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Investment decisions in the renewable energy sector: An analysis of non-financial drivers

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ABSTRACT

Notwithstanding their many environmental, economic and social advantages, renewable energy technologies (RE) account for a small fraction of the world's primary energy supply. One possible cause for this limited diffusion is that private investments in the RE sector, although potentially appealing, remain insufficient. The lack of adequate financing is also a clear indication that our understanding of the process by which investors fund RE ventures is still incomplete. This paper aims to fill in this gap and to shed new light on RE investment decisions. Building upon behavioral finance and institutional theory, we posit that, in addition to a rational evaluation of the economics of the investment opportunities, various non-financial factors affect the decision to invest in renewables. We analyze the investment decisions of a large sample of investors, with the objective to identify the main determinants of their choices. Our results shed new light on the role of institutional and behavioral factors in determining the share of renewable energy technologies in energy portfolios, and have important implications for both investors and policy makers: they suggest that RE technologies still suffer from a series of biased perceptions and preconceptions that favor status quo energy production models over innovative alternatives.

1. Introduction

The debate on Renewable Energies (RE) continues to attract a significant amount of attention within the academic, managerial and policy making communities. While some scholars and industry experts remain skeptical about the technical and economic viability of these technologies [1,2], a different view, championed by the IPCC and especially popular in some European countries, considers RE as one of the most effective solutions to curb greenhouse gas emissions [3]. Despite mixed empirical evidence [4,5], RE have been also indicated as a powerful instrument to tackle unemployment and stimulate economic growth [6–8]. The advocates of this view argue that — if the objective of halving CO_2 emissions by 2050 is to be achieved through the diffusion of RE — the contribution of these technologies to primary energy supply must exceed 50% [9,10].

Yet, notwithstanding the public support received in various countries under the form of incentive schemes, taxation or other governmental expenditures, RE technologies only account for a small fraction of the world's primary energy supply. One reason for this limited diffusion is that, while the transition towards a low-carbon economy requires important investments [11,12], private finance has so far played a relatively marginal role in this industry [13]. Mobilizing private capital to support RE projects is challenging, particularly in the current economic context, as investors are reluctant to allocate resources to new technologies that guarantee uncertain returns in the short term. The majority of high-tech VCs prefer to invest in technologies with low-risk low-return profiles and "seem to be steering clear of risky green investments, suggesting that clean-tech companies for a variety of reasons don't work" [14; p. 23].

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Furthermore, most of the resources so far attracted by the RE industry have been channeled towards mature RE technologies that are closer to grid parity, such as on-shore wind or hydro,[1] on the ground that "accelerated deployment of existing technologies will get you down the cost curve much more rapidly than a breakthrough" [14; p. 23]. Compared to these technologies, radically innovative systems that may display higher long-term potentials have somehow failed to attract the amount of capital necessary to pay for the greater upfront investments they usually require. In the long run, this strategy of privileging relatively mature technologies could stifle the development of technological breakthroughs and, ultimately, cause the premature extinction of technological alternatives with potentially superior performance [16]. Investment strategies that focus on a few mature technologies may be myopic in the short term too, because they reduce valuable opportunities for diversifying energy portfolios and hedging against price fluctuations [17,18].

Some scholars have argued that investments in RE technologies can be stimulated only through dedicated policies [19]. Indeed, with the exception of stand-alone systems for remote off-grid applications where RE is sometimes the only available option [20], most RE markets are heavily reliant on direct subsidies, energy taxes, or feed-in tariffs. Yet, most of the mechanisms so far implemented to stimulate RE investments have produced mixed results [21,22], partly because the proposed instruments have been unable to leverage all the drivers of the investment decision process and to fit the broader socio-economic context in which they are deployed [23]. The limited effectiveness of these policies, and the variety of stances that investors take on renewables, suggest that our understanding of the process by which these agents allocate capital to RE technology ventures remains limited.

With a few exceptions [24,25], and despite some recent calls to further investigate the role that private finance can play to accelerate RE market deployment [13], the renewable energy policy literature has seldom incorporated the investors' perspective. Moreover, it has generally focused on the economics of energy systems, adopting market efficiency and full rationality as underlying assumptions to study the behaviors of agents [26]. Yet, there is increasing evidence that a purely rational economic evaluation of the investment alternatives does not suffice to explain how investors deploy capital or how agents choose among competing energy technologies. An emerging stream of literature suggests that broader social and psychological considerations must be included in the analysis of energy systems [27,28]. Behavioral finance and the bounded rationality perspective have long challenged the validity of the rational-actor models of classical economics in many decision making contexts [29,30]. Recently, these perspectives have started to draw the attention of energy economists too, mostly for policy evaluation purposes [31]. However, to our knowledge, they have not been applied to study the investors' behaviors in the RE industry and to examine why these agents have very different and often antithetical attitudes towards RE technologies.

This paper intends to fill this gap in the literature by shedding new light on the process by which investors allocate capital to renewable energy technologies. We posit that, in addition to a rational evaluation of the investment opportunities, a number of non-financial factors affect the investors' decisions, which may lead to very different resource allocation outcomes. We refer specifically to non-financial variables linked to the investors' personal histories, backgrounds or professional experiences that may also affect decisions. These factors include: i) the opinions that investors have formed over time on RE and on the regulatory context in which they operate (i.e. their a priori beliefs vis-à-vis renewable energy technologies); ii) the extent to which investors are influenced by the socio, economic and political environment in which they operate (i.e. their response to institutional pressure); iii) the extent to which investors are willing to invest into radically new technologies with a high degree of technical uncertainty and, iv) their knowledge of the operational context in which RE are deployed.

To fill in this gap, we develop and empirically test a model that examines the impact of non financial factors on RE investments. Following the recent emphasis on energy portfolio diversification [17,18] we examine the impact of these factors not only on the overall share of RE technologies in the investment portfolio, but also on its degree of diversification and the adoption rate of each specific RE technology. The model is empirically tested using primary data collected from a sample of European investors. Europe was chosen as an appropriate context for our empirical analysis, both for its leading role on climate change and energy policies and because it is the world region that, perhaps as a direct consequence of these policies, has attracted the largest share of new RE investments in the past few years [32]. It is worth stressing that, as a consequence of this choice, our results may not necessarily hold for investors operating in other regions.

The paper aims to make several contributions. First, by providing a better understanding of the investors' decision making process, it will help the RE industry attract badly needed capital. Second, it will help policy makers design more effective policy instruments to support the market deployment of RE technologies. Finally, the paper makes a methodological contribution too, as it analyzes a broader set of agents than what usually considered in studies of this nature.

The reminder of the paper is structured as follows: the next section provides an overview of RE investments and it positions our work against extant literature. Section 3 lays out theoretical foundations and it proposes testable hypotheses. Section 4 describes the research design and the empirical methods. Section 5 illustrates the main findings. Finally, Section 6 highlights the main conclusions and discusses implications for theory and practice as well as the limitations of the paper.

