**Closing the green finance gap – a systems perspective**

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**Abstract**

Meeting its climate policy objectives requires the UK to rapidly decarbonise its energy sector. This demands high levels of investments into low carbon energy infrastructure, which are currently not undertaken at required scale, leading to a green finance gap. We explore (1) key investment barriers, (2) a theoretical framework for investigation and (3) possible solutions, drawing on a review of academic literature and policy reports, and interviews conducted with financial investors and experts. Our study confirms that policy uncertainty and short-termism in the financial system are the two main investment barriers. Our results show that identified barriers form a complex system characterised by path-dependency, lock-in and non-linearity. We recommend the adoption of systems theory as an analytical framework to inform the related policy debate and propose the expansion or development of sustainable investment vehicles as a useful near-term solution while preparing a long-term policy intervention based on a systems perspective.

**Keywords**: Energy transition; green finance gap; low-carbon investments; green investment barriers review; systems thinking; complexity

**Highlights:**

* Systematic literature review on green energy investments barriers
* Evaluation of 17 conducted interviews with financial investors, advisers or experts
* Green investment barriers are found to be interrelated and to form a complex system
* The application of a systems perspective as theoretical framework for successful long-term policy intervention is recommended
* A systems approach supports the exploitation of synergies, whilst avoiding adverse side effects

## Introduction

Almost every country in the world committed in the Paris Agreement to collectively hold “the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels” (UNFCCC, 2015, p.3). On a national level, the UK has committed to a reduction of at least 80% of emissions by 2050 against 1990 baseline within the Climate Change Act 2008” (e.g. UK Government, 2008; HM government, 2011). In June 2016, the UK confirmed this previously agreed target and set additionally a 57% interim-target for 2030 (CCC, 2016). More recently, the independent Committee on Climate Change (CCC) has recommended the UK adopt a net zero emissions target by 2050 (CCC, 2019).

The UK aims to generate 75% of the UK’s electricity from low-carbon sources by 2030 with a carbon intensity of under 100 gCO2/kWh (CCC, 2018). Figure 1 shows that in 2018, 42% of total electricity generated originated from gas (40%) and coal (2%). Therefore, the UK Government (2017) recommends a significant and rapid increase in the low-carbon electricity generation capacity in the coming years (see also HM Government, 2017). In particular, a scenario based on high electrification would require low-carbon generation to be more than quadrupled between now and 2050 (CCC, 2018). CCC (2018) expects an additional amount of 130 TWh low-carbon generation to be online in 2020, which implies installing an additional 130 to 145 TWh generating capacity of low-carbon infrastructure during the 2020’s to reach 255 – 275 TWh of low carbon generating capacity in total by 2030 (see CCC Scenarios, 2030).

Figure 1: Electricity generation in the third quarter2018

*Source: Data taken from Department for Business, Energy & Industrial Strategy (2018)*

Current projections of future UK greenhouse gas emissions show that the UK will not reach its climate target without the introduction of additional policies to restructure and decarbonise its economy (CCC, 2016). In particular, CCC (2018) reports that there is a policy gap of more than 20 Mt CO2 emissions corresponding to a gap of 45 to 65 TWh low carbon electricity generation out to 2030 (see also HM government, 2011; DECC, 2014). DECC (2014) estimated the required investments into low-emission energy infrastructure to be £100 bn (if transmission & generation are included) by 2020 and £130 bn by 2030. However, some organisations, including the Committee on Climate Change and Vivid Economics estimate the required investment to be higher and ranging up to £300 bn by 2030 (Vivid Economics, 2012; CCC, 2013). All these estimates imply that the required investments into low-carbon infrastructure in the next decades will need to be significantly higher than during the 2000’s (Blyth et al., 2015). Traditional sources of capital (e.g. project finance) will not be enough to cover the required energy infrastructure investments (Ernst & Young, 2010). Therefore, additional funding sources, such as finance from institutional investors (e.g. pension funds, insurance companies) or private investors (e.g. mainstream investors or high-net-worth individuals) are required to cover the green finance gap (OECD, 2016a; Irena, 2016). However, currently private and institutional investors are not investing sufficiently into green energy infrastructure due to lack of confidence given the technology risks, unstable policies, high up-front capital requirements of renewables, high capital costs for commercialization, lack of information, lack of experience and capacity gaps and high transaction costs etc. (Ernst & Young, 2010; Irena, 2016; OECD, 2016a; Jones, 2015).

The mobilization of further investments into green energy infrastructure requires the introduction of additional policies that tackle those investment barriers. However, although the literature on the requirement of policies to scale up green investments into the renewable energy infrastructure sector is growing rapidly, there is not yet an unambiguous conclusion on the importance of different barriers and solutions. This renders the determination of the most effective policy interventions or the prioritization of different possible interventions difficult. In light of this background, this study has three research objectives:

1. What are the key barriers towards more green investments into renewable energy infrastructure from the perspective of (financial) investors?
2. What theoretical framework conceptualises the green finance gap and would contribute to the elaboration of policy recommendations to close it?
3. What are possible policy interventions to scale-up investments into renewable energy infrastructure at sufficient scale and pace?

We approach the first research question by conducting a systematic academic literature review, by drawing on an evaluation of policy reports conducted by Hafner et al. (2019) and by analysing 17 conducted interviews with financial investors, advisers or experts in this area. We address the second and third research question based on the evaluation of the insights and findings of the first research question. We approach the search for possible policy interventions from a high-level perspective and we therefore do not aim to provide in-depth insights into the political negotiation of different policy priorities and trade-offs in this paper.

The key motivation for conducting this study is the urgent requirement to determine suitable solutions and (policy) interventions to scale up green investment into energy infrastructure at the required scale and speed in the UK (CCC, 2018; Bolton & Foxon, 2016). To focus the review of our study, we limit this study to (i) developed countries and (ii) to commercialised large-scale energy infrastructure. With regard to (i) we assume that the investment conditions from an investor perspective of developed countries are sufficiently comparable to the ones in the UK. With regard to (ii) we thus do not address the question on the potential further decentralisation of the UK energy infrastructure and the related barriers or solutions towards this and neither do we consider the question on how to scale-up finance into not yet commercialised energy technologies.

There are a number of already existing studies evaluating investment barriers into renewable energy infrastructure. On one hand, there are studies that conduct literature reviews on green barriers (e.g. Hu et al., 2018; Polzin, 2017). On the other hand, there are different types of empirical studies, including (i) surveys or interviews (e.g. Bolton & Foxon, 2015;[[1]](#footnote-1) Bolton et al., 2016; Geddes at al., 2018; Holbrun et al., 2010 Groot et al., 2013) and (ii) case studies (e.g. Byrnes et al., 2013). In addition, Chassot et al. (2014) undertake choice experiments with investors, Jones (2015) applies the Delphi method based on a couple of roundtables with investors and Masini & Menichetti (2012) construct an econometric model based on 93 questionnaires filled in by investors. However, our study combines a review of the academic literature with additional insights from policy reports and interviews with financial investors, their advisers or experts. Following our results on green investment barriers we suggest a systems/complexity perspective as a novel theoretical framework for the investigation of the green finance gap and the elaboration of systematic long-term solutions to close it. We argue that the analysis of the green finance gap through the lenses of systems thinking supports the elaboration of effective policies that avoid adverse side effects whilst exploiting potential co-benefits (e.g. Sterman, 2000). In addition, from a theoretical perspective, the application of a complexity framework opens up the discussion about a broader spectrum of policy instruments, such as market-shaping policies (e.g. Mazzucato, 2016; Mazzucato & Penna, 2016; Bolton & Foxon, 2015). Finally, we give an overview on possible solutions to tackle identified green investment barriers and propose the expansion of green bonds as a short-term solution given the urgency of a rapid green energy transition, thus complementing current literature.

The remainder of this article is organised as follows. Section 2 presents our methodology. Section 3 describes our results. The presentation of our main findings is followed in section 4 by a discussion of our results introducing a systems perspective as a theoretical framework to conceptualise the key investment barriers. Section 5 introduces a set of solutions to upscale green investments into energy infrastructure, and section 6 concludes and states future research recommendations.

## Methodology

There were three different methods used in this study.

### Policy reports

We use the results of Hafner et al. (2019) with regard to the green investment barriers reported in policy reports. This study investigated policy reports which focussed on informing policymakers about barriers towards more green investments into energy infrastructure. The policy reports were found by an internet search and by the use of the following set of keywords (see Hafner et al., 2019):

*(Investment OR invest OR finance) AND energy AND (renewable OR green OR “low-carbon” OR climate)*

Moreover, the following criteria for inclusion of policy reports have been applied (Hafner et al., 2019):

* Published since 2009
* Published by organisations in developed countries
* Include specific reference to barriers in large-scale clean energy infrastructure investment
* Published by multi-stakeholder groups, or an organisation, either public or private, that regularly consults multiple parties across the investment community

Overall, the identified sample of policy reports is representative for this type of literature and captures the current state of knowledge with regard to the barriers related to renewable energy infrastructure investments (Hafner et al., 2019).

In total, the study identified 11 themes and 35 code words (or phrases). Table 1 presents the themes and code words used. In addition, the key word “barrier” was used to consider barriers outside the main barrier topics (e.g. fiscal policy reforms). It is important to note, the results of this study might be biased based on the choice of barrier themes and the related code words as this is to some extent a subjective choice. This limitation would consequently also apply to this study.

Table 1: Themes and code words identified through the analysis of the practice policy reports in Hafner et al. (2019)

|  |  |  |
| --- | --- | --- |
| ***Nr.*** | ***Theme*** | ***Code words*** |
| 2 | Lack of a stable climate change policy frameworks and policy direction[[2]](#footnote-2) | Policy framework; Policy direction; Long term; Policy uncertainty; Stable regulatory framework; Policy stability; Certainty |
| 3 | Policies are in favour of 'brown' energy-infrastructure (e.g. fossil fuel subsidies[[3]](#footnote-3) or limited pricing of carbon emissions[[4]](#footnote-4)) | Fossil fuel subsidies; Carbon price; Perverse incentives; Distorted |
| 4 | Constraints on decision making within investor companies[[5]](#footnote-5) | Fiduciary duty; Trust; Investor perceptions; Awareness; Short term; Accounting; Solvency |
| 5 | Perceptions that returns of renewable infrastructure investments are too low and require high initial capital investment | Risk return |
| 6 | Requirement that projects need a certain credit rating so that it is possible to invest[[6]](#footnote-6) | Credit rating; Risk rating; Credit worthy |
| 7 | Technology-risk associated with uncertain technologies | Technology risk |
| 8 | Disclosure on climate related risks and integrating them into financial decision-making or a lack of standardised ESG-data[[7]](#footnote-7) | Climate disclosure; Standards; ESG; Benchmark |
| 9 | Limited projects with acceptable risk-return profiles or lack of liquidity in markets | Liquidity; Liquid market; Scale |
| 10 | Lack of suitable financial vehicles/financial instruments[[8]](#footnote-8) | Financial vehicle; Financial instruments |
| 11 | High transaction costs or fees[[9]](#footnote-9) | Transaction costs; High fees |
| 12 | Lack of knowledge/technical advice on green infrastructure investment[[10]](#footnote-10) | Technical advice; Technical knowledge |
| 15 | Other barriers | Barrier |

*Source: Hafner et al. (2019) – reprinted with permission*

In total, the study analysed 31 reports (see table 1a in the appendix or Hafner et al. (2019) for an overview of the reviewed policy reports).

### Academic literature

The second step in our methodology was a systematic review of the relevant academic literature. This builds on the earlier scoping review as presented in Hafner et al. (2019) but includes a further database of articles and snowball process as described here to ensure a systematic review of literature. For this review, we used a similar set of keywords as previously used for the google search of the policy reports combined with the code words identified. We searched articles in the databases Isi Web of Science and Scopus. The following set of key words was used to search these databases:

*(Investment OR invest OR finance) AND energy AND (renewable OR green OR “low-carbon” OR climate) AND ("one of the code words indicated in table 1")*

We only considered academic articles published since 2009. We downloaded the relevant information (i.e. information on author, title, year etc. and the abstract) of articles from these databases into excel spreadsheets. Subsequently, a first researcher determined all relevant academic articles for our study from the saved database. Thereby, we excluded all articles that were not relevant for our research question. That is, we excluded for example articles focusing on solar rooftop installation or barriers towards investment in renewable energy technologies pre-commercialisation. Subsequently, a second researcher conducted the same endeavour. All differences with regard to determined relevant articles have been discussed between the two researchers and one additional researcher working on this study. Subsequently a list with relevant academic articles for our studies has been determined.

