. & Semieniuk, G. (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change*, *127*, 8–22.

McInerney, C. & Bunn, D. W. (2019). Expansion of the investor base for the energy transition. *Energy Policy*, *129*, 1240–1244.

Menz, F. C. & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796.

Mignon, I. & Bergek, A. (2016). System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. *Journal of Cleaner Production*, *128*, 105–115.

Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, *29*(1), 1–16.

Moussavou, J. & Branellec, G. (2018). La problématique du risque dans le financement de projets innovants : une analyse juridique et managériale du crowdfunding base sur le rendement financier. *Innovations*, *56*(2), 217–238.

MTES (2017). Loi de transition énergétique pour la croissance verte.

MTES (2019a). Adaptation de la france au changement climatique.

MTES (2019b). Le label greenfin.

MTES (2020a). Loi énergie-climat.

MTES (2020b). Programmations pluriannuelles de l'énergie (ppe).

MTES (2020c). Stratégie nationale bas-carbone (snbc).

Narbel, P. A. (2013). What is really behind the adoption of new renewable electricity generating technologies? *Energy for Sustainable Development*, *17*(4), 386–390.

National Park Service (2019). Joseph pulitzer—statue of liberty national monument new york.

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? a review of innovation system problems. *Renewable and Sustainable Energy Reviews*, *16*(6), 3836–3846.

NGFS (2019). *A call for action: Climate change as a source of financial risk*.

Nicolini, M. & Tavoni, M. (2017). Are renewable energy subsidies effective? evidence from europe. *Renewable and Sustainable Energy Reviews*, *74*, 412–423.

Nicolosi, E. & Corbett, J. B. (2018). Engagement with climate change and the environment: a review of the role of relationships to place. *Local Environment*, *23*(1), 77–99.

Nigam, N., Mbarek, S., & Benetti, C. (2018). Crowdfunding to finance eco-innovation: Case studies from leading renewable energy platforms. *Journal of Innovation Economics and Management*, *2*(26), 195–219.

Nyiwul, L. (2017). Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in sub-sahara africa. *Clean Technologies and Environmental Policy*, *19*(2), 437–450.

OECD (2017). *Mobilising financing for the transition*.

Okkonen, L. & Suhonen, N. (2010). Business models of heat entrepreneurship in finland. *Energy Policy*, *38*(7), 3443–3452.

Omri, A. & Nguyen, D. K. (2014). On the determinants of renewable energy consumption: International evidence. *Energy*, *72*, 554–560.

Onnée, S. & Renault, S. (2013). Le financement participatif: atouts, risques et conditions de succès. *Gestion Revue Internationale de Gestion*, *38*, 54–65.

OpinionWay for Qualit'EnR (2019). *Les Français et les énergies renouvelables Baromètre Vague 9*. Janvier 2019.

Osterwalder, A. (2004). *The Business Model Ontology: a proposition in a design science approach*. Ph.d. dissertation, Université de Lausanne, Ecole des Hautes Etudes Commerciales.

Osterwalder, A. & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons.

Osterwalder, A. & Pigneur, Y. (2011). *Business Model nouvelle génération - Un guide pour visionnaires, révolutionnaires et challengers*. Pearson.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2015). *Value Proposition Design*. Pearson.

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems*, *16*, 1–25.

Ostrom, E. (2012). Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? *Economic Theory*, *49*(2), 353–369.

Painuly, J. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, *24*(1), 73–89.

Perboli, G., Ferrero, F., Musso, S., & Vesco, A. (2018). Business models and tariff simulation in car-sharing services. *Transportation Research Part A: Policy and Practice*, *115*, 32–48.

Perea-Moreno, M.-A., Hernandez-Escobedo, Q., & Perea-Moreno, A.-J. (2018). Renewable energy in urban areas: Worldwide research trends. *Energies*, *11*(3).

Pfeiffer, B. & Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics*, *40*, 285–296.