[1] Ironically, even mature RE technologies are not totally risk-free, as demonstrated by the failure of T. Boone Pickens' 500 MW wind farm or by the wind turbines accidents reported in the press [15].

2. Background and literature review

2.1. Renewable energy investments

Investments in renewable energy technologies were still negligible until the early 2000s, with non-governmental expenditures representing a minor share. Since then, they have recorded a substantial growth, reaching almost 150 USD billion in 2007 with a 30% CAGR between 2002 and 2009. After the global financial crisis of 2008–2009, investments in clean energy rebounded, attaining USD 145 billion at the end of 2009. This growth continued in 2010, when the 5 most active players (China, Germany, US, Italy and Brazil) totaled almost 150 USD billion of RE investments [33] (Table 1).

Despite this activity, RE proponents claim that RE investments remain below the level that would be required to attain the CO_2 abatement targets set by the Kyoto Protocol. The contribution of RE technologies to global energy supply is still limited: in 2007 non-hydro renewable energy sources contributed to 3% of global electricity generation [10]. Between 1990 and 2007, the share of non-hydro renewables increased, but only marginally (around 2% in OECD countries, and around 1% in non-OECD countries). It has been estimated that, to attain the CO_2 emission reduction targets set by the Kyoto Protocol, investments will need to increase up to 500 USD billion by 2030 [34] and that "the amount of investment required to replace all the petrol consumed in America with renewable fuels will run into the hundreds of billions of dollars" [14; p. 22].

The same RE proponents, particularly in Europe, suggest that achieving the emission reduction targets set by the Kyoto Protocol by means of an accelerated deployment of RE technologies will require a radical departure from existing practices. It will also require dedicated policies that can stimulate RE investments in a much more effective way, by removing barriers and leveraging all the investment decision drivers. Unfortunately, the extant literature does not seem to have shed full light on all the factors that affect investment decisions in the renewable energy sector. We recognize two gaps in this literature. First, as studies have been mostly framed under the general umbrella of mainstream finance theories, there is a general lack of understanding of how non-financial factors affect investment decisions in the specific domain of renewable energies. Second, the majority of studies that have looked at the RE investment drivers have done so only at an aggregated level. That is, they have not paid sufficient attention to how these factors affect technology-specific investments and to how they impact portfolio diversification. This is a gap which is worth addressing too. Given the importance of diversifying energy portfolios, incentive mechanisms that channel investments towards one specific technology (no matter how good) may ultimately become counterproductive.

2.2. The role of non-financial factors in RE investment decisions

The renewable energy literature has dedicated a significant amount of attention to study the factors that affect the success or failure of RE systems and to examine RE investments and adoption barriers [35,36]. Scholars in this area have mostly focused on technical and economic attributes of energy systems and typically adopted full rationality as the paradigmatic approach to explain how agents choose among uncertain options. Various economic constraints to renewable energy development have been suggested, including high capital and maintenance costs [37]; limited experience with new energy technology [38]; as well as under-valuing the long-term benefits of environmental investments [39,40].

More recently, other scholars have noted that a mere rational techno-economic analysis of energy alternatives is not sufficient to explain RE diffusion and RE adoption barriers. They suggested that a broader perspective, incorporating behavioral and social aspects, is needed [28]. This perspective advocates the use of social and psychological theory to examine why people form particular views on environmental problems and technologies [41,42], and suggests that the actual development of an emerging

Table 1
Renewable energy investments 2010 and suggested CO_2 emissions reduction targets by country.
Adapted from [33].

	Financial new investment and small distributed capacity in renewable energy by country, 2010, and growth on 2009 ($bn)				CO_2 emissions reduction from the Kyoto protocol
	New financial investments	Small distributed capacity	Total	Growth 09–10 (%)	Emission reduction target (% emissions over base year emissions)
China[a]	49.00	0.80	49.80	28%	n.a.
Germany	6.70	34.30	41.00	100%	92%
US[b]	25.00	4.60	29.60	58%	93%
Italy	7.00	6.80	13.80	136%	92%
Brazil	7.50	−0.60	6.90	−5%	n.a.
Canada[c]	5.00	0.20	5.20	52%	94%
Spain	4.70	0.20	4.90	−53%	92%
France	1.20	2.80	4.00	26%	92%
India	3.80	0.20	4.00	29%	n.a.
Czech Republic	1.10	2.50	3.60	102%	92%

[a] Did not ratify the Kyoto protocol.
[b] Signed but did not ratify the Kyoto protocol.
[c] Withdrew.

technology is influenced not only by the technology's performance, but also by its perceived potential influence [43–45]. Along the same lines, bounded rationality [46] has been suggested as the appropriate framework to study energy technology choices [27], the reaction of local stakeholders to renewable energy projects [47] as well as the design of environmental policies [48].

Yet, despite the increasing recognition it is receiving in different fields, this behavioral perspective has not yet been used to examine RE investments. A related stream of literature has recently started incorporating the investors' perspective to evaluate the effectiveness of RE policies and to shed light on how actors operating in the financial sector perceive policy instruments [24]. Although these studies have the clear merit of bringing the investors' perspective into the picture, they, too, overlook the role of non-financial and behavioral factors. As such, they only represent a first step towards a better understanding of the investment decision process in the renewable energy sector. Furthermore, most of this literature has focused on public finance. Conversely, and despite many agrees that mobilizing private capital is key to stimulate RE deployment, the role of private finance in the RE sector has somehow been overlooked [13].

To summarize, we argue that, while bounded rationality and behavioral factors have started to gain recognition in a number of fields, this perspective has not yet been applied to study whether and how investors allocate resources to renewable energy technologies. We believe this is an important and interesting gap that is worth addressing.

2.3. A portfolio approach to estimate the value of renewable energy technologies

A second gap in the literature on RE investments is that the majority of studies in this area have examined the factors affecting RE investments at an aggregated level, without including portfolio diversification considerations. A recent stream of research emphasizes the value of energy portfolio diversification and the importance of using a portfolio perspective to correctly value energy technologies. These scholars argue that renewable energy technologies should not be compared on stand-alone costs but should be rather evaluated on the basis of portfolio cost, i.e. a technology's cost contribution relative to its risk contribution to a portfolio of generating resources [49]. Using this approach, they find that adding RE technologies to a portfolio of conventional generating assets decreases the overall portfolio cost and risk, even though the stand-alone generating costs of each RE technology may be higher [17,18].