The relevant characterised articles have been read again by the two researchers who identified green investment barriers in these studies and attributed them to a similar set of barrier topics as used for the policy reports (see table 1). That is, we used the same barrier topics as for the policy reports as a basis, but allowed additional barrier topics to emerge. Differences in classification of the indicated barriers in these articles have again been discussed between the two researchers and one additional researcher working on this study. Furthermore, we distinguish between different types of academic articles in our review. First, we classified articles as type i) academic articles when they investigate empirically different investment barriers topics as defined in this study, without pre-assuming the existence of one specific barrier prior to the application of the empirical method. Moreover, academic studies that conduct literature reviews or literature-based overviews on several green investment barriers are characterised as type ii) academic literature studies. Type iii) articles are studies, which investigate not more than two green investment barriers topics as defined in this study (either empirically or by using a qualitative research method). We are mainly interested in type i) or type ii) studies as they analyse several barriers at the same time and are therefore deemed to be more systematic for our purpose.

Finally, we conducted a snowball research based on the references of type i) and ii) studies in our database, adding additional relevant studies to our article database and identifying the barriers indicated in these studies. In order to keep our database manageable, we only added additional studies if they were of type i) or ii).

Overall, we found 3,357 articles from the Isi Web of Science database and 2,049 additional academic articles and studies from the Scopus database. After reviewing them, determining their relevance to our research question and performing a snowball search, we identified 42 type i) and ii) articles and 31 type iii) articles, thus 73 academic articles in total.

We identified three other important barriers in the academic literature that were not included in the policy documents, including the following: (1) Complex and long administration processes mainly due to electricity market regulations, (2) Attitudes of the public, resistance of society and (3) path-dependency or lock-in. The emergence of these additional topics might be related to the fact that academic literature often includes energy developers or energy firms as investors whereas policy-reports and interviews focused on financial investors.

We acknowledge that there is a need to understand the relevant barriers for the different types of investors as pointed out in earlier research (e.g. Wells et al., 2013; Mazzucato & Semieniuk, 2018), which is why our overview tables 4a, 5a and 6a indicate from which investor type perspective academic studies have been written. Moreover, for our research question the perspective of financial investors (e.g. institutional investors) are considered more relevant than the perspective of energy developers. This is because we are mainly interested on how to increase green investments from alternative financing sources, i.e. other than from energy firms, as this will be required for the scale and urgency of the green finance challenge related to a rapid energy transition in the UK or comparable countries. Therefore, reported results in section 3 refer only to those studies that investigated investment barriers from the perspective of financial investors. That is, we excluded in the result section the studies which report barriers only from the perspective of energy developers or other actors within the energy industry or when the investor type was not specified.

### Interviews

We collected primary qualitative data through in-depth semi-structured and structured interviews (Bryman, 2008). Our interviews were conducted with private investors, asset-owners and asset-managers, banks and pension funds representatives, actuaries and academic researchers with expertise in investment decisions. Conducting semi-structured interviews as a first step allowed us to explore key topics in the perceptions of the interviewed investors or investment experts in a more flexible way (e.g. Bryman, 2008). Once data saturation appeared to have been achieved through the semi-structured interviews a set of structured questions were developed and a further set of interviews conducted to explore specific issues in more detail. The questions for the semi-structured interviews are in the supplementary material (1) and questions asked within the structured interviews are in the supplementary material (2). In total, we performed 8 semi-structured and 9 structured interviews from December 2017 until December 2018. Listed interview participants in table 2a and table 3a in the appendix were found via personal contacts and a subsequent snow-ball sampling. In total 11 out of the 17 interviewees already had experience in investing in renewable energy infrastructure, which might bias their answers to some extent. Ethical approval from the department’s ethics research panel was obtained. Within the study conditions, the participants were guaranteed that their information would only be reported in anonymous format. Therefore, no participant’s names or affiliations are indicated in this study. The interviews were coded in a similar way as the academic literature.

Additionally, field notes were taken during the following round-table events and workshops: “Understanding risk in sustainable infrastructure investments” organized by the Aldersgate Group in October 2017, “Finexus conference” held at the University of Zurich in January 2018, “Financial Institutions, Business and Climate Change: Addressing Risks and Finding Opportunities in a Changing World” organised by the World Bank Group (Climate Change), Carbon pricing Leadership Coalition and the Swiss Confederation in January 2018 and finally the “Actuarial and accounting approaches to sustainable prosperity: a professional dialogue” held at the institute of Actuaries in London on behalf of the Observer Research Foundation in May, 2019. The insights gained during these round-tables and conference confirmed the insights gained from the literature review and the interviews. However, generally these conferences and workshops did not reveal any additional barriers compared to the identified set of barrier topics in the conducted interviews. Therefore, the data from these field notes were only used as a validation for our data from the conducted interviews.

## Results

* 1. *Results on key green investment barriers*

Table 2 presents an overview of the identified barriers and indicates how often each barrier topic (as defined in this paper) has been reported in the reviewed academic papers of type (i) and ii) from the perspective of financial investors, thus excluding energy firms (see column 1), in the policy reports (column 2) and in the conducted interviews (column 3). The additional barrier topics that emerge subsequently through academic literature are not displayed here and are accounted for in barrier topic “other barriers”.

Overview table 7a (in the appendix) presents the results in more detail for the academic studies and shows that the order of importance of the investments barriers does not change significantly when energy firms are included as investors. Further, tables 4a, 5a and 6a in the appendix show the identified barrier topics for each type of the reviewed academic articles. The academic articles presented in these tables are also classified according to their research method and the type of investor perspective (e.g. energy developers, institutional investor’s perspective etc.), the type of renewable energy and the geographical region considered by each of these relevant academic articles.

Table 2: Overview on the identified barrier topics. The number in the columns indicates the number of documents or interviews that included that theme. The number in parentheses indicates the order of ranks with regard to importance of each barrier topic.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Nr.*** | **Theme** | **Results policy-based literature** | **Results academic literature** | **Results interviews** |
| 2 | Lack of a stable climate change policy frameworks and policy direction | 8 (5) | 21 (1) | 16 (1) |
| 3 | Policies are in favour of 'brown' energy-infrastructure (e.g. fossil fuel subsidies; limited pricing of carbon emissions) | 8 (5) | 3 (8) | 3 (7) |
| 4 | Constraints on decision making within investor companies | 11 (2) | 17 (2) | 14 (2) |
| 5 | Perceptions that returns of renewable infrastructure investments are too low and require high initial capital investment | 4 (7) | 7 (4) | 10 (5) |
| 6 | Requirement that projects need a certain credit rating so that it is possible to invest | 6 (6) | 4 (7) | 2 (8) |
| 7 | Technology-risk associated with uncertain technologies | 11 (3) | 13 (3) | 6 (6) |
| 8 | Disclosure on climate related risks and integrating them into financial decision-making / Lack of standardised ESG-data | 10 (4) | 4 (7) | 11 (3) |
| 9 | Limited projects with acceptable risk-return profiles; lack of liquidity in markets | 14 (1) | 3 (8) | 11 (3) |
| 10 | Lack of suitable financial vehicles/financial instruments | 10 (4) | 3 (8) | 11 (3) |
| 11 | High transaction costs or fees | 10 (4) | 0 (9) | 0 (9) |
| 12 | Lack of knowledge/technical advice on green infrastructure investment | 1 (8) | 13 (3) | 9 (4) |
| 15 | Other barriers | 28 | 50 | 12 |

*Source: own elaboration and the keywords indicated in the second column are taken from Hafner et al. (2019)*

Both in the academic literature and in the interviews, barrier topic “lack of a long-term climate change policy framework and lack of stable policies” has been mentioned the most often, indicating that this is an important barrier deterring investors from investing in renewable energy infrastructure. In the policy reports instead, the “lack of appropriate projects or investment possibilities” has been indicated as the most important barrier towards more green investments. In all the different information sources, the barrier topic “constraints on decision making within investor companies”, which is related to the short-termism in the financial system has been reported as the second most important barrier. Furthermore, the academic literature and practice-based reports shows that the barrier topic “Lack of knowledge/technical advice on green infrastructure investment” is the third important the barrier topic from this literature. From the perspective of the interviewees the barrier topics “lack of suitable financial instruments”, “lack of liquidity in the markets” and “climate disclosure” are all the third most important barrier topics.

Importantly it is worth mentioning that the interviewees were asked to rank the different barrier topics according to their relative importance in comparison to all other investment barriers (see supplementary material (2)) and around half of them indicated that they were not sure on the order of importance concerning the barrier topics. This points towards the possibility that the different barriers are a system of interrelated barriers topics rather than single barrier topics considered in separation. We will describe this in more detail in the remainder of this paper.

## *3.2. Adding a novel theoretical framework to the discussion of the green finance gap: systems thinking and complexity*

We argue that the application of an appropriate theoretical framework for the analysis of the green finance gap is equally important as, or indeed a prerequisite for the elaboration and implementation of the increasingly urgently required policy interventions. f. This is because based on our conducted literature review and interviews we found that the use of systems theory as a novel theoretical framework for the investigation of the green finance gap might not only be helpful, but required, to inform the related policy debate in the UK and in country contexts.

Systems thinking (Arnold & Walde, 2015) is a way of thinking to understand how different components within systems or sub-systems influence one another over time. Solving a policy challenge based on systems thinking involves trying to understand the mechanism in the system(s) underlying the policy problem from a holistic perspective, thus taking for example potential desired and undesired consequences of potential solutions into consideration (Sterman, 2000; Forrester, 1993; Senge, 1990; Sweeney & Sterman, 2000). Additionally, a system approach is suitable for long-term and collaborative planning across areas of organizations (e.g. Kopainsky, Alessi, & Davidson, 2011).

In the following, we list key characteristics of complex systems and relate them to the identified green investment barriers by providing illustrative examples – in order to demonstrate how the green barriers can be conceptualised as a complex system, thus providing a rational for the application of a complexity or systems perspective to understand and solve the policy challenge under consideration.

A systems perspective is typically applied to solve problems caused by complex systems that are characterised by the following features (Sterman, 2000; Senge, 1990; Sweeney & Sterman, 2000):

1. **Two-way interconnections and interrelationships (on multiple levels) among system’s components**: The underlying system of a complex problem is a “whole” of various interlinked components or sub-systems which cause the overall observed behaviour or problem.

We introduce the following examples to illustrate this complexity feature in our case: first, different barriers are connected to each other. For example, the non-introduction of a carbon price at sufficient level and the introduction of fossil-fuel support policies (barrier topic 3) contributes to inconsistency in the long-term climate policy framework (barrier topic 2). Further, the climate policy framework (barrier topic 2) influences the structure of electricity regulations (barrier topic 1). Current financial regulations do not make it mandatory for investors to include climate related risks and ESG values (topic 4 & 8) in their investment decisions. This has implications on the availability of (i) standardised and high-quality data and metrics on these matters (topic 8), (ii) standardised empirical evidence on the performance of sustainable investments (topic 5) and (iii) credit ratings (topic 6). Further, standardised metrics on climate-related risks and ESG values (topic 8) lead to lower costs for the verification of green bonds and thus to lower fees and transaction costs for sustainable investment (topic 11). While none of our interview participants referred directly to a “system of interrelated green investment barriers” most of them agreed that different barriers would be connected and interrelated when asked and most of them refused to rank the relative importance of the indicated investment barriers. In addition, different studies refer to notions such as a “system of nested barriers” (Aldersgate Group, 2018; Bolton & Foxon, 2015[[11]](#footnote-11); Polzin et al., 2017; Granoff et al., 2016; Hall et al., 2017) or distinguish between fundamental and symptomatic barriers (Hu et al., 2018; Richards et al., 2012; Boie et al., 2014). Moreover, not only are green investment barriers interrelated, but so are major stakeholders that influence the relevant system and the implementation of viable solutions (CPI, 2016).

1. **Path-dependency and lock-in caused by multiple reinforcing and balancing feedback loops**: Complex systems are typically characterised by multiple interlinked positive and negative feedback loops, leading to path-dependency and lock-in.