Pickering, C. & Byrne, J. (2014). The benefits of publishing systematic quantitative literature reviews for phd candidates and other early-career researchers. *Higher Education Research & Development*, *33*(3), 534–548.

Pickering, C., Grignon, J., Steven, R., Guitart, D., & Byrne, J. (2015). Publishing not perishing: how research students transition from novice to knowledgeable using systematic quantitative literature reviews. *Studies in Higher Education*, *40*(10), 1756–1769.

Ponchel, T. & Bordier, C. (2017). Orienter l'épargne des ménages vers le financement des énergies renouvelables : quelle contribution du bonus au financement participatif ? *I4CE Point Climat number 48*.

Popp, D., Hascic, I., & Medhi, N. (2011). Technology and the diffusion of renewable energy. *Energy Economics*, *33*(4), 648–662.

Reboredo, J. C. (2015). Renewable energy contribution to the energy supply: Is there convergence across countries? *Renewable and Sustainable Energy Reviews*, *45*, 290–295.

REN21 (2018). *Renewables 2018 Global Status Report*.

REN21 (2019). *Renewables 2019 Global Status Report*.

Richter, M. (2013). Business model innovation for sustainable energy: German utilities and renewable energy. *Energy Policy*, *62*, 1226–1237.

Riebe, L., Girardi, A., & Whitsed, C. (2016). A systematic literature review of teamwork pedagogy in higher education. *Small Group Research*, *47*(6), 619–664.

Robano, V. (2018). Case study on crowdfunding. *OECD SME and Entrepreneurship Papers*, (4).

Rochet, J.-C. & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Rochet, J.-C. & Tirole, J. (2006). Two-sided markets: a progress report. *The RAND Journal of Economics*, *37*(3), 645–667.

Romano, A. & Scandurra, G. (2014). Investments in renewable energy sources in opec members: A dynamic panel approach. *Metodoloski Zvezki*, *11*(2), 93–106.

Romano, A. & Scandurra, G. (2016a). Divergences in the determinants of investments in renewable energy sources: hydroelectric vs. other renewable sources. *Journal of Applied Statistics*, *43*(13), 2363–2376.

Romano, A. A. & Scandurra, G. (2011). The investments in renewable energy sources: do low carbon economies better invest in green technologies? *International Journal of Energy Economics and Policy*, *1*(4), 107–115.

Romano, A. A. & Scandurra, G. (2016b). Investments in renewable energy sources in countries grouped by income level. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(10), 929–935.

Romano, A. A. & Scandurra, G. (2016c). "Nuclear" and "nonnuclear" countries: Divergences on

investment decisions in renewable energy sources. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(6), 518–525.

Romano, A. A., Scandurra, G., Carfora, A., & Fodor, M. (2017). Renewable investments: The impact of green policies in developing and developed countries. *Renewable and Sustainable Energy Reviews*, *68*, 738–747.

Rüdinger, A. (2019). *Participatory and citizen renewable energy projects in France - State of play and recommendations (in French)*. Study number 03/19.

Sadorsky, P. (2009a). Renewable energy consumption and income in emerging economies. *Energy Policy*, *37*(10), 4021–4028.

Sadorsky, P. (2009b). Renewable energy consumption, co2 emissions and oil prices in the g7 countries. *Energy Economics*, *31*(3), 456–462.

Salim, R. & Rafiq, S. (2012). Why do some emerging economies proactively accelerate the adoption of renewable energy? *Energy Economics*, *34*(4), 1051–1057.

Sannajust, A., Roux, F., & Chaibi, A. (2014). Crowdfunding in france: A new revolution? *Journal of Applied Business Research*, *30*, 1909–1918.

SAP (2017). Designing business models for the digital economy.

Sen, S. & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development – a discussion. *Renewable and Sustainable Energy Reviews*, *69*, 1170 – 1181.

Short, J. C., David J. Ketchen, J., McKenny, A. F., Allison, T. H., & Ireland, R. D. (2017). Research on crowdfunding: Reviewing the (very recent) past and celebrating the present. *Entrepreneurship Theory and Practice*, *41*(2), 149–160.