So far, such perspective has been applied to study the value of RE in energy portfolios that include both renewable and non renewable resources. We argue that it is important to study diversification *within* a portfolio of RE technologies too, for two reasons. First, similar to the case of diversification between fossil fuel technologies and RE, increasing the number of RE technologies in a portfolio allows investors to hedge against the risk of sudden changes in exogenous factors that may affect the viability of a specific RE technology, such as raw material prices, regulatory frameworks or consumer preferences. The second argument pertains to the well known trade-off between exploration and exploitation. In environments characterized by technological heterogeneity, performance uncertainty and learning curve effects, any technology selection policy that emphasizes exploitation of the current best option at the expenses of exploration of radical innovations may cause the premature extinction of alternatives that are potentially more valuable in the long term [50,51]. Limiting investments to mature technologies may obviously stifle the development of capital intensive systems with promising long term performance but higher current cost, in favor of systems that have lower current cost but lower improvement opportunities. For instance, while onshore wind is expected to face a 23% total cost reduction by 2050 compared to current levels, turn-key system prices and electricity generation costs for solar photovoltaics (PV) are expected to fall by a much greater extent, and already so by 2030 [52]. These estimates suggest that even PV, which is currently one of the most expensive renewable energy technologies, should achieve market competitiveness in the next 10 to 20 years, but only if appropriate investments are made to stimulate technological improvements [53]. Yet, wind absorbed around 45% of total investments in clean energies between 2004 and 2008 (around 160 USD billion), suggesting that investors are less likely to allocate capital to more radical innovations with higher long-term potentials [54].

It is clear, therefore, that investment decisions and policies that affect investment decisions should be evaluated also with respect to their ability to guarantee diversification even within a portfolio of RE technologies, so as to limit the risk that potentially promising technologies get selected out before their true potential is fully revealed. Furthermore, it is important to understand how different factors affect RE investment decisions not only at an aggregated level, but, also, technology-by-technology, because factors that may favor the deployment of one specific technology may not necessarily be useful to support other renewable energy options.

The present paper intends to complement and extend this literature. In the following section we propose a conceptual model (Fig 1) that examines how non-financial factors influence the willingness to invest in renewable energy technologies as well as the degree of diversification of investment portfolios.

3. The impact of non-financial factors on the RE investment decision process

A review of the literature and a series of exploratory interviews with industry experts have provided the groundwork for the development of the conceptual model presented in Fig 1. Controlling for the investor's experience and the type of firm undertaking the investment, we expect an agent's willing to invest in renewable energy technologies to be affected by four non-financial factors: a priori beliefs, institutional pressure, propensity for radical technological innovations and the investors' knowledge of the RE operational context.

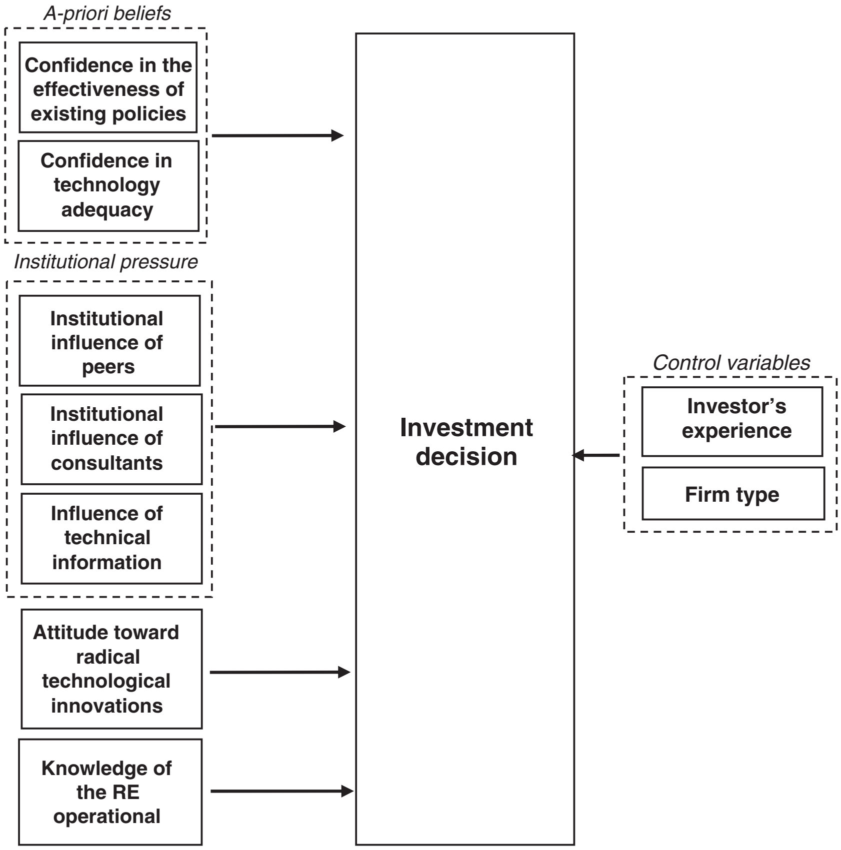

Fig. 1. Conceptual model.

3.1. A priori beliefs

Since long ago institutional theorists and behavioral economists have questioned the rational-actor models of classical economics and proposed that cognitive and cultural factors, as well as personal beliefs affect individual decisions [30]. The renewable energy literature has started considering the role of personal beliefs especially to study barriers to RE diffusion. Scholars in this area have suggested that, in addition to the well known NIMBY syndrome and to mere techno-economic considerations, a broader range of social and personal factors affecting human interactions with social and political institutions may cause resistance to RE systems [28,55–58]. They have also noted how individuals use their a priori beliefs to form viewpoints on RE, and then use different information sources to rationalize these viewpoints ex-post [59–62].

In line with this perspective, we expect a priori beliefs that agents form as a result of their personal history, educational backgrounds, and previous experience with renewable energy investments to affect investment decisions too. We consider two distinct types of beliefs. First, as the technological feasibility (or lack thereof) of a project has been identified as one of the most relevant barriers to RE adoption [63] and one of the main reasons for conducting demonstration projects [64], we expect the potential appeal of a RE project for an investor to depend on her a priori beliefs about the technical adequacy of the RE technology underlying the investment opportunity.

Second, as the economic viability of most RE projects is often dependent on incentive mechanisms, we expect investors to be influenced by their level of confidence in the effectiveness of RE policy measures. The uncertainty of public policies, in particular, has been identified as a powerful deterrent in securing private-sector investment [65], as demonstrated by the investment downturns caused by changing regulation in Denmark [66], in Germany [67] and in the US [68]. Incentive mechanisms and public policies are particularly important to support radical technological innovations at an early stage of their life cycle (i.e. when they are far from full market competitiveness). We therefore expect their impact to be relevant not only for the aggregated RE share, but also for portfolio diversification. That is, we expect investors with a high degree of confidence in the effectiveness of RE policies to be more willing than their counterparts to include radical RE innovations in their portfolios.