For illustration, energy infrastructure lock-in arises due to the long-term nature of infrastructure in general. In particular, once “brown” infrastructure is built, it is typically costly or technically impossible to green it, which therefore creates a high danger of a sub-optimal long-term path-dependency. In addition, current supply chains, investment vehicles or electricity regulations, which are adapted towards the undertaking of brown investments reinforce this path-dependency (e.g. Granoff et al., 2016). Risk perceptions or perception in general, investment knowledge, herd behaviour related to investor practices, available data and metrics and cultural or personal values are other factors creating (soft) path-dependency (Bolton & Foxon, 2015; Savacool, 2009; Granoff et al., 2016; Hu et al., 2018; Polzin, 2017; Hampl & Wüstenhagen, 2013). Moreover, the institutional setting combined with vested interests, for example put forward by incumbent industries or (financial) investors with an expertise and investments in “brown” projects/assets, further leads to path-dependency and lock-in (Grandoff et al., 2016; Wüstenhagen & Menichetti; 2012).

1. **The system structure generates observed behavior:** Complex systems do not necessarily converge towards an optimal equilibrium. Instead, the underlying causal mechanisms of the entire system determine the state of the system which is also called the emergent or observed behaviour (Sterman, 2000).

Related to our context, Hall et al. (2017) illustrate why the understanding of investment decisions requires a new framework, comparable to the evolutionary framework for the analysis of the real economy as opposed to a neoclassical framework. Masini & Menichetti (2012; 2013), Salm (2017) and Folton & Boxon (2015) confirm the importance of behavioural impacts in investment decisions, including among others the personal attitude and expectation of investors, peer behaviour or the application of heuristics. This points towards the concept that agents are bounded rational and take decisions not only based on price-signals, which implies that (financial) markets do not necessarily converge towards an equilibrium, but are instead determined by the complex interactions of various bounded-rational agents (see Simon, 1957; Tversky & Kahneman, 1974).

1. **Non-linearity (e.g. due to threshold values, delays or sudden non-linear changes):** Complex systems are characterised by non-linearity of the overall system behaviour or individual components. In particular, non-linear and/or sudden changes of system’s components can trigger larger and seemingly random changes in the overall system due to the amplification of these changes by reinforcing feedback loops.

For illustration, professional investors have often a maximal amount of value-at-risk and if the risk related to certain investments is above this threshold value they will not invest at all. However, once the value of a specific investment project is below that value, they will consider investing in this project, which then leads to a non-linear change in financial flows. Various interviewees also pointed out that they would not consider investing in renewable energy infrastructure projects at all given the current unclear and changing energy and climate policy framework and direction of the UK. Consequently, once the UK or comparable countries convincingly implement a credible and coherent long-term policy framework, it will upscale green investments in a non-linear way. Finally, introducing various solutions (e.g. introduction of incentives towards long-term sustainable investments in the financial regulations) will suffer inevitable delays as first related metrics, methodologies, guidelines, investment skills and expertise need to be updated or elaborated accordingly, thus contributing to non-linearity.

1. **Dynamic behaviour**: In a complex system, components or sub-components change over time, and thus the system itself as well as the observed behaviour change over time. In addition, changes of system’s components can occur due to external triggers.

With regard to our case, one could think of various examples, including single investors changing their risk-perceptions or personal values (e.g. related to ESG values), or international pressure causing a change in the national investments incentives towards long-term sustainable investments.

1. **Transdisciplinary**: Complex systems generally include various sub-systems (e.g. technical, economic and social ones) and actors (e.g. retail investors, government, regulators etc.). This makes it necessary to investigate complex systems from a transdisciplinary perspective.

We have shown that various interrelated institutional, behavioral, cognitive, cultural or political barriers and barriers in the financial system or the electricity market system are deterring green investments (see also e.g. Grüning & Moslener, 2016; Hampl & Wüstenhagen, 2013; Wüstenhagen & Menichetti, 2012; Erickson et al., 2015; Groot et al., 2013; Polzin, 2017; Masini & Menichetti, 2012; 2013; Salm, 2017).

Figure 2 gives a simplified illustration of the complexity underlying the policy challenge to close the green finance gap. It goes beyond the scope of this study to determine the exact links between the different green investment barriers, the involved actors and institutions, and other relevant components. We recommend this as an important question for future research. For this reason, figure 2 does not display the accurate links between various investment barriers as illustrated under point 1 above. However, the arrows between the subsystems underlying the green finance challenge, namely the electricity market, financial market, the governance and institutional setting, and the labour market or the economy, indicate that there exist various two-way links between investment barriers across different subsystems (see figure 2). However, figure 2 does not display any links between investment barriers in the same subsystem although these likely exist. Moreover, we indicate some of interlinkages between the different stakeholders involved, however, neither the indicated stakeholders nor the indicated connections should be considered as complete (see e.g. CPI, 2016 for more information on interactions among stakeholders related to the green finance gap). Finally, the arrows between the “Green finance barrier space” and “Actor space” point out that these two components are interlinked as well (see CPI, 2016 and point 1 above).

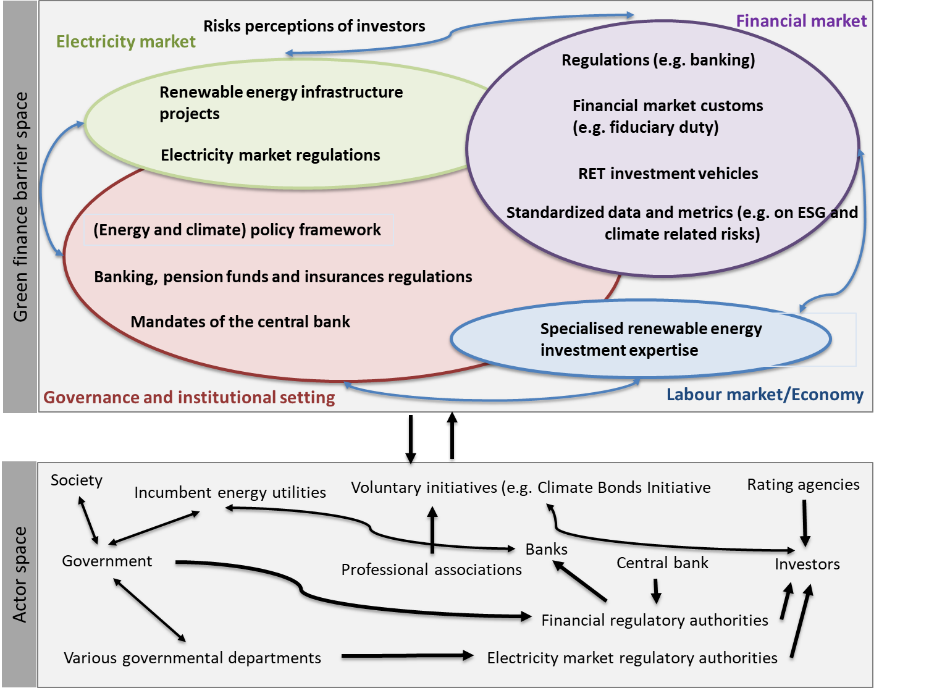


Figure 2: Simplified complexity of the green finance gap

The application of a systems approach can lead to insights and added value on different levels for policy assessment and intervention. Firstly, the application of a systems approach (combined with a conceptual or quantitative model) can support policymakers to understand better the underlying system of their policy objective(s) or challenge(s). This understanding of the underlying system, including its main mechanisms, supports the identification of “leverage points”[[12]](#footnote-12) for policy intervention and thus the implementation of more effective policies that address various barriers at the same time.

Secondly, a holistic approach, taking into account various policy objectives, contributes to avoid negative indirect policy consequences (e.g. on inequality, employment or ecosystems) and to exploit synergies by exploiting co-benefits of policies (e.g. increase in employment, increase in sustainable long-term investment in infrastructure, steering the entire economy towards a sustainable economy).

Finally, at the theoretical level, a framework based on complexity abstracts away from the assumption that economies converge towards an optimal equilibrium (in the long-term) and from the idea that agents are rational (Mankiw, 2013) and only act at the margin based upon price signals. In particular, an analytical underpinning based on complexity allows the consideration of dynamic non-marginal changes and processes, which involves various subsystems and interlinkages between them. These characteristics are, however, relevant for complex transitions, such as the decarbonisation of the UK energy system. The choice of theoretical framework is not only relevant from a theoretical perspective, but its choice has also important implications on the practical level.

As different theoretical frameworks represent the characteristics and (causal) linkages of a certain policy challenge in different ways, they typically recommend different policy instruments as solutions. That is, a theoretical underpinning based on neoclassical economics typically leads to the conclusion that price incentives (e.g. taxes) are the most effective policy response and abstracts away from the potential importance of, for example, market-shaping policies or systemic changes. In contrast, an investigation through the lense of a systems approach allows for the consideration of a more diverse set of policy instruments, including market-shaping policies, regulations or reporting standards. A diverse set of policy solutions or system’s changes is indeed required to scale-up green investments into renewable energy infrastructure at required scale and pace due to the complexity involved (e.g. Mazzucato, 2016; Mazzucato & Penna, 2016; Bolton & Foxon, 2015; Hall et al., 2017)[[13]](#footnote-13).

A policy process based on a systems approach is systematic and involves the following stages (based on Sterman, 2000):

1. **Determination of key policy objective(s):** the main policy objectives are determined (e.g. decarbonisation of the UK energy system).
2. **Articulation of the policy problem and identification of its underlying system:** the policy problem and its “relevant” underlying system is identified. The “relevant” system includes the main mechanisms causing the policy challenge. In our case, the policy problem is the lack of green investments into large-scale renewable energy infrastructure. The relevant system includes, to some extent, the financial system, the economy, the institutional settings and governance, and the electricity market.
3. **Information collection**: once the underlying system(s) is/are identified, information on these systems is collected. Information here refers to both quantitative and qualitative data from various information sources, including, but not limited to, databases, research studies or information received from experts or multi-stakeholder workshops (e .g. Howarth & Monasterolo, 2017). It might occur that once information is collected, the specification of the problem or the “relevant” systems needs to be refined, which would lead us back to step 2.
4. **Elaboration of a system framework or model**: as a fourth step, a conceptual or quantitative model or system framework is elaborated. One possibility to develop a model is via participatory modelling, involving the main stakeholders and relevant experts for the policy problem (e.g. Antunes et al., 2006; Videira et al., 2010).
5. **Policy analysis, evaluation and formulation**: based on that model and the understanding of the main determining feedback loops and mechanisms for the policy problem under consideration, effective policy solutions intervening at “leverage-points” are elaborated. Leverage-points are useful to trigger important feedback loops of the system under consideration and thus determining policies that tackle directly or indirectly several of the identified barriers. To illustrate this in our case, a change in the incentive mechanisms and investment practices in the financial system could lower the required investment benchmark returns and thus at the same time relatively increase the returns on infrastructure investments compared to benchmark returns. Step 5 includes further the assessment of potential synergies with other (cross-sectorial) policy objectives across departments. For example, Granoff et al. (2016) showed that various green investment barriers lead both to lower investment in green energy infrastructure investments as well as to lower infrastructure investments in general. Our interview results confirmed this finding (see also Bergsten et al., 2019). Importantly, unintended consequences should be assessed too. For example, green finance policies can have impacts on inequality. In particular, the UK energy policy has been designed as such to meet the demands of market-based finance (Bolton & Foxon, 2015). Hall et al. (2018) demonstrate the multi-billion mobilisation of energy finance can have significant justice impacts, with most of them not yet taken into account by the current literature on green finance. The same applies to impacts of low-carbon policy on inequalities (see Markkanen & Anger-Kraavi (2019) for an overview). If tested policies have unintended adverse impacts, it is suggested to go back to step (2) in order to better understand the policy challenge from a holistic perspective or to step (5) in order to elaborate new policies and to test it again by the elaborated model.
6. **Policy implementation**: this concerns the policy implementation itself.
7. **Policy review**: this step concerns the evaluation of the direct and indirect policy impacts and capturing the lessons learns. Depending on the policy review, the process is either finished or goes back to step 3) as the evaluation revealed that the policy caused unintended negative indirect policy impacts or was not impactful at all. The lessons learnt should also be exploited for future policy challenges.

Figure 3 visualizes the systematic policy process based on a complexity approach.