Sick, N., Golembiewski, B., & Leker, J. (2013). The influence of raw material prices on renewables diffusion. *Foresight*, *15*(6), 477–491.

Sovacool, B., Ryan, S., C Stern, P., Janda, K., Rochlin, G., Spreng, D., Pasqualetti, M., Wilhite, H., & Lutzenhiser, L. (2015). Integrating social science in energy research. *Energy Research & Social Science*, *6*, 95–99.

Suman, S. (2018). Hybrid nuclear-renewable energy systems: A review. *Journal of Cleaner Production*, *181*, 166 – 177.

Suna, D. & Resch, G. (2016). Is nuclear economical in comparison to renewables? *Energy Policy*, *98*, 199 – 209.

TCFD (2017). *Recommendations of the Task Force on Climate related Financial Disclosures*.

TCFD (2019). Task force on climate-related financial disclosures: Status report.

Tracfin (2016). Le crowdfunding et ses risques. *Annales des Mines - Réalités industrielles*, (1), 61–64.

UNFCCC (2019). The Paris Agreement.

UNFCCC (2020a). What do adaptation to climate change and climate resilience mean?

UNFCCC (2020b). What is the Kyoto Protocol?

Valdés Lucas, J. N., Escribano Francés, G., & San Martín González, E. (2016). Energy security and renewable energy deployment in the eu: Liaisons dangereuses or virtuous circle? *Renewable and Sustainable Energy Reviews*, *62*, 1032–1046.

Vasileiadou, E., Huijben, J., & Raven, R. (2016). Three is a crowd? exploring the potential of crowdfunding for renewable energy in the netherlands. *Journal of Cleaner Production*, *128*, 142–155.

Vieira, L. C., Serrao-Neumann, S., Howes, M., & Mackey, B. (2018). Unpacking components of sustainable and resilient urban food systems. *Journal of Cleaner Production*, *200*, 318–330.

Vismara, S. (2018). Information cascades among investors in equity crowdfunding. *Entrepreneurship Theory and Practice*, *42*(3), 467–497.

Wehinger, G. (2012). Bank deleveraging, the move from bank to market-based financing, and sme financing. *OECD Journal: Financial Market Trends*, (1), 65–79.

Wirtz, B. W., Pistoia, A., Ullrich, S., & Göttel, V. (2016). Business models: Origin, development and future research perspectives. *Long Range Planning*, *49*(1), 36–54.

WiseEuropa, NewClimate Institute, and I4CE (2019). *Domestic Landscape of Climate Finance. Why systemic approach to climate finance matters?*

Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach. Fifth Edition*, chapter 7. South-Western, Cengage Learning.

World Bank (2013). Crowdfunding's potential for the developing world.

Wu, L. & Broadstock, D. (2015). Does economic, financial and institutional development matter for renewable energy consumption? evidence from emerging economies. *International Journal of Economic Policy in Emerging Economies*, *8*, 20–39.

Yin, R. K. (1981). The case study crisis: Some answers. *Administrative Science Quarterly*, *26*(1), 58–65.

YouGov France for FPF and the MTES (2019). Enquête sur le financement participatif des énergies renouvelables.

YouGov France, FPF, and the MTES (2019). *Restitution de l'enquête sur le financement participatif des énergies renouvelables*.

Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected saarc countries: Progress towards green economy. *Renewable Energy*, *71*, 123–132.

Zhao, Y., Tang, K. K., & li Wang, L. (2013). Do renewable electricity policies promote renewable electricity generation? evidence from panel data. *Energy Policy*, *62*, 887–897.

Şener, S. C., Sharp, J., & Anctil, A. (2018). Factors impacting diverging paths of renewable energy: A review. *Renewable and Sustainable Energy Reviews*, *81*, 2335–2342.

List of Figures

Chapter 1

List of Tables