We therefore argue for a positive impact on two a priori beliefs above, which should be reflected in both the aggregated percentage of RE in the portfolio and the degree of technological diversification of the portfolio, as indicated by the following hypotheses:

Hp. 1a. Greater confidence in the effectiveness of existing policies is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

Hp. 1b. Greater confidence in technology adequacy is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

3.2. Institutional pressure

A second set of factors influencing the investment process is related to institutional isomorphism, i.e. the tendency of decision makers to conform to the rules and the norms prevailing in their institutional environment. Organizational scholars have highlighted the role of institutional theory in various settings, demonstrating that by allowing individuals and organizations to acquire legitimacy, conformance to explicit or implicit norms it may shape decisions more than a fully rational evaluation of the options available [69–72].

Energy and environmental scholars have recently recognized the importance of considering the broader institutional context in which technology adoption decisions are made [73,74]. For instance, Escobar and Vredenburg [75] have unveiled the role of normative, coercive and mimetic isomorphism on the willingness of multinational enterprise to adopt sustainability strategies, whereas Delmas and Monte-Sancho [23] have applied institutional theory to study the effectiveness of energy policies.

We argue that institutional isomorphism affects the behaviors of investors too, because agents facing similar institutional pressures will eventually adopt similar investment strategies. Institutional pressure can be of coercive nature (e.g. deriving from regulation), of normative nature (e.g. as a result of explicit or implicit industry standards), or mimetic (i.e. deriving from the influence of successful examples). Accordingly, for an investor to invest in a RE project, there must be either legal obligations (coercive isomorphism), some sort of pressure exerted from senior managers or the community of reference (normative isomorphism), or there must be proven evidence of successful RE investments undertaken by other investors (mimetic isomorphism).

In the context of our study, institutional pressure is primarily exerted through mimetic and normative isomorphism. In turn, this is determined by the information sources investors use to make decisions. The effect of institutional isomorphism is even more significant in contexts of incomplete information, because when decision makers lack the necessary knowledge to make objective assessments of complex technological options, they refer to experts and recognized authorities to draw conclusions [76]. Interviews with RE investors indicated that these agents use three primary sources of information to make their investment decisions: first, they observe the behavior of their peers (i.e. well known investors in the same industry); second, they consider the opinion of external consultants who specialize in the RE industry, and third, they also use factual information originating either from technical reports or from due diligences conducted in house. Accordingly, we expect that both the degree of RE share in the investment portfolio, as well as the rate of adoption of each individual technology to be influenced by the extent to which investors are sensitive to these information sources. However, while it is legitimate to argue for a significant impact of institutional pressure on RE adoption, it is more difficult to anticipate the direction of this impact. As both the business and the academic communities seem to be evenly split between RE enthusiasts and die-hard skeptics, it is impossible to hypothesize whether an investor receive positive or negative institutional pressure without knowing which community (pro or against RE) she referred to before making decisions. We therefore propose the following hypotheses:

Hp. 2a. Institutional pressure from peers exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.

Hp. 2b. Institutional pressure from external consultants exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.

Hp. 2c. Institutional pressure from published technical information exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.

3.3. Attitude towards radical technological innovations

A third factor influencing the investment process pertains to the attitude toward radical technological innovations and the uncertainty which is inherently associated with them. Uncertainty plays an important role in technology adoption and investment decisions [29]. In the energy sector, different forms of uncertainty, including regulatory, technical and market uncertainty have been found to have an effect (typically negative) on RE adoption and RE investments [65,77–79]. Technological uncertainty is also inherently related to the investors' attitude towards risk, which has been a central theme in behavioral finance [80]. Not surprisingly, some scholars have also noted an agent's *attitude* towards technological uncertainty and risk has a strong influence on technology adoption decisions [81] and, also, on portfolio diversification strategies [79].

As renewable energy technologies are often perceived as unproven technologies with greater technological uncertainty but, also, with the potential to generate higher future returns, we argue that an agent's attitude vis-à-vis technological uncertainty has also a strong influence on investment decisions. We expect investors with a favorable attitude towards radical (and hence more uncertain) technological innovations to be more likely to invest in RE compared to more conservative actors. In other words, we expect that investors who manifest a preference for radical technological innovations over more mature systems will be inherently less risk-averse, and, therefore, more inclined to select technologies with a greater upside potential, even if they display a higher expected cost. This argument is formalized by the following hypothesis.

Hp. 3. Greater propensity for radical technological innovations is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

3.4. Knowledge of the operational context

Finally, we expect investment decisions to be influenced by the level of knowledge that investors have of the broad operational context in which RE projects are deployed. Scholars have noted that incomplete or imperfect information on RE technologies may increase adoption barriers and slow down RE diffusion. For instance, Richards et al. [82] suggest that many barriers to wind energy adoption can be explained by the presence of knowledge or information gaps. The impact of knowledge gaps is further reinforced by the presence of a priori biases because if incorrect or incomplete knowledge about a particular technology fits with the decision maker's personal biases, it is taken as a fact and perpetuated [83].

These findings resonate with well known results on cognition from behavioral economics. Differences in individual cognitive abilities and skills have been associated with differences in judgment and decision-making performance [84,85]. Individuals with higher cognitive abilities (i.e. individuals that can acquire more complete or more accurate knowledge and can do so faster) tend to make optimal choices more often than people with lower cognitive abilities [86].

In line with these findings, we expect an agent's knowledge of the operational context in which RE are implemented (i.e. her knowledge of the whole RE ecosystem) to affect RE investment decisions. We expect industry knowledge to influence investment decisions primarily through its effect on uncertainty. Imperfect knowledge of the RE operational context increases the perceived level of uncertainty of the investment opportunity. As greater uncertainty is usually associated with greater barriers to RE adoption, risk-neutral investors with more limited industry knowledge will be less likely to invest in RE projects. Also, even risk-seeking investors that may value the higher upside potential of projects with greater technological uncertainty may feel unable to hedge against this technological uncertainty if they have limited understanding of the overall context in which they operate. These arguments are summarized by the following hypothesis.

Hp. 4. Greater knowledge of the RE operational context is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

In the following section we examine the impact of the factors highlighted above on three distinct variables: i) the overall degree of RE share in the investment portfolio; ii) the degree of technological diversification of the portfolio and iii) the share of each specific technology in the investment portfolio.

4. Methods

4.1. Sample selection and data collection

The above hypotheses were tested by analyzing a sample of primary cross-sectional data. The research design included a combination of qualitative and quantitative methods [87,88] and was articulated into two phases. In the first phase, documentary analysis and interviews with experts were carried out to refine the conceptual model and assure content validity for the various constructs in the model. In the second phase, a web-based survey questionnaire was developed, pre-tested, and administered to a sample of European investors.

As a first step of the data collection process, a database of target respondents was developed. Contact details of companies and their senior representatives were gathered from multiple sources, including the websites of the European Venture Capital Association and its national affiliates, The Business Place website and other specialized directories. Additional sources of information included the lists of participants to some of the most reputed international conferences on sustainable energy finance, such as the Wind Energy Conference for Equity Investors, the Renewable Energy Finance Forum, and the New Energy Finance Summit. Overall, a list of about 300 contacts in various European countries was collected. Investor profiles included Venture Capitalists, Private Equity Funds, Asset Managers, Investment Funds, Commercial Banks and Energy Companies. We received 136 responses of which 43 responses had to be discarded because they were either plainly unreliable or greatly incomplete. As a result, 93 questionnaires were ultimately retained for the analysis, corresponding to an effective return rate of 31%, which is in line with studies of this nature.