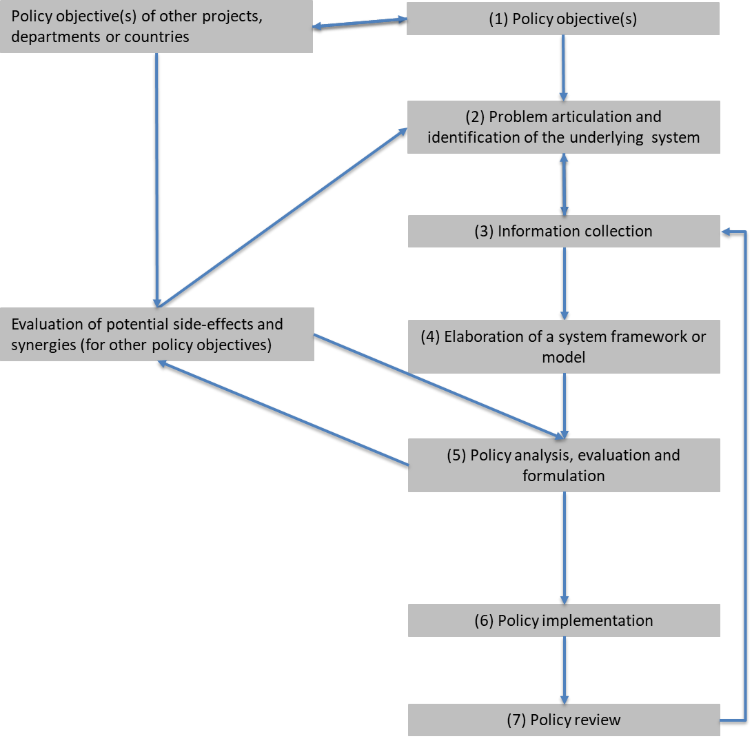


Figure 3: Systematic policy process based on a systems approach

*Source: own elaboration based on Sterman (2000)*

In a nutshell, a coherent and integrated mix of policy instruments based on a holistic systems perspective, which considers various policy objectives, helps to close not only the green finance gap, but likely also to steer the wider economy towards a “sustainable economy”. A systems approach can support the clarification of policy trade-offs and mitigating adverse policy side-impacts, which would endanger a rapid and smooth low-carbon transition. However, there is the danger that long-term planning can necessitate large and costly efforts in the short-term and/or postpone fast and partial policy-action in specific areas (EC, 2019). To mitigate this risk, we propose in the next section a policy response in the short-term to tackle the problem at least partially. Another general challenge of a systems approach is to balance a variety of trade-offs between policy objectives and diverting interests of various stakeholders (*ibid.;* Scherer et al., 2018). Multi-stakeholder discussion could be promoted to address this challenge (see e.g. Howarth & Monasterolo 2016).

We argue that national long-term policy planning based on a systems approach and the implementation of an integrated and coherent policy mix, ensuring environmental sustainability, economic production and social justice, is both overall beneficial as well as unavoidable in the long-term. The reason is that various policy objectives and policy (side-) impacts are strongly interrelated in the wider system (e.g. HM Government, 2005; EC, 2019) and our study showed that the green finance gap is by itself already a complex system.

## *Solutions to tackle green investments barriers*

While we point towards the importance of a systems approach for effective policy intervention in the medium- and long-term, we believe that a short-term policy response is as important in the background of the increasing pressure for rapid climate actions (e.g. Guardian, 2019; Forbes, 2019) or the recent UK ‘climate emergency’ declaration (BBC, 2019). Further, additional ‘brown’ energy infrastructure investments lead to an undesirable lock-in of a brown energy trajectory and thus contribute to postponing the urgently required green transition (e.g. Bolton & Foxon, 2015) and calling as well for near-term policy action to mitigate the risk of brown infrastructure lock-in. However, we emphasise that any short-term solution needs to be considered in a medium and long term perspective so as not to, in itself, lock in a policy direction that does not support a systems approach nor lead to postponement or avoidance of implementing an adequate medium- and long-term policy approach based on a systems approach

Table 3 summarises these solutions for each of our considered barrier topics drawing on current academic literature and policy reports. This overview ought to be helpful for our endeavour to propose immediate policy responses to close the green finance gap as well as for future research on solutions for this challenge within a systems approach. That is, while these solutions can be considered as a linear response to the barriers identified we argue that implementing any one of these solutions will not be enough to tackle this issue and that they must be taken holistically within a systems perspective in the medium and longer term. We particularly note that the implementation of the policies will likely need to be phased appropriately (for example a national infrastructure roadmap and strategy will need to developed prior to electricity market regulations that then support this strategy). However, the exact phasing of these policies is beyond the scope of this paper. The indicated solutions in table 3 should not be interpreted as comprehensive, however, we attempted to indicate the most direct and effective solutions for each barrier topic. The implementation of most solutions would additionally require amending current applied investment, accounting or evaluation metrics and frameworks in a standardised way. However, due to space reasons this is not indicated separately for each case in the table. For example, the introduction of sustainable investment regulations would require the collection of necessary data as well as the elaboration of appropriate metrics and measurement criteria in addition (Kay, 2012; OECD, 2017). Also, while the role of professional associations for investors, banking, insurances, pension funds or accounting is indicated where this role is deemed to be most relevant, these bodies can play a relevant role in the implementation of all proposed solutions (e.g. via lobbying, provision of tailored information briefs etc.).

Table 3: A set of possible solutions for each barrier topic

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic Nr.** | **Possible solutions** | **Enforcement body** | **Selected references for further information** |
| 1 | * Transparent, clear, consistent and long-term (i.e. in line with infrastructure investment timelines) electricity market regulations | Gas and Electricity Markets Authority (GEMA) | **Electricity market regulations:**   * Lüthi & Prässler (2011); Polzin et al. (2015); Ländner et al. (2019) |
| 2 | * Development and establishment of a transparent, clear, consistent and long-term (i.e. in line with infrastructure investment timelines) policy framework, direction and vision * Establish a national infrastructure strategy and road map with project pipeline. This strategy should indicate timing, capacity needs, the location for new assets, the duration and level of support policies and technology specific considerations[[14]](#footnote-14) * Conduct public opinion campaigning, lobbying and coalition building | Amendment of the policy framework: UK Government and relevant sub-departments (e.g. Department for Business, Energy & Industrial Strategy)  Information provision to society and other stakeholders: educational charities, NGO’s or Schools/Universities (e.g. Curriculum amendments) | **Consistent long-term policy framework and direction:**   * Hamilton (2009); IIGCC et al. (2011); OECD (2012; 2015; 2017); House of Commons (2016); Lüthi & Wüstenhagen (2012); Jones (2012; 2015); Vogt-Schilb & Halegatte (2017); Bellantuono (2017) |
| 3 | * Removal of incentives for the production or use of fossil fuels or gas (e.g. in form of tax breaks; reduced VAT rates on electricity and gas) * Pricing of carbon emission via a carbon tax or a cap-and-trade system and thus integrating the social costs of carbon emissions and correcting for the market failure of the otherwise unpriced negative externalities of carbon emissions | UK Government and relevant sub-departments | **Removal of ‘perverse’ incentives**:   * Kaminker et al. (2013); Rentschler & Bazilian (2017); Hoffert (2010); Monasterolo & Raberto (2019)   **Carbon pricing:**   * Bowen (2011); Ellerman & Buchner (2008); Weitzman (2014); Nordhaus (2013); Stiglitz et al. (2017 |
| 4 | * Amendments of insurance, pension funds and banking regulations[[15]](#footnote-15) (e.g. Introduction of prudential requirements in favour of green infrastructure investments, correction disincentives in the investment chain towards short-termism) * Application of a wider (internationally harmonised) definition of ‘fiduciary duty’[[16]](#footnote-16). In particular, include in this definition the duty to consider ESG values, climate related (long-term) risks and long-term returns of principals * Realignment of reward incentives in the financial industry by better relating remuneration to long-term sustainable performance of investments and change current investor practices towards sustainable long-term investment practices * Issuance of more Green bonds[[17]](#footnote-17) or other (new) sustainable investment vehicles * Direct investments, issuance of green loans or introduction of other de-risking policies by the government or Investment Banks * Green quantitative easing | Changes in regulations and the definition of fiduciary duty:   * Pension funds: UK government, Pensions Regulator and Financial conduct Authority (FCA), relevant international bodies * Insurance: UK government, Prudential Regulation Authority (PRA), FCA and relevant international bodies * Accounting: Regulatory authorities and supervision for Accounting (IASB) * Banks: UK government (Treasury), PRA, FCA, Bank of England (BoE), European Banking Authority, international bodies, IMF   Changes in investment practice on voluntarily basis: Professional associations, Investors and financial intermediaries (e.g. asset managers)  Issuance of green bonds: UK government, (commercial) banks, BoE; Energy utility sector, Financial sector and other corporates, investment banks (e.g. EIB)  Introduction of green loans, re-risking policies or co-investments: UK Government, Green Investment Banks  Quantitative easing: BoE | **Changes in the pension funds and insurances regulations, the application of a wider definition of fiduciary duty and changes in remuneration incentives in the financial system**:   * UNEP FI (2005); Kay (2012); UNPRI (2015); Sullivan (2015); Louche et al. (2019); Pfeifer & Sullivan (2008)   **Shareholder engagement**:   * Louche et al. (2019); Goodman et al. (2014)   **Banking and macro-prudential regulations:**   * D’Orazio & Popoyan (2019) & Campiglio (2016); Van Lerven & Ryan-Collins (2018); Campiglio et al. (2017); Alexander (2014)   **Green bonds and new financial vehicles:**   * Climate Bonds Initiative (CBI) (2018); Reichelt (2010); Della Croce & Yermo (2013); Ehlers & Packer (2017); Berensmann et al. (2018); Lee & Zhong (2015); OECD (2017); McInerney & Bunn (2019); Agliardi & Agliardi (2019); Barua & Chiesa (2019)   **Role of the Government:**   * Jones (2012); Aglietta & Espagne (2016)   **Roles of Green Investment banks**   * Geddes et al. (2018); McInerney & Bunn (2019)   **Green quantitative easing:**   * Matikainen et al. (2017); Dafermos et al. (2018); Campiglio et al. (2017) |
| 5 | * More high-quality and standardised (and thus comparable) evidence and disclosure on the actual returns or defaults and other risks of RET investments in order to make a robust, quantitative case for investors and rating agencies * Provision of standardised sustainable indexes for asset managers to invest against * Direct government interventions: (i) de-risking of RET investment (incl. de-risking of technology risk, development risk and pricing risk) via government guarantees[[18]](#footnote-18), provision of insurances against potential risk losses or low-interest loans; (ii) the UK Governments could directly leverage increased private capital inflow by providing seed capital or concessional finance for large investment structures such as public-private partnership fund structures | Information provision:  Professional associations, various initiatives (e.g. CBI)  Provision of sustainable benchmarks for asset managers to invest against: index providers, credit rating agencies, various voluntary initiatives (e.g. CBI)  De-risking intervention or other policy intervention: UK Government, Green Investment bank or European Central | **Sustainable indexes:**   * López et al. (2007); Escrig-Olmedo et al. (2010); Berry & Junkus (2010); Pagano et al. (2018); Rezec & Scholtens (2017 * Example: The S&P 500 ESG Index aligns investment objectives with ESG values   **De-risking and direct investments by the UK government or Green investment banks:**   * Jones (2012); Geddes et al. (2018); Steckel & Jakob (2018) |
| 6 | * As more data becomes available it should be possible to attribute ratings to all RET * Investment grade policy in general will help to improve the rating of RET investments | UK Government; Green Investment Banks | **Investment grade policy:**   * Hamilton (2009); Jones (2012) |
| 7 | * Training of skilled RET advisors for investors * As more data becomes available on RET technology, this barrier will also be reduced (risks will be better known) | Independent institutions / UK government |  |
| 8 | * Strengthen the implementation standardised metrics on climate related risks, ESG values and other metrics which can be used for financial decision making and that help investors to align their investments with the two degree target[[19]](#footnote-19) * Tracking of brown investments[[20]](#footnote-20) * Amendments in regulations of Pension funds, insurances and banks as such that they obligated to consider (long-term) climate change risks in investment decision making and/or establish green finance requirements and frameworks for investing and lending * Sustainability disclosure criteria in listing requirements on stock exchanges * Credit rating agencies should continue to account for climate related risks in their ratings and adjust their rating methodologies if required * Central banks should legislate and measure financial stability[[21]](#footnote-21). In particular, they should assess financial effects of climate related risks on the financial system and ensure financial systems stability. This also involves coordination among central banks and authorities and to track financial flows globally * Lobbying and production of research, guides and policy papers that assist investors and financial intermediaries (voluntarily) consider climate change risks and ESG values in investing, and to conduct investment in line with the two-degree initiative | Voluntary Green/Brown Disclosure Standards: Voluntary initiatives (e.g. two-degrees investing initiative, CPI, Carbon Disclosure Project (CDP[[22]](#footnote-22)), Global Reporting initiative[[23]](#footnote-23), [Network for Greening the Financial System](https://www.banque-france.fr/en/financial-stability/international-role/network-greening-financial-system) (NGFS) etc.), European Commission as funding provider (see also the European Technical Expert Group on Sustainable Finance)  Mandatory Green/Brown Disclosure Standards: this would require changes in regulation, see topic 4.  Disclosure rules on stock exchanges: Market exchanges responsible for listing rules and information disclosure rules  Amendment in rating methodology: Credit rating agencies  Introduction of mandatory climate stress testing: Government, central banks, the European Systemic Risk Board (ESRB) advisory scientific committee, international financial stability board (FSB); Bank for international Settlement (BIS)  Lobbying and production of information helpful for the voluntarily inclusion of ESG criteria: professional associations of investors, banking sector, auditors and actuaries; NGO or other research institutes | **Standardised climate-Related Financial Disclosure[[24]](#footnote-24):**   * Financial Stability Board (FSB) (2015); Task Force on Climate-Related Financial Disclosures (TCFD) (2017; 2018)[[25]](#footnote-25); two-degrees investing initiative (2019); Millar et al. (2018)   **Standardised data and metrics on ESG values or indexes:**   * Thomä & Chenet (2017); Meltzer (2016); two-degrees investing initiative (2019); Cubas‐Díaz & Martínez Sedano (2018); Fifka & Drabble (2012) * Example: The S&P 500 ESG Index aligns investment objectives with ESG values[[26]](#footnote-26) or see also S&P Global Clean Energy Index.   **Standardised data and metrics on brown investments:**   * Bodnar et al. (2017); Robins (2018)   **Systemic risks of stranded carbon assets on the financial system:**   * Battiston et al. (2017); Battiston & Martinez-Jaramillo (2018); Volg (2017); Monasterolo et al. (2017); Smets et al. (2014); Carney (2015; 2019) |
| 9 | * Creation and support of facilities focused on improving the “bankability” of projects through preparation and selection and support initiatives * Facilitation of the partnership between the various actors along the project finance chain, thus also improving the transparency of bankable infrastructure projects * Creation of financial products (for renewable energy infrastructure) that are appropriate for institutional investors | Coordination: UK Government or government-linked institutions, new facilities designed for coordination  See above (green bonds) | **Support of a transparency and coordination of bankable projects:**   * Bielenberg et al. (2016)**;** Kaminker et al. (2013)   See above (green bonds) |
| 10 | * Creation of appropriate financial products for RET infrastructure investments (e.g. further issuance of green bonds; establishment of new instruments) | See above (green bonds) | See above (green bonds) |
| 11 | * Reduction of fees and transactions costs for RET infrastructure investments (e.g. by a further standardisation of contracts, further aggregation and knowledge-sharing) | Financial system intermediaries | OECD (2017) |
| 12 | * Government funded training for technical advisors/consultants for RET infrastructure investments * Mandatory training units in sustainable investments for CFA curriculum | Green technical training: UK Government, Chartered Financial Analysts) CFA institute |  |
| 13 | * Public opinion campaigning. In particular, provision of education and information on climate change implications and benefits of RET technology * Assurance that potential additional costs of RET infrastructure are shared in a fair way across the society and that adverse indirect policy impacts are mitigated (if not avoidable) * Assessing and minimisation of RET infrastructure impact on ecological biodiversity (e.g. destruction of ecosystems by wind mills) * Increase the sustainability of the supply chain of RET technology sustainable (e.g. production of material, transport of imported production inputs/products). If necessary, funding into research of new possibilities should be increased | UK Government, educational institutions or NGO’s |  |
| 14 | * Market shaping policies and avoidance of incentives for fossil fuel investments (e.g. tax rebates) * Changes in banking, insurance and pension regulations * All of the above mentioned solutions in a combination | UK Government, Green Investment bank, BoE and all other relevant regulatory authorities involved | **Market-shaping policies:**   * Mazzucato (2016); Mazzucato & Penna (2016) |
| 15 | * All of the above mentioned solutions | All of the above | All of the above |