The administration of the survey took place between June and September 2009. Before launching the survey, a pre-test with a limited number of investors from the sample and other relevant stakeholders was conducted in order to validate the measurement and refine the research instrument. The investors selected for the full survey received individual invitations via email. Reminders were also sent at regular intervals. Furthermore, a link to the survey was posted on the UNEP Sustainable Energy Finance Initiative website. In order to limit the impact of self-assessment and maximize the accuracy of responses, we followed Huber and Power's [89] guidelines: we guaranteed that the information collected would remain completely confidential; we agreed to distribute a personalized feedback document and we promised to share the final results of the study with respondents.

Table 2, which displays descriptive statistics, suggests that the sample is fairly well diversified with respect to the degree of renewable energy penetration in the investment portfolios, the types of technologies included in the portfolios, as well as the profile of investors. The data indicate that about two thirds of the respondents currently invest in renewables. Renewables represent at least 10% of the portfolio for over 70% of respondents, while 27% of respondents invest only in these technologies.

Table 2
Descriptive statistics for the research sample.

	N	%
Exposure to the RE investing domain		
- Yes	62	67%
- No	31	33%
Investment by technology		
- Solar photovoltaic	36	57%
- Wind onshore	29	47%
- Biomass	21	33%
- Solar thermal	15	24%
- CSP	14	23%
- Hydropower	13	21%
- Wind offshore	12	19%
- Geothermal	11	17%
- Biofuels	4	7%
- Tidal/Wave	3	5%
Share of renewables in the investment portfolio		
- Less than 5%	12	19%
- From 5 to 9%	6	10%
- From 10 to 49%	16	26%
- From 50 to 99%	11	18%
- I only invest in renewables	17	27%
Experience in the RE investing domain		
- No experience	10	16%
- Less than 5 years	29	47%
- From 5 to 10 years	17	27%
- More than 10 years	6	10%
Company profiles		
- Venture capital, private equity or hybrid	34	37%
- Banks, hedge funds, pension funds and insurance companies	10	11%
- Project developers and utilities	5	6%
- Infrastructure funds	4	4%
- Private companies	8	8%
- Engineering/other	5	6%
- No response	26	28%
Age of respondents		
- Under 30 years	10	11%
- From 31 to 40 years	35	37%
- From 41 to 50 years	11	12%
- More than 50 years	6	7%
- No response	31	33%
Educational background		
- Economics and business administration	24	25%
- Finance	16	18%
- Legal	2	2%
- Engineering	24	25%
- Multidisciplinary	27	29%

Solar photovoltaics and wind onshore are the two most represented technologies. Biomass, solar thermal and concentrated solar power follow, while tidal and wave are the least represented technologies.

4.2. Operationalization of variables

The variables in the conceptual model were operationalized using a combination of quantitative indicators and psychometric scales, as appropriate. A priori beliefs were operationalized by means of multi-item psychometric scales. Respondents were first asked to express their degree of agreement with some statements reflecting six common beliefs about renewables, using a 5-point Likert scale. These questions were developed using a cognitive psychology approach, employing alternative formulations of the same problem to assess the influence of variations in framing on choice selection. The items were then factor analyzed using orthogonal rotation. After eliminating two items with high levels of cross loadings, the procedure yielded a two-factor solution representing, respectively, the degree of confidence in renewable energy technological adequacy and the degree of confidence in policy effectiveness. The two variables were finally operationalized by aggregating the items tapping into each construct. The degree of *confidence in RE technological adequacy* was assessed by means of the following two items: a) energy supply from new renewable electricity sources (e.g. wind and solar) will grow by more than 10% per year worldwide over the next 20 years; b) solar energy is a low-density resource, requiring a lot of land: therefore it will never achieve a significant share of the world's energy mix (reversed). The *confidence in the effectiveness of existing policies* was assessed by means of the following two items: c) market forces alone will never lead to a significant exploitation of renewables; d) government intervention does more harm than good, let governments stay out of the way (reversed).

The three institutional pressure variables were measured as follows. Respondents were first asked to rank the following 5 sources based on the extent to which they influenced their investment decisions: i) investments by well-known/high-profile investors in the sector; ii) technical reports; iii) their personal intuition; iv) in-house due diligence; and v) consultants' opinion. The five variables were then factor analyzed using a principal component approach with orthogonal rotation. The analysis revealed the existence of the three hypothesized factors: *institutional influence of peers*, *institutional influence of outside consultants* and *influence of technical information*. The corresponding variables were then formed by aggregating the items tapping into each construct.

The *attitude toward radical technological innovations* was assessed by means of a two-step procedure. Respondents were first asked to allocate a hypothetical investment budget of USD 10 million to three different solar technologies with increasing degrees of technological uncertainty: crystalline silicon cells, thin film cells, and third-generation solar cells based on nanostructures. The construct was then measured as the ratio of the amount allocated to the radically innovative technologies (nanostructures) to the amount allocated to the less innovative technologies (crystalline silicon and thin films).

To assess the level of *knowledge of the RE operational context* we followed a slightly different procedure. Respondents were first asked to express the extent to which they considered the following four different levels of investments in renewables appropriate to attain the CO_2 abatement targets indicated by the Kyoto protocol: a) an increase in the global investment needs of USD 17 trillion between 2005 and 2050; b) an increase in the global investment needs of USD 45 trillion between 2005 and 2050; c) an increase in the investment needs of 1.1% of cumulative global GDP between 2005 and 2050; and d) an increase in the investment needs of 0.4% of cumulative global GDP between 2005 and 2050. The four questions were designed so that options a) and d) and options b) and c) were perfectly equivalent (i.e. USD 17 trillion corresponds to 0.4% of the cumulative global GDP, whereas USD 45 trillion corresponds to 1.1% of the cumulative global GDP). The construct was then measured as the reciprocal of the average of the absolute difference between the answers to questions a) and d) and the answers to questions b) and c).[2]

The model included two main control variables: *investor's experience* was measured as the number of years of experience respondents had with the renewable energy sector. To control for *firm type*, we used two dummy variables: dummy_VC included venture capitalists and private equity firms; dummy_funds included pension funds, hedge funds and banks.[3]

The *share of RE in the investment portfolio* was measured through a 5-point scale, where each point corresponded to increasing percentages of renewable energy technologies in the investment portfolio.[4] Finally, portfolio diversification was measured by means of two different variables. First, we have computed a raw *degree of portfolio diversification* by simply counting the number of different RE technologies in which the company had invested, among the following options: biofuels, biomass, geothermal, hydropower, CSP, PV, solar thermal, tidal/wave, wind onshore, wind offshore and other technologies. Second, to take into account the relative share of each technology in the portfolio, we have computed an "*adjusted*" *degree of portfolio diversification*, in which the number of different technologies in the investment portfolio was weighted by the total % of RE in the portfolio. The analysis was repeated using both portfolio diversification variables.

Given the confidential nature of the information collected, all our dependent variables could not be obtained from public sources and had to be self-assessed. As a result, we could not exclude a priori the presences of common method variance (CMV). However, we tested for CMV using Harman's single factor test [90]. Results (available upon request) showed no evidence of this problem in our data. Descriptive statistics for the above variables and Pearson's correlations are displayed in Table 3.

4.3. Econometric analysis

The hypotheses from our conceptual model were tested by estimating the general linear model (1) below:

$$Y_{j,i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \sum_j \beta_j control_{ij} + \varepsilon_i \quad j = 1, 2. \tag{1}$$

Where:

Y_1 RE share in the investment portfolio
Y_2 Degree of diversification of the RE investment portfolio

[2] It could not be excluded a priori that our measure of industry knowledge was just a proxy for the educational background of respondents. To rule out this option, we have re-run all models adding the variable educational background and tried different model specifications, also using different versions of the variable. Respondents were classified into different background categories (Economics and Business Administration, Finance, Legal, Engineering, Other). We therefore created dummy variables with different levels of aggregation (from the most precise one in which all the five categories were individually coded, to the less precise one in which background was classified simply as engineering vs. non engineering). We also tried different model specifications: in the first set of tests the variable educational background was added to the model without replacing the variable 'knowledge of the RE context'. In the second set of tests the variable educational background was used to replace the variable 'knowledge of the RE context' (once again, using all the different dummy coding options). The results were remarkably similar. Educational background had no significant effect on the dependent variables in any of the model tested, not even when knowledge of the RE context was removed from the model. Likewise, the magnitude and the significance of the coefficient of the knowledge variable did not change when educational background was added to the model. For space considerations we have not included the details of these additional tests in the manuscript. They are available from the authors upon request.

[3] Ideally, it would have been appropriate to control for firm size too. In very large organizations the opinion of one senior representative (our typical respondent) may not necessarily reflect the decisions actually implemented by individual investors. Unfortunately this information was not available from our data set.

[4] The scale intervals were defined as follows: (1 = from 0% to 5%; 2 = from 5% to 9%; 3 = from 10% to 50%; 4 = from 51% to 99%; 5 = 100%).

x_1 Confidence in the effectiveness of existing policies
x_2 Confidence in technological adequacy
x_3 Institutional influence of peers
x_4 Institutional influence of outside consultants
x_5 Influence of technical information
x_6 Attitude toward radical technological innovations
x_7 Knowledge of the RE operational context
$Control_j$ Investor's experience, dummy VC, dummy funds;

Eq. (1) was estimated using different econometric techniques as a function of the dependent variable retained (RE share in the investment portfolio vs. degree of technological diversification in the investment portfolio). The degree of diversification in the investment portfolio was measured through a continuous scale. The model could be conveniently estimated by means of Ordinary Least Squares because none of the assumptions required to use OLS was violated by our data (the largest variance inflation factor was below 1.5 and a White test confirmed that heteroskedasticity was not an issue). Yet, as the analysis was based on cross sectional data, to further exclude the possibility of obtaining biased estimates the significance of estimates was assessed using heteroskedasticity consistent standard errors.

Conversely, the RE share was measured through a 5-point scale with uneven intervals. The analysis of this variable was therefore conducted by estimating the models by means of both OLS and multinomial logit, which is well suited for rank-ordered categorical dependent variables. The results of the two estimation techniques were consistent and are both reported.

Finally, to analyze the determinants of investment decisions for each specific technology we estimated the series of logit models (Eq. (2)) below:

$$P\left(T_j = 1\right) = \frac{1}{1 + e^{\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \sum_j \beta_j control_{ij} + \varepsilon_i}}. \tag{2}$$

Where (in addition to the variable described above):

$P(T_j = 1)$: probability that technology j is included in the investment portfolio, with j = hydro, solar thermal (including concentrating solar), photovoltaics, wind and other technologies.

The results of the analysis are presented in Table 4 (analysis of RE share in the investment portfolio), Table 5 (analysis of the degree of portfolio diversification) and Table 6 (analysis of individual technology choices).

5. Results

A descriptive analysis of the responses reveals that the investors in our sample have clear preferences for mature and well established renewable energy technologies such as on-shore wind. Against this background, our study has brought some interesting findings to light. Table 4 displays the results of the regression models analyzing the impact on RE share (OLS and logit). Both models are significant ($F = 4.58$ with $p < 0.01$ and $-2LL = 37.769$, with $p < 0.01$ respectively). Table 5 reports the impact on portfolio diversification. These models (with either the raw or the adjusted degree of portfolio diversification) are significant too ($F = 2.92$ with $p < 0.01$ and $F = 5.03$ with $p < 0.01$) and fully consistent. Finally, Table 6 summarizes the results of the logit models examining the impact of behavioral factors on individual technological choices. All these models are also significant, with the only exception of the model examining 'other' RE technologies and, to a more limited extent, of the model examining investments in wind generators.

As hypothesized, a priori beliefs have a positive influence on the investors' willingness to back renewable energy projects and to diversify their portfolios. However, the degree of confidence in technology effectiveness has a stronger impact than the confidence in policy effectiveness in both the model analyzing RE share as a whole ($\beta = 0.49$ with $p < 0.01$ versus $\beta = 0.16$ with

Table 3
Descriptive statistics and Pearson correlations.

	Min	Max	Mean	Std	1	2	3	4	5	6	7	8	9
1. Confidence in the effectiveness of existing policies	1.00	5.00	3.45	0.80									
2. Confidence in technological adequacy	2.00	5.00	3.55	0.72	−0.02								
3. Attitude toward radical technological innovations	0.00	9.00	2.40	1.74	−0.05	−0.14							
4. Investor's experience	1.00	4.00	2.29	0.63	0.23	0.12	−0.05						
5. Knowledge of the RE operational context (reversed)	0.00	1.50	0.54	0.46	0.15	0.14	0.01	−0.18					
6. Institutional influence of peers	1.00	5.00	2.62	1.15	−0.21	−0.10	0.19	−0.25	0.10				
7. Institutional influence of outside consultants	1.00	5.00	3.28	0.84	−0.03	0.14	0.18	0.04	0.03	0.20			
8. Influence of technical information	1.00	5.00	2.25	1.03	−0.06	0.19	−0.02	−0.03	0.15	−0.04	0.21		
9. RE share in the investment portfolio	0.00	5.00	2.15	1.95	0.38	0.13	−0.22	0.34	0.08	−0.29	−0.05	−0.08	
10. Degree of diversification of the investment portfolio	0.00	10.00	2.03	2.33	0.30	0.11	−0.15	0.35	0.01	−0.32	−0.08	−0.16	0.57

Table 4
Impact of non-financial factors on RE share: results of the regression models.