Legend:

Nr 1. = ‘Complex and long administration processes mainly due to electricity market regulations ‘,

Nr. 2 = ‘Lack of a stable climate change policy frameworks and policy direction’,

Nr. 3 = ‘Policies are in favour of 'brown' energy-‘,

Nr. 4 = ‘Constraints on decision making within investor companies’,

Nr. 5 = ‘Perceptions that returns of renewable infrastructure investments are too low and require high initial capital investment’,

Nr. 6 = ‘Requirement that projects need a certain credit rating so that it is possible to invest’,

Nr. 7 = ‘Technology-risk associated with uncertain technologies’,

Nr. 8 = ‘Disclosure on climate related risks and integrating them into financial decision-making / Lack of standardised ESG-data’,

Nr. 9 = ‘Limited projects with acceptable risk-return profiles; lack of liquidity in markets’,

Nr. 10 = ‘Lack of suitable financial vehicles/financial instruments’,

Nr. 11 = ‘High transaction costs or fees’,

Nr. 12 = ‘Lack of knowledge/technical advice on green infrastructure investment’,

Nr. 13 = ‘Attitudes of the public, resistance of society’,

Nr. 14 = ‘Path-dependency or lock-in’ and

Nr. 15 = ‘Other barriers’

With regard to the call for an immediate policy response, we propose the increased issuance of green bonds (or the development of other, equity-based, investment vehicles) for renewable energy projects (e.g. CPI, 2016; 2017) as a promising near-term solution (see also OECD, 2017; McInerney & Bunn, 2019; Chiesa & Barua, 2019; Agliardi & Agliardi, 2019)[[27]](#footnote-27). However, while our suggestion is based on the considerations introduced next, we underline that additional research is required to investigate alternatives and potential adverse impacts of this solution.

We consider the increased issuance of green bonds as a relevant short-term solution as it addresses (at least to some extent) various barriers topics, including the most important barriers, at the same time. In addition, the issuance of green bonds does not imply that the government needs to introduce further financial incentives, which would add to the direct cost of a green energy transition. Finally, it seems realistic that an increase in the issuance of green bonds, or other green investment vehicles, can actually be implemented in a relatively short time horizon. This is because this solution is compatible with the current investment culture and does not require any major regulatory changes.

In the following, we describe how green bonds contribute to solve the most important green investment barrier topics. However, this description holds for other green investment vehicles, to a large extent, as well. Firstly, an expansion in the issuance of green bonds does not directly tackle the lack of a consistent and long-term policy framework and the perceived risks of investors related to the lack of a clear policy direction. However, investors might nevertheless consider investing in green bonds as they can sell these bonds if they wish (given there is enough liquidity in the bonds market) as opposed to investments in energy infrastructure directly. Secondly, the introduction of green bonds does not directly tackle the barriers related to short-terminism in the financial system neither. However, green bonds seem nevertheless a promising instrument from this perspective if structured accordingly to investors’ (short-term) risk-return preferences or combined with governmental tax-based incentives as bonds are already familiar to investors[[28]](#footnote-28), including to institutional investors who are already dominant players in traded equity and bond markets[[29]](#footnote-29) (CPI, 2016; 2017; Granoff et al., 2016; Blyth et al., 2015). In addition, the improved availability of green bonds, or other green financial vehicles, increases liquidity in the market as investors can sell their bonds or shares when they wish to do so (Meltzer, 2016; CPI, 2016). This is required in the case of institutional investors as they are regulated through mandates that restrict investments into (renewable energy) infrastructure or long-term investments in general. Further, pension funds typically apply asset-liability management and insurance companies have ongoing payment obligations to policyholders, making it mandatory for them to invest, to a large extent, in liquid assets, such as for example green bonds. Financial vehicles also help to address the lack of bankable projects and pipelines as they can aggregate several energy projects and thus make them attractive to the preferences of institutional or other private investors (see Mielke, 2019).

Overall, CBI (2018) estimates that the issuance of green bonds could access up to USD 100 tn of patient private capital managed by global institutional fixed-income investors. However, a currently existing barrier towards the long-term growth of green bonds is the lack of a set of standardised metrics (defining “green”) and mandatory standards for green bonds issuers (OECD, 2017; Bloomberg, 2017). This barrier could be addressed by a standardisation of mandatory requirements by government involvement and collective action taken by the G20 (Meltzer, 2016; OECD, 2017). This agreement would in addition decrease the cost of green bonds verification (OECD, 2017) as well as support the further expansion of other policies over time.

It is important to consider that ultimately, when a majority of barriers, including, but not limited to, perceptions of high renewable technology risks, lack of appropriate investor advice, high short-term benchmark returns or payback periods, short-term investment practices, non-inclusion of climate-related risks and ESG values in investment decisions or an inconsistent policy framework, still exist and are not addressed directly, required returns of green bonds, or of other green investment vehicles, will be higher as compared to a situation where several solutions address a majority of barriers directly. CCC (2015) states that the cost of renewable generation options are sensitive to the required return of investment. If required returns would be 1 % lower by 2020, procured low-carbon projects would save around £ 1 bn per year from 2020 until 2030 (CCC, 2015). This is another important reason why we argue in the longer-term for the adoption of a systems perspective for the investigation of what combinations of solutions would be the most effective to solve this policy challenge in a holistic way; rather than increase in the issuance of green bonds as a single long-term policy solution.

**4. Conclusions**

Drawing on our findings from an evaluation of key policy reports presented in Hafner et al. (2019), a systematic academic literature review and 17 interviews with financial investors, advisors or acknowledged experts in this area, our study has the following two main findings.

Firstly, our study shows that the identified green investment barriers form a complex system of interrelated barriers which is characterised by path-dependency, lock-in, delays and non-linearity, deterring the green finance gap from closing. The different investment barriers originate from multiple interrelated subsystems, including but not limited to the electricity market, the institutional settings or financial markets, which adds complexity. Based on this first finding, we recommend the adoption of a systems approach as analytical framework for the investigation of this policy challenge and in particular for the identification of key leverage-points for a more effective policy intervention in the longer term. In the background of the urgency to mitigate the considered policy challenge, we suggest the implementation of a near-term solution while preparing an effective and systematic long-term intervention based on a systems approach. A systems approach would further support policymakers to better understand linkages with other (cross-sectorial) policy objectives, and thus to consider in a systematic way potential adverse indirect impacts or co-benefits of policies. Finally, from a theoretical perspective, we argue that the adoption of a systems or complexity perspective as analytical underpinning would allow the consideration of dynamic non-marginal and non-linear changes and policy instruments beyond price incentives, such as changes in regulations or market-shaping policy approaches in general. This will be required to scale-up investments into renewable energy infrastructure at necessary scale and pace.

Secondly, we identify policy uncertainty and short-termism in the financial system as the two most important green investment barriers. We propose the development or expansion of mature, yet innovative green financing mechanisms (e.g. green bonds) as an effective solution to increase green finance, to some extent, in the near-term. This solution would address or circumvent the most important identified green investment barriers. In addition, this approach would not require the government to introduce further financial incentives which would add to the financial costs of a green transition. However, we underline that this response will not in itself be sufficient to tackle the green finance gap.

A general challenge of the adoption of a systems approach is balancing different trade-offs between (cross-sectorial) policy objectives and diverting interests of various stakeholders. Therefore, careful planning, efficient communication and multi-level (regional-national) coordination between government departments and other (international) actors, including the wider society, will be required for policy implementation based on a systems approach. We suggest further research to investigate what tools and institutional settings would support systematic planning and goal-oriented multi-stakeholder engagement, at all stages of policymaking.

Finally, our study does not investigate how different green investment barriers are interlinked exactly, how and what policy interventions based on a systems perspective should be applied and how much finance would flow into renewable energy infrastructure when different ‘linear’ solutions or systematic policy interventions would be introduced. Therefore, future research should clarify the underlying complexity of the green finance gap for different types of investors (e.g. pension funds, insurances, sovereign wealth funds). This could be achieved for example by conducting multi-stakeholder participatory (conceptual) systems modelling building sessions. We also recommend future research to investigate in more detail potential undesired and desired side effects of systematic policy intervention to close the green finance gap.

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## Conflicts of Interest

The authors declare no conflict of interest.

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**Appendix**

Table 1a: Overview on reviewed policy reports in Hafner et al. (2019)

|  |  |  |
| --- | --- | --- |
| **Author/Organisation** | **Year of publication** | **Title** |
| Aldersgate Group | 2018 | Towards the new normal: How to increase investments in the UK’s green infrastructure? |
| British Banking Association | 2015 | Financing the UK's infrastructure needs |
| Climate Policy Initiative | 2013 | The challenge of Institutional Investment in Renewable Energy |
| E3G | 2016 | A Sustainable Finance Plan for the European Union |
| EU High Level Expert Group On Sustainable Finance | 2018 | Financing a Sustainable European Economy |
| European Commission | 2017 | Financing Sustainability. Triggering Investments for the Clean Economy |
| EY | 2016 | Climate change. The investment perspective |
| G20 | 2016 | G20 Green Finance Synthesis Report |
| Green Finance Initiative | 2017a | The Renewable Energy Infrastructure Investment Opportunity for UK Pension Funds |
| 2017b | Fifteen Steps to Green Finance |
| Green Finance Taskforce | 2018 | Accelerating Green Finance |
| Green Investment Bank Commission | 2010 | Unlocking investment to deliver Britain's low carbon future |
| GREEN-WIN | 2017 | Financing the Low-Carbon Transition: Current Landscape and Future Direction |
| IFC | 2013 | Mobilizing Public and Private Funds for Inclusive Green Growth Investment in Developing Countries |
| IIGCC, INCR, IGCC and UNEP-FI | 2011 | Investment-grade climate change policy: financing the transition to the low-carbon economy |
| Institutional Investors Group on Climate Change | 2015 | Achieving the Investment Plan for Europe's £315 billion ambition: 12 fixes |
| International Centre for Trade and Sustainable Development | 2015 | Breaking down the barriers to clean energy trade and investment |
| International Energy Agency | 2007 | Climate Policy Uncertainty and Investment Risk |
| IRENA | 2016 | Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance |
| Mercer | 2015 | Investing in a time of climate change |
| Organisation for Economic Co-operation and Development (OECD) | 2011 | The Role of Pension Funds in Financing Green Growth Initiatives |
| 2012 | Towards a Green Investment Policy Framework: The Case of Low-Carbon, Climate-Resilient Infrastructure |
| 2013 | Long-term investors and green infrastructure |
| 2013 | Institutional Investors and Green Infrastructure Investments |
| 2014 | Public Financial Institutions and the Low-carbon Transitions: Five Case Studies on Low-carbon infrastructure and project investment |
| 2015b | Mobilising private investment in clean-energy infrastructure |
| 2015c | Overcoming Barriers to International Investment in Clean Energy |
| 2016b | Progress Report on Approaches to Mobilising Institutional Investment for Green Infrastructure |
| UNEP | 2015 | The financial System We Need: Aligning Financial System with Sustainable development |
| Vivid Economics | 2014 | Financing Green Growth |
| World Bank | 2012 | Green Infrastructure Finance |

*Source: Hafner et al. (2019) – reprinted with permission*

Table 2a: Interview Sample (semi-structured interviews)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nr.** | **Type of institution** | **Function** | **Information related to** | **Main experience** | **Date** |
| **1** | Private investor  organisation | Private investor | Retail investors | Advisor and actuary in the area of Life and general insurances and pensions | Oct 17 |
| **2** | Private investor organisation | Private Investor | Retail investors | Private investment, career in a FTSE100 company, trustee director of a corporate pension fund for 15 years | Nov 17 |
| **3** | Private investor | Private investor | Retail investors | Consultant & managing director of different companies | Nov 17 |
| **4** | Bank | Global asset management | Banks, pension funds | Portfolio management, global assets management, pension scheme management and financial markets, asset class expertise includes credit, equity and infrastructure as well as commodities alongside practical understanding of the associated derivative markets. | Nov 17 |
| **5** | Responsible investment advisory firm & research institution | Co-Founder and Director, advisor & senior Research fellow | Institutional investors, retail investors | Asset management, responsible investment, expertise in investment implications of climate change and energy issues. extensive experience in working as a consultant & adviser on environmental finance, regulation and policy issues for various international bodies such as EBRD, OECD, World Economic Forum, UNEP and UNDP. | Nov 17 |
| **6** | Private Policy Think Thank | Associate fellow | Private investors | Operates at the nexus of policy and finance, works on ‘investment grade’ policy conditions for investment, international climate and energy policy. Knowledge in energy-finance, clean energy investment and policy, and international climate policy (UNFCCC, Kyoto Protocol). Observer at UN talks. | Feb 18 |
| **7** | Charity & independent | Researcher, author & journalist | Private investors | Expertise in financial markets, hedge funds, commodity markets, economic aspects of climate change, and socially responsible banking | Nov 17 |
| **8** | Research Institute &Consultancy company | Visiting research fellow, director & managing Director | Pension funds, private investors | Actuarial advice, policy development and public-sector reform; design and implementation of administrative and legislative frameworks in the pension sector | Nov 17 |

Table 3a: Interview sample (structured interviews)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Type of institution/investor** | **Function** | **Expertise related to** | **Main experience** | **Date** |
| **9** | Asset management company | Head of Responsible Investment | Institutional investors | Experience in institutional investment and responsible investment; member of several working groups and international committees related to ESG topics | Apr 18 |
| **10** | Investment company (or Asset management company?) | Investment Director | Institutional investors | Pensions consultancy, investment strategy, asset liability modelling and investment manager research | May 18 |
| **11** | Research institute / Sustainable investment advisory firm | Sustainable Finance and Investment Executive / Institutional investor / senior advisor | Institutional investors | Sustainable Finance and Investment Executive; over 30 years working in international banking and finance | May 18 |
| **12** | Responsible investment advisory firm | Founder/Director | Private investors | Responsible Investment, Actuarial work | May 18 |
| **13** | Investment company | Advices Investors in unquoted sustainable businesses | Retail investors | Sustainable Private Equity; Private Equity and Venture Capital Specialties: Sustainable Investments, Renewable Energy. Jim has 25 years’ experience in sustainable and clean technology, including 16 years’ private equity. | May 18 |
| **14** | Research services business with expertise in sustainable investment, research and analytics. | Managing director | Private investors | Investment management, institutional sales, research, business development and product management. | Sep 18 |
| **15** | (Sustainable) investment management firm | Head of SRI Policy | Private investors | Ethical finance and responsible investment | Oct 18 |
| **16** | Provider of UK workplace pensions | Asset owner | Pension funds | Asset owner in pension fund investments; expertise in sustainable & responsible Investment, climate change and ESG. | Oct 18 |
| **17** | Research institute | Director | Pension funds | Expert in pension fund investments and sustainable finance | Apr 18 |