	Dependent variable: RE share in the investment portfolio			
	OLS		Logistic regression	
	Parameter estimate	Heteroskedasticity consistent std. error	Parameter estimate	St. error
Confidence in the effectiveness of existing policies	0.16	0.17	0.09	0.23
Confidence in technological adequacy	0.49***	0.16	0.53**	0.23
Attitude toward radical technological innovations	−0.33***	0.08	−0.53	0.38
Investor's experience	0.42**	0.18	0.48**	0.23
Knowledge of the RE operational context	0.63***	0.20	0.80***	0.27
Institutional influence of peers	−0.15	0.18	−0.20	0.23
Institutional influence of outside consultants	−0.23*	0.14	−0.28*	0.23
Influence of technical information	−0.05	0.17	−0.10	0.22
Dummy funds	−0.86	0.69	−0.95	0.86
Dummy VC	0.41	0.42	0.39	0.54
R^2	0.38			
F	4.58			
p	<0.01			
−Log likelihood			37.69	
p ($>\chi^2$)			<0.001	

* Significant at the 0.1 level.
** Significant at the 0.05 level.
*** Significant at the 0.01 level.

p > 0.10) and the model examining the degree of portfolio diversification (β = 0.14 with p < 0.10 versus β = 0.06 with p > 0.10). This might be interpreted as an indication that the proven reliability of a technology is a *conditio sine qua non* for investing. In other words, investors seem to have a strong preference for technologies that have already overcome both the technology and cash flow "valleys of death" [54]. This finding confirms the results of a previous survey, which highlighted that during an economic downturn investors tend to invest in less innovative technologies in the short term [91].

Quite surprisingly, and in sharp contrast with the hypothesized effect, a positive attitude toward radical technological innovations which are still far from commercial viability is negatively associated with the renewable energy share in the portfolio (β = −0.33 with p < 0.01), whereas its impact on portfolio diversification is less strong and moderately significant (but only in the adjusted portfolio diversification case with β = −0.09 and p < 0.1). This can be due to the fact that most of the portfolios are skewed towards relatively well known renewable energy technologies. Investors who have an appetite for technological risk and invest in radically new technologies need to hedge against this risk by including a higher share of conventional technologies in their portfolios compared to those who invest in less innovative options. Thus, the total renewable energy share in their portfolios will be lower than that in the portfolios of investors with a moderate appetite for technological risk. As our dependent variables do not distinguish among types of renewable energy investments, this effect cannot be singled out. However, the phenomenon is consistent with standard portfolio theory. When a specific asset becomes more volatile, investors tend to compensate for that volatility increase by adding less risky assets in their portfolios. It is also implicitly consistent with recent research on the impact of risk attitudes on energy portfolios. Risk-neutral investors focus on the minimization of expected costs and prefer less diversified portfolios at lower cost. Conversely, risk-averse actors minimize Conditional Value at Risk (CVaR) and seek more diversification, even if this comes at higher costs [79]. Another explanation could be that investors willing to invest in radically new technologies still do not find enough credible and well documented investment opportunities.

Institutional factors generally exert a negative influence on both RE share and portfolio diversification. However, the magnitude of this influence is different for the two dependent variables and changes as a function of the specific factor considered. The institutional pressure of both peers and outside consultants has a strong negative impact on portfolio diversification (β = −0.16 and β = −0.22, both significant at the 5% level) but a less significant impact on RE share (only the impact of outside consultants is significant with β = −0.23 and p < 0.1). Institutional pressure does not necessarily induce investors to stay away from RE projects. Rather, it forces them to concentrate their investments on a few specific technologies. Interestingly, the influence of technical information (specialized press, technology reports, technology briefs, etc.) is insignificant in both models, confirming that the technological opinions are influenced more by a priori beliefs than by factual information.

The investors' experience has a very relevant positive impact on the RE share in the investment portfolio (β = 0.42, p < 0.05); and a relevant positive impact on the portfolio diversification too (β = 0.23, p < 0.05). These results suggest that while, on average, institutional factors exert a moderately negative pressure against renewable, more experienced investors are able to resist this pressure and accept higher shares of RE technologies in their portfolios. Fund managers who have greater experience with the renewable energy sector are possibly more capable of recognizing the value of innovative technologies and prefer renewables over more traditional energy sources.

Finally, as hypothesized, the investors' knowledge of the RE operational context plays a significant role in determining investment decisions (β = 0.63, p < 0.01 in the RE share model; β = 0.23, p < 0.05 in the portfolio diversification model). It seems

Table 5
Impact of non-financial factors on portfolio diversification: results of the regression models.

	Degree of diversification of the investment portfolio		Adjusted degree of diversification of the invest. portfolio	
	Parameter estimate	Heteroskedasticity consistent std. error	Parameter estimate	Heteroskedasticity consistent std. error
Confidence in the effectiveness of existing policies	0.06	0.11	−0.01	0.11
Confidence in technological adequacy	0.14*	0.09	0.21***	0.08
Attitude toward radical technological innovations	−0.07	0.05	−0.09*	0.05
Investor's experience	0.23**	0.10	0.24**	0.11
Knowledge of the RE operational context	0.23**	0.10	0.30***	0.11
Institutional influence of peers	−0.16**	0.08	−0.17**	0.07
Institutional influence of outside consultants	−0.22**	0.09	−0.25***	0.08
Influence of technical information	−0.04	0.08	−0.03	0.08
Dummy funds	0.00	0.38	−0.01	0.32
Dummy VC	0.24	0.22	0.24	0.21
R^2	0.28		0.40	
F	2.92		5.03	
p	<0.01		<0.01	

* Significant at the 0.1 level.
** Significant at the 0.05 level.
*** Significant at the 0.01 level.

natural that investors with specific industry knowledge are more likely to go against the conventional wisdom and make above average investments in RE projects with risky returns.[5]

The results of the individual technology adoption model provide interesting findings too. They suggest that investments in photovoltaics are the ones most positively affected by the degree of confidence in technological effectiveness ($\beta=0.90$, $p<0.01$) and most negatively affected by the institutional pressure of external consultants ($\beta=0.58$, $p<0.1$) Also, whereas the degree of confidence in policy effectiveness does not have an influence on the RE share at an aggregated level, it does have an influence on investments in PV ($\beta=0.57$, $p<0.1$) and hydro ($\beta=0.58$, $p<0.1$). This is tantamount to saying that dedicated polices to support RE technologies are likely to foster investments in these specific technologies only.

6. Conclusions and implications for theory and practice

RE proponents, especially in Europe, suggest that renewable energy sources have the potential to play a crucial role in reducing carbon emissions and fossil fuel consumption in all sectors of the economy. Yet, the difficulties encountered by many countries in meeting their Kyoto emission reduction targets [92],[6] as well as the resistance to setting new legally binding targets at the Copenhagen Summit, prove that exploiting this potential is far from obvious. Indeed, while the advocates of the RE option suggested that huge additional investments are needed to realize the RE potential and achieve the proposed carbon emission reduction targets, no agreement could be reached on this point [93].

Needless to say, this is particularly challenging in a context of global economic uncertainty. Although investors can play a key role in mobilizing capital to support renewable energy technologies, evidence suggests that they are often reluctant to do so. Clearly, dedicated policies can be, and have been, implemented to stimulate renewable energy investments. However, many of the efforts conducted so far have been only moderately effective because, by failing to understand the behavioral context in which investors make decisions, they have been unable to leverage some key drivers of the investment process.

In a market economy, the effectiveness of a policy is dependent upon its impact on investors' behaviors. Thus, to maximize the impact of future policies, policy makers need to get a better understanding of how investors behave and take their decisions, particularly in relation to the psychological factors that may influence their behaviors and actions.

Yet, despite this evidence, there is a surprising lack of rigorous empirical studies examining these issues in the energy literature. This paper represents one of the first attempts to fill in this gap. Drawing upon studies in behavioral finance and institutional theory, we have examined how investors' a-priori beliefs, response to institutional pressure, attitude toward radical technological innovations and knowledge of the RE operational context affect investments in renewable energy projects.

Our analysis has revealed that a priori beliefs on the technical adequacy of the investment opportunities play a much more important role in driving investments than the perceived effectiveness of existing policies. Implicitly, this suggests that agents consider the proven reliability of a technology as a necessary condition for investing in it, while they believe that market

[5] As this effect remained significant even after controlling for educational background, it is reasonable to argue that the knowledge influencing investors' behaviors is practical knowledge acquired with experience, rather than theoretical knowledge derived from formal education.

[6] Although at the end of 2010, the EU-15 was on track to achieve its Kyoto target, some of its member states such as Austria, Italy Spain and Luxembourg seemed to struggle with it. Other countries faced difficulties too, including Switzerland, Australia and Canada. In December 2011, Canada even expressed its intention to withdraw from the Kyoto Protocol.

Table 6
Impact of non-financial factors on specific technology choices: results of the logistic regressions.

	Hydro		PV		Solar thermal		Wind		Other	
	Par est	St. error	Par est	St. error	Par est	St. error	Par est	St. error	Par est	St. error
Confidence in the effectiveness of existing policies	0.58*	0.36	0.57*	0.35	−0.07	0.31	0.32	0.28	−0.63*	0.37
Confidence in technological effectiveness	−0.49	0.38	0.90***	0.34	0.19	0.31	0.43	0.27	0.34	0.35
Attitude toward radical technological innovations	−1.53	1.29	−0.90	0.80	−0.20	0.51	−0.61	0.66	0.19	0.28
Investor's experience	0.85*	0.46	0.25	0.31	0.29	0.29	0.09	0.27	0.42	0.32
Knowledge of the RE operational context	−0.51	0.45	−0.28	0.32	0.31	0.30	−0.14	0.28	0.22	0.33
Institutional influence of peers	−0.80*	0.49	−0.22	0.32	−0.44	0.36	−0.69**	0.32	−0.57	0.40
Institutional influence of outside consultants	−0.75	0.53	−0.58*	0.34	−0.07*	0.31	−0.13	0.27	−0.02	0.30
Influence of technical information	0.09	0.42	0.22	0.30	−0.50	0.30	0.14	0.28	−0.29	0.35
Dummy funds	−2.10	1.95	−0.55	1.10	1.09	1.10	−0.12	1.04	2.03*	1.20
Dummy VC	0.33	0.92	2.06	0.77	1.06*	0.66	−0.44	0.63	0.93	0.73
−Log likelihood	56.502		86.240		82.319		101.462		69.265	
p $(>\chi^2)$	0.01		0.00		0.00		0.11		0.18	

* Significant at the 0.1 level.
** Significant at the 0.05 level.
*** Significant at the 0.01 level.

inefficiencies can be corrected through the adoption of appropriate policy instruments. The results have also revealed a group of investors with extremely short investment horizons, who are extremely sensitive to the institutional pressure of peers and external consultants in their investment decisions.

The paper makes a contribution to the energy policy, strategic management and behavioral finance literatures, and has some implications for managerial practice and policy making. Firstly, the incorporation of cognitive and behavioral elements is an important theoretical contribution and produces a more accurate description of the phenomena underlying investment decisions in RE technologies. Second, the research can advance the emerging field of sustainable investments. The few studies on this topic have focused on a restricted group of investors, namely venture capitalists. By expanding the scope to a broader set of actors operating in the sustainable energy field, this work contributes to validate and extend previous findings. Our results appear also relevant for practitioners in the sustainable energy market. A priori beliefs and limited knowledge of the broader RE context create additional barriers that restrain the likelihood of raising capital for clean energy investments. The analysis of these elements as opposed to more rational factors can help investors get a more balanced view of risks and opportunities in this industry.

Finally, the implications for policy makers are also clear. Investors seem to have very little faith in dedicated policy measures that directly support RE technologies (for instance through short lived subsidies). Conversely, they seem much more sensitive to the technical feasibility or the proven performance record of a technology as well as to institutional pressure. As a consequence, RE budgets should be redirected to leverage these factors, for instance by supporting R&D programs in the public and private sectors, by promoting demonstration projects, and by further disseminating information on RE systems within the relevant business circles and key stakeholders.

Like most research, our study is not exempt from limitations. A first limitation is that the results may be difficult to generalize because the study was restricted to a specific empirical and geographical context (Europe). It is therefore important to stress that the conclusions may not hold outside this context. We acknowledge that the focusing on a sample of European investors may introduce a bias in favor of RE for at least two reasons. First, in Europe the market for renewable energy has been traditionally supported by stronger incentives than, say, the United States. Second, European consumers are traditionally more sensitive to environmental concerns than their American or Asian counterparts, thereby creating a more favorable environment for RE investments.

A second limitation pertains to the fact that the dependent variables used in the models are self assessed. Although we have controlled the presence of CMV, the use of objective, quantitative measures of technology adoption would be necessary to further validate our findings. A third limitation is that we did not include any financial investment variables in the model. Yet, we believe that omitting these variables had little effect on the estimated impacts of the factors included in the model. Given that our sample included a relatively homogeneous set of investors who operated in the same geographical region and in the same time window, we would have hardly found enough variance in the variables describing the financial characteristics of the technologies. Finally, although we did control for some exogenous factors, the relatively limited sample size did not allow for a better differentiation among renewable energy investments. The survey included investments in a wide range of different renewable energy technologies with different degrees of innovativeness and risk. Clearly, some of the phenomena observed may be technology-dependent and require further investigation. We expect to address some of these issues in follow-up works.

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