Table 4a: Summery of barriers reported in type i)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Barrier-topics** | **Method** | **Investor type** | **Technology and regional scope** |
| Bolton & Foxon (2015) | 2;7;13;14 | The study applies a socio-technical system analysis that is based on:   * The main source is work conducted as part of the ‘Transition Pathways to a Low Carbon Economy’ research consortium * A qualitative analysis of key policy documents * 15 semi-structured interviews with stakeholders (e.g. developers) and financial experts and professionals (e.g. investment managers, institutional investors) | Institutional investors and energy developers | All renewables / UK |
| Blyth et al. (2015) | 2;5;15 | The findings of this study are based on:   * Semi-structured interviews * A literature review * An evaluation of key policy reports | Private investors | All renewables / Global |
| Bolton et al. (2016) | 2;4.3;13 (only institutional investors: 2;4.3;7;12) | The primary source of this empirical study were 15 in-depth semi-structured interviews with individuals in the investment and energy policy communities in the UK. All interviews were recorded, transcribed and manually coded according to key emerging themes. | Energy developers and institutional investors | All renewables / UK |
| Boie et al. (2014) | 1;2;13 | The study uses data from a ‘weighting questionnaire with hierarchical structure’ (integrated in an online platform) and involving 140 submitted replies from RE project developers, generators and utilities, consultants in the energy sector, policy representatives and RE-research institutions. | Private investors | All renewables / US & EU |
| Byrnes et al. (2013) | 1;2;3 (lack of internalisation of carbon costs);7;12;15 (different priorities of different government levels) | Discussion and critical analysis of barriers (in particular related to the regulatory environment) faced by the energy industry based on Australia as a case study. | Energy developers or generators | All renewables /  Australia |
| Bucher et al. (2016) | 7;12;15 (uncertainty of future revenues) | The study applies system dynamics modelling and the findings are based on:   * Insights gained in the literature * Interviews with 44 managers, experts and specialists from 13 stakeholder groups | Institutional investors | Tidal energy / Global |
| Chassot et al. (2014) | 1;2;15 (worldviews of investors) | Choice experiments with 29 venture capital investors from Europe and the United States, which conducted 1064 investment decisions. | Venture capital investors | All renewables / EU & US |
| Del Rio & Tarancon (2012) | 1;2;15 | The findings in this study have been gained based on cross-section linear regressions with ordinary least squares. In the econometric model, capacity additions are explained according to several variables, including wind resource potentials, support levels, electricity generation costs, type of support scheme, administrative barriers, social support for wind electricity, the general investment climate in the country, electricity demand, the share of other low-carbon technologies, country area and whether there have been major or minor changes in the support scheme. | Not specified | Onshore wind / EU |
| Del Rio (2011) | 1;4.1;15 (exhaustion of places with the best wind resources) | The study is based on the results of simulation models providing insights on future outlooks and complemented with an analysis of regulations and other drivers and barriers. | Private investors | All renewables / EU |
| Del Rio et al. (2014) | 1;2;15 | The results of this study are based on an econometric model in which capacity additions are explained according to several variables, including the following: wind resource potentials, support levels, electricity generation costs, type of support scheme, administrative barriers, social support for wind electricity, the general investment climate in the country, electricity demand, the share of other low-carbon technologies, country area and whether there have been major or minor changes in the support scheme. | Not specified | Wind / EU |
| Gatzert & Kosub (2016) | 2;7;15 (weather-related uncertainty; financing risk) | The findings of this study have been obtained based on:   * A review of the present academic and industry literature * A review of 6 surveys (published via other institutions) with wind industry participants | Developers and industry representatives | Wind / EU |
| Geddes et al. (2018) | 2;4.1;6;7;12;15 (construction risks; non-standard engineering, procurement and construction (EPC) contracting structures) | This study is based on:   * An evaluation of 52 in-depth semi-structured interviews with 56 interviewees (incl. ow-carbon energy project developers, equity and debt providers, bankers (SIBs and commercial banks) and industry experts) * Key themes within the data set were identified via a qualitative content analysis | Project developers, equity and debt providers and banks | All renewables /  Australia, Germany & UK |
| González & Lacal-Arantegui (2016) | 1;2;3;4;7;8;9;12;15 ( government budget allocation process; difficulties to accessing finance possibilities) | This study undertakes a critical analysis of the barriers faced by the industry based on a review of regulatory framework for wind energy in the European Union. | Focus on energy developer and generators | Wind energy / EU |
| Groot et al. (2013) | 2;4.1;5;7;15 (long construction times; strategic goals; need for healthy cash position; herd behaviour; permit approval risk) | Empirical investigation of power plant investment decision-making processes based on nine semi-structured interviews with power company investment analysts and decision makers. | Power plants | All renewables  / Holland |
| Hall et al. (2017) | 4.2;9;12;15 (need to apply a different analytical framework) | 16 in-depth interviews across the RE investment chain. Interviewees included five institutional, RE investment professionals or fund managers, three utility executives, two independent RE project developers, two alternative RE finance providers, two public-sector policy professionals, and two institutional finance NGO representatives. | Focus on capital markets and financial investors | All renewables / UK |
| Holburn et al. (2010) | 1;2;15 (natural wind conditions, lack of availability of transmission capacity for the foreseeable future) | Internet-based survey with 29 wind developers. The online survey included questions on developers’ perceptions on regulatory and operational environments for the wind industry in Ontario. | Wind developers, wind energy firms | Wind /  Canada (Ontario) |
| Jones (2015) | 2;6;8;9;13 | Delphi process with institutional investors, including:   * Literature review * Semi-structured interview with finance sector experts * Presentation of findings to workshops - with each including around 20 experts (e.g. asset management, pension funds, re-insurance, insurance, investment banking, Banking)- to refine arguments | Institutional investors | All renewables / Global |
| Kann (2009) | 2;4.3;15 (semi-privatisation of the energy market) | The findings of this study are based on:   * An evaluation of literature * 21 stakeholder semi-structured interviews (incl. wind developers, electricity retailers, integrated utilities, financiers, government agencies, and energy consultancies) * All interviews were analysed using the framework of the grounded theory | Wind developers, wind energy firms | Wind /  Australia |
| Karltorp (2016) | 2;4.1;5;7;12 | The study applies a technological innovation system (TIS) framework analysis based on 22 semi-structured interviews with technology developers and actors in the financial sector, including commercial banks, institutional investors, private equity firms and a venture capital firm. | Private investors, including venture capital and private equity and institutional investors, and banks | Biomass gasification & offshore wind / EU |
| Leete et al. (2013) | 2;4.1;7 | The findings of the study are based on a qualitative evaluation of 12 in-depth interviews with Investment community, device developers and industry support. | Private investors | Wave and tidal energy / UK |
| Linnerud & Holden (2015) | 2;15 (lack of access to required transmission grid, to entrepreneurial and other services or to funding sources) | Regression based on a survey with 172 investors (which covers 446 planned hydropower projects in Norway). The survey included question on what type of barriers would prevent the projects from being realized and how likely it would be that different projects will be realized. | (Experienced and unexperienced) project developers | Hydropower /  Norway |
| Lozano & Reid (2018) | 2;15 (balancing supply-demand of energy) | The findings of this study are based on:   * An analysis of five semi-structured interviews with investors working at a major European asset manager company with over €250 Billion in assets under management and who have day-to-day involvement in the utilities sector. * The data gathered through the interviews was analysed with Grounded Theory (GT). | Asset managers | All renewables / EU |
| Lüthi & Prässler (2011) | 1;2;15 (lack of grid access and of access to credit; legal security, return level) | The study builds up on existing literature and applies conjoint analysis as a scenario tool for estimating potential effects of specific policy measures based on dataset of 119 onshore wind energy developers' preferences. | Project developers | Onshore wind / US & EU |
| Masini & Menichetti (2012) | 2;4.2 for venture and equity investors in particular);7;15 (time horizon of support level and the support level of the policy is too low) | Estimation of an econometric model (using OLS regression and 2 stage least square (SLS) based on 93 questionnaires. Thereby, the RE share in the investment portfolio was used as the dependent variable and the confidence in market efficiency, the confidence in technology effectiveness, the technological risk attitude, the perceived importance of policy-type, the perceived importance of support level and the perceived importance of support duration. The estimated model also control the investor’s experience by the use of different dummy-variables. | Venture capital and private equity and investment funds, asset managers, commercial banks, project developers and energy companies | All renewables / EU |
| Masini & Menichetti (2013) | 2;4.2;7;12;15 (institutional and peer pressure; effectiveness of existing policies) | The study develops a conceptual framework based on:   * A review of the literature * Several interviews with experts * A web-based survey questionnaire (93 questionnaires were ultimately retained for the analysis)   The study also tests an empirical model by operationalization of the collected data. Thereby, the share of RE in the investment portfolio is the dependent variable. | Venture Capitalists, Private Equity Funds, Asset Managers, Investment Funds, Commercial Banks and Energy Companies | All renewables / EU |
| Martin & Rice (2012) | 1;4.1;5;12;15 (lack of project finance availability, grit access or lack of other infrastructure; lack of skilled workforce; large availability of coal) | Application of stakeholder theory to investigate barriers to RE supply growth in Queensland (Australia) based on:   * Data collected on from the Queensland government web pages that were established for the inquiry into ‘Growing Queensland’s Renewable Energy Electricity Sector’, conducted by the state’s Environment and Resources Committee. * The data was in form of written submissions by firms, stakeholder organizations, GOs and NGOs in the RE industry sector. | Project developers | All renewables / Australia |
| Mielke (2019) | 2;9;15 | Discussion with focus groups, including key stakeholders such as utilities, infrastructure companies, representatives from the financial sector as well as civil society | Not specified | All renewables / EU |
| Richards et al. (2012) | 2 (lack of political leadership);3;7;12;15 (disinterest from society) | Application of grounded based on 18 interviews (with government representatives, academic, environmental non-government organizations, corporates). | Private investors | Wind energy /  Canada |
| Salm & Wüstenhagen (2018) | 2;4;5;7;12;15 (e.g. Most pension funds preferred investment  volumes smaller than a typical large-scale hydro project) | Choice experiment with 53 investment professionals from incumbent firms and pension funds in Switzerland, conducting 1,129 experimental investment choices in total. | Pension funds | Hydropower / Switzerland |
| Sovacool (2009) | 2;4.1;12;13;14 (in terms of mental thinking) | The findings of this study are based on:   * 181 semi-structured research interviews at 93 institutions, which were selected to represent the diverse array of stakeholders in the electricity utility sector (including utilities and power providers, research institutes, regulatory agencies, manufacturers, interest groups, and consumer advocates). * The author additionally spent seven months in two separate fellowships at the Oak Ridge National Laboratory; worked for four months as a Senior Research Fellow at the Virginia Center for Coal and Energy Research; and conducted on-site visits to ten renewable, conventional, and nuclear power plants. | Private investors | All renewables / US |
| Stokes (2013) | 2;13;15 (informational asymmetries on costs of RE production; conflicts over job creation and innovation) | This paper presents a case study of Ontario's (Canada) feed-in tariff policies between 1997 and 2012. | Private investors | All renewables / Canada |
| Wells et al. (2013) | 2 (role of the government in general) ;4.2 (and fiduciary duty);5;7;12;15 (investors personal values) | Thematic analysis of 14 in-depth semi-structured interviews with representatives from renewable energy producers, banks and investment companies. | Private investors | All renewables / UK |
| Zhong & Bazilian (2018) | 5;9;12 | Evaluation of ‘grey’ literature since the early 2000. This includes the evaluation of sources taken from IOCs’ press, releases, annual reports, and websites, public databases of venture capital funding, which are cross-referenced with news articles, media sources reporting investments, and SEC filings. | Oil and gas companies | All renewables /  Focus on EU & US |

Table 5a: Summery of barriers reported in literature-based type ii) studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Barrier-topic** | **Method** | **Investor-type** | **Technology and regional scope** |
| Gatzert & Kosub (2017a) | 4.2;6;9 (lack of project and lack of liquidity);10;12;15 (need for the adoption of a new theoretical framework) | Literature-based analysis of investment barriers into renewable energy infrastructure with focus on the insurance industry and Solvency II along with the impact of several European initiatives that are intended to reduce barriers, thereby also providing numerical examples regarding solvency capital requirements. | Insurances | All renewables / EU |
| Granoff et al. (2016) | 1;2;3;4.1;4.2;5;7;12;13 (due to lack of information);14 (due to cultural values and invested capital); 15 (lack of skilled labour, supply chain bottle necks, vested interests and political lobbies) | Perspective article | Private investors | All renewables / Global |
| Grüning & Moslener (2016) | 2;4.1;7;8;9;10;12;15 (institutional barriers within finance institution, psychological, cultural and behavioural barriers; technological barriers; lack of transmission infrastructure; lack of skills for operation and maintenance at the project side; lack of standards for renewable energy products) | Literature overview | Private investors | All renewables / Global |
| Hampl & Wustenhagen (2013) | 2;7;13;15 (completion risk; operation risk; supply risk; behavioural elements that impact perceptions: over-confidence, loss-aversion, anchoring, herd-behaviour and peer effects;) | This paper develops a conceptual model of investor acceptance of wind power megaprojects and its management based on insights from literature on behavioural finance, social acceptance of wind power projects, megaproject management and stakeholder management. | Private investors | Wind power / Global |
| Hu et al. (2018) | 4;5;6;15 (higher due diligence costs for small and medium projects) | A survey of relevant literature based on a few targeted keywords, such as “investment decision-making”, “renewable energy” and “barrier”. A snowball method was used in addition to facilitate the literature survey process. A total number of 140 literature sources were reviewed. | Banks | All renewables / Global |
| Hu et al. (2018) | 1;2;3 (low carbon price; subsidies for fossil fuels); 4.1; 5;6;7;12;13;14 (due to biased risk-perceptions or sunk costs in terms of invested capital/skills); 15 (lack of sustainable strategic value; worldview and culture of investors; misperception on Renewable energy infrastructure lifetime) | Energy developer |
| Ivanova et al. (2011) | 1;2;3;4.1;15 (lack of access to finance; insufficient support and incentives from the government; lack of RE skills; Import tariffs and technical barriers impede trade in renewables; technology standards are lacking for some RE technologies and fuels) | Narrative literature review | Focus on energy developer or generators | All renewables / Global |
| Jacobsson & Jacobsson (2012) | 2;4.2;5;7;10;15 (undergoing change in the business logic of the financial sector e.g. increasing focus towards speculative and high-risk financial investments; very limited availability of debt provided by banks and also for an only limited duration) | Narrative literature review and analysis of the current financial system | Financial investors | All renewables / Not specified |
| Klessmann et al. (2011) | 1;2;4.1;5;7;12;13 (due to lack of information);15 (cognitive barriers, cultural differences, , grid access, supply chain bottlenecks (e.g. lack of skilled labour; lack of production capacity), high power of other players in the power market) | Literature review | Energy developer and generators | All renewables / EU |
| Louche et al. (2019) | 4;8;15 (challenges related to forecast forward looking uncertainty (e.g. uncorrelated to past data) by traditional financial models; use of the efficient market hypothesis) | Narrative literature review | Private Investors | All renewables / Global |
| Polzin (2017) | 1;2;3;4;5;8;12;13;14 | Narrative literature review. Reviewed articles were identified and classified, and the texts analysed and mapped into a theoretical framework. | Mainly financial investors | All renewables / Not specified |
| Wüstenhagen & Menichetti (2012) | 2;3 (environmental externalities of non-renewable technologies are not always internalised in the policy framework); 5;12;13;14 (also due to vested interests and cognitive perceptions);15 (cognitive factors) | Introduction to a special issue | Private investors | All renewables / Not specified |

Table 6a: Summery of barriers reported in type iii)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Barrier topic** | **Method** | **Investor type** | **Technology and regional scope** |
| Barbosa et al. (2018) | 2 | Real options model | Private investors | All renewables / Not specified |
| Barradale (2010) | 2 | The study is based on an evaluation of:   * An online survey which includes 272 US energy professionals * interviews with energy industry representatives | Energy industry professionals | Wind / US |
| Bhattacharya et al. (2015) | 15 (weather risk) | Simulation model applied to empirical data | Private investors | All renewables / US |
| Boute (2012) | 2 | Narrative literature review and analysis of legal sources | Private investors | All renewables / EU |
| Breitschopf & Pudlik (2013) | 15 (perceived default risk of RE technology too high resulting in high risk requirements of Basel III and Solvency II increasing cost of capital) (for banks and institutional investors: stricter requirements when it comes to investment in RE infrastructure) | The impact of Basel III on finance costs of PV in Germany is assessed and compared to the RE default risk based on a simple cash-flow model. | Private investors | PV & wind / Germany |
| Chen & Kettunen (2017) | 2 | Application of a game-theoretical model to historical data | Power generating firms | All renewables / EU |
| Dalby et al. (2018) | 2 | Real option modelling with a Bayesian learning framework | Private investors | Wind / EU |
| Erickson et al. (2015) | 14 (due to political, market and social factors) | Analysis of the carbon-lock in based on previous literature | Private investors | All renewables / Global |
| Eryilmaz & Homans (2015) | 2;15 (market risks) | Dynamic optimization model applied to empirical data | Renewable electricity producers / private investors | Wind/ US |
| Fan et al. (2010) | 2 | Theoretical simulation model (risk-adversity is simulated by assumption) | Private investors | All renewables / US |
| Fragkos & Kouvaritakis (2018) | 2;15 (diverse sources of uncertainties e.g. volatility in fuel and electricity prices) | Application of multi-objective stochastic modelling (PROMETHEUS and BARA model) designed to optimize budget allocation decisions. | Private investors | All renewables / EU |
| Fragkos & Kouvaritakis (2018) | 2;15 (sources of uncertainty, especially with regard to volatility of fossil fuel and electricity prices, technological costs) | Multi-objective stochastic model designed to optimize budget allocation decisions for power generation in the context of risk aversion taking into account several sources of uncertainty, especially with regard to volatility of fossil fuel and electricity prices, technological costs, and climate policy variability. | Private investors | All renewables / EU |
| Fuss et al. (2012) | 15 (various sources of uncertainty incl. policy uncertainty) | Real options analysis applied to real data (GGI Scenario Database). | Financial investors | All renewables / Not specified |
| Gatzert & Kosub (2017b) | 2 | Drivers of policy uncertainty are investigated based on a narrative review of the academic literature and supported by industry studies regarding cases of support scheme cuts in Europe (from the end of 2010 until the end of 2013). | Private investors | All renewables / Not specified |
| Gatzert & Vogl (2016) | 2;15 (other sources of risks not specific to RET) | The study provides a stochastic model framework to quantify policy risks associated with renewable energy investments (e.g. a retrospective reduction of a feed-in tariff), thereby also taking into account energy price risk, resource risk, and inflation risk. The model is illustrated by means of simulations and scenario analyses, and it makes use of expert estimates and fuzzy set theory for quantifying policy risks. | Private investors | Onshore wind / Germany & France |
| Gross et al. (2010) | 15 (Revenue/price risk for different RE technologies) | The study is based on levelised cost estimates by factoring in different risk categories. | Private investors | All renewables / UK |
| Jami & Walsh (2014) | 15 | The study is based on a case study of Ontario, Canada. | Private investors | All renewables / Canada |
| Karneyeva & Wüstenhagen (2017) | 2 | The methodology of the study is a cross-case study analysis of three PV markets – Germany, Italy and Switzerland – to investigate the role of feed-in tariffs for the near- and post-grid parity stages of diffusion. The study also compares the investor landscape in the three countries, calculates profitability for different business models, and quantifies the policy risk affecting PV investors. | Private investors | Solar / Germany, Italy & Switzerland |
| Ländner et al. (2019) | 1;2 | Literature overview | Not specified | All renewables / EU |
| Linnerud & Simonsen (2017) | 2 | Real-option model based on interviews with 204 investors (project developers) covering 280 single hydropower projects with a total planned annual production of 8.2 TWh. We apply econometric techniques on primary data collected in two surveys of Norwegian investors in hydropower, and we use real options theory to predict and interpret investors' responses. | Project developers | Hydropower / Norway |
| Linnerud et al. (2014) | 2 | Real options theory is tested based on panel data of 214 licenses to construct small hydropower plants. That is, it has been empirically tested whether the predictions for investment timing given by real options investment holds. Additionally, the authors interviewed the owners of 179 of the 214 licenses to determine the year of the investment decision, the expected investment outlay, capacity, and production level at this point in time and to check whether the investment was delayed for non-economic reasons not included in the regulator's database. | Traditional utilities and other professional investors in the energy market | Hydropower / Norway |
| Mazzucato & Semieniuk (2018) | 7 | The analysis is based on data from the BNEF database of deal-level global RE asset finance, from 2004 to 2014, as well as aggregate BNEF data on public banks. | Different investors are considered, including: energy firms, private utilities, commercial banks, institutional investors, charities/foundations, public investors (e.g. state banks) | All renewables / Global |
| Nelson et al. (2013) | 2 | The study is based on the evaluation of results of a survey of renewable electricity market participant views in relation to policy and pricing, and partial equilibrium analysis of electricity price impacts related to ongoing policy uncertainty. | Private investors | All renewables / Australia |
| Rezec & Scholtens (2017) | 5 | Quantitative analysis and qualitative assessment of the risk and return characteristics of the international renewable energy equity markets | Financial market investors-such as pension funds, insurance companies, and mutual funds | All renewables / EU |
| Romano & Fumagalli (2018) | 2;15 (diverse sources of uncertainties e.g. volatility in fuel and electricity prices; investment costs) | Survey of studies in the academic literature on this topic | Private investors | All renewables / EU |
| Sick et al. (2013) | 15 (Raw material prices) | The authors develop a regression model to test the influence of raw material prices on RET diffusion, using investments in RET capacities as indicators of diffusion, and crude oil and natural gas prices as well as public R&D subsidies as main independent variables. The model is then applied to emerging RET (wind and solar power) for electricity generation in 18 OECD-countries. | Private investors | Solar & wind / OECD |
| Sisodia et al. (2016) | 2 | The study used a random effect panel data modelling approach over the period 1995-2011 for studying the impact of the levelized cost, regulation perception, carbon emissions and climatic condition on wind and solar investments over the three samples. | Private investors | Solar & wind / EU |
| Steckel & Jacob (2018) | 4 | Literature overview | Not specified | All renewables / Global |
| Szolgayová et al. (2011) | 2 | This study applies a real options model, thus considering uncertainty and irreversibility at the plant level, and uses the results in a dynamic portfolio model, where the Conditional Value-at-Risk (CVaR) is the risk measure. | Private investors | All renewables / Not specified |
| Zenghelis (2014) | 2 | Narrative literature review | Private investors | All renewables / Global |
| Romano & Fumagalli, E. (2018) | 2;15 (various sources of uncertainty) | Literature review on uncertainty as a barrier for investments | Private investors | All renewables / IEA (International Energy Agency) member countries, plus China |

Table 7a: A detailed overview on the barrier topics reflected in the academic literature

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nr. | Barrier theme | Number of times cited in the papers of type (i) and (ii) (incl. 42 studies) | Number of times cited in the papers of type (i) and (ii) **excl.** project developers or not specified (incl. 30 studies) | Number of times cited in the papers of type (iii) | Number of times cited in total |
| 1 | Complex and long administrative processes / regulation, grid regulation and transparent grid development; lack of compatibility with existing transmission and distribution networks | 15 (5) | 5 (8) | 1 | 16 (5) |
| 2 | Lack of a stable climate change policy frameworks and policy direction | 37 (1) | 23 (1) | 21 | 58 (1) |
| 3 | Policies are in favour of 'brown' energy-infrastructure (e.g. fossil fuel subsidies; limited pricing of carbon emissions) | 7 (8) | 4 (8) | 0 | 7 (9) |
| 4 | Constraints on decision making within investor companies (4.1. high capital costs/long pay back periods; 4.2. short-term focus and 4.3. capital requirements due to solvency II or Basel III and also increased due to the financial crisis) | 24 (2) | 18 (2) | 1 | 25 (2) |
| 5 | Perceptions that returns of renewable infrastructure investments are too low and require high initial capital investment | 13 (6) | 8 (5) | 1 | 14 (6) |
| 6 | Requirement that projects need a certain credit rating so that it is possible to invest | 5 (9) | 4 (7) | 0 | 5 (10) |
| 7 | Technology-risk associated with uncertain technologies | 19 (4) | 15 (3) | 1 | 20 (4) |
| 8 | Disclosure on climate related risks and integrating them into financial decision-making / Lack of standardised ESG-data | 5 (9) | 4 (7) | 0 | 5 (10) |
| 9 | Limited projects with acceptable risk-return profiles; lack of liquidity in markets | 7 (8) | 5 (6) | 0 | 7 (9) |
| 10 | Lack of suitable financial vehicles/financial instruments | 3 (10) | 3 (8) | 0 | 3 (11) |
| 11 | High transaction costs or fees | 0 (11) | 0 (9) | 0 | 0 |
| 12 | Lack of knowledge/technical advice on green infrastructure investment | 21 (3) | 15 (3) | 0 | 21 (3) |
| 13 | Attitudes of the public, resistance of society | 12 (7) | 10 (4) | 0 | 12 (7) |
| 14 | Path-dependency or lock-in (14.1 technological; 14.2. institutional) | 7 (8) | 5 (6) | 1 | 8 (8) |
| 15 | Other barriers | 35 | 22 | 12 | 57 |
|  | Total papers found in total | 43 | 28 | 28 | 71 |

1. Bolton & Foxon (2015) investigate how socio-technical studies can inform policy debate in relation to low carbon investment challenges in the UK electricity sector drawing on a set of conducted interviews. That is, while their study focuses on understanding uncertainty, lock-in and support of low carbon finance ‘niches’ from a socio-technical perspective, our study first investigates the most important barrier and investigates in a second step the green finance policy challenge through the lenses of systems perspective. [↑](#footnote-ref-1)
2. See Notes [↑](#footnote-ref-2)
3. See Notes [↑](#footnote-ref-3)
4. See Notes [↑](#footnote-ref-4)
5. See Notes [↑](#footnote-ref-5)
6. For example, institutional investors typically need to hold certain amount of low risk securities and often require green bonds to be rated as investment-grade bonds by a credit rating (Meltzer, 2016). [↑](#footnote-ref-6)
7. See Notes [↑](#footnote-ref-7)
8. See Notes [↑](#footnote-ref-8)
9. High fees can for example be related to costly information verification of green bonds due to a lack of standardised information sources (OECD, 2017). [↑](#footnote-ref-9)
10. See Notes [↑](#footnote-ref-10)
11. Bolton & Foxon (2015) apply socio-technical perspective on investment challenges. Thereby, the main features of the socio-technical perspective are to a large extent shared by the systems/complexity approach put forward in our paper (van den Bergh, 2013; van den Berg et al., 2011). [↑](#footnote-ref-11)
12. In system dynamics, *leverage-points* or *key-points* affect feedback loops in the entire system; therefore, the system is sensitive to changes in those variable values. System dynamics aims to identify those points for policy implementation (Sterman, 2000). [↑](#footnote-ref-12)
13. Bolton & Foxon (2015, p.168) indicate “a key underpinning of the ‘hands off’ relationship which emerged since the 1980s between government and the industry has been basic assumptions of neo-classical economic theory”. That is, it has been assumed that investments are most efficiently made by the private sector and that the governments should implement appropriate price signals leading the market towards an optimum. Bolton & Foxon (2015, p.169) argue that UK energy policy would move into a new phase of energy governance “where new investment to meet long term climate policy and energy security objectives is the main priority”. [↑](#footnote-ref-13)
14. This also was a point raised by a majority of our interviewees. [↑](#footnote-ref-14)
15. For example the liquidity requirements of banks regulated within the Basel III banking regulations might negatively affect banks' willingness to lend to green projects (D’Orazio & Popoyan, 2019). [↑](#footnote-ref-15)
16. See Notes [↑](#footnote-ref-16)
17. A green bond is a fixed-income financial instrument for raising capital from investors through the debt capital market and aimed at financing low-carbon or other environmentally sustainable activities (OECD, 2017). For more detailed categorisation, see e.g. CBI (2018). [↑](#footnote-ref-17)
18. See Notes [↑](#footnote-ref-18)
19. See Notes [↑](#footnote-ref-19)
20. See Notes [↑](#footnote-ref-20)
21. See Notes [↑](#footnote-ref-21)
22. See Notes [↑](#footnote-ref-22)
23. See Notes [↑](#footnote-ref-23)
24. See Notes [↑](#footnote-ref-24)
25. See Notes [↑](#footnote-ref-25)
26. See https://eu.spindices.com/indices/equity/sp-500-esg-factor-weighted-index [↑](#footnote-ref-26)
27. The increase of carbon prices is often suggested in the research literature as an effective policy instrument to decarbonise the global economy. This suggestion has also been made by various interviewees of our study and investors of the visited conference in Switzerland. However, we think that the possibility to increase (global) carbon prices at sufficient scale and applied to all industries (incl. aviation) is relatively small due to political challenges. [↑](#footnote-ref-27)
28. From an investment perspective, green bonds resemble standard bonds, aside from the fact that they give the investor an opportunity to invest in projects that have a positive effect on climate (Meltzer, 2016). [↑](#footnote-ref-28)
29. The great majority of institutional investment is allocated to liquid assets such as bonds & shares. Over recent years, a small but growing fraction of allocation is being made in alternative (illiquid) investment vehicles (Mercer, 2018). [↑](#footnote-ref-29)