European Commission

The representation and implications of the financing challenge

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Executive summary

Context

The financial sector is increasingly cited as an **important pillar of the energy transition**. In EU policy, the importance of private investments has been highlighted in the 2020 Climate and Energy Package, the 2030 Climate and Energy Framework, the Governance of the Energy Union Regulation and the long-term decarbonisation strategy. It is not without reason that discussions are shifting towards the financial sector, since this unprecedented transition will require **trillions of euros** in investments, most of which will be sourced from the private sector.[1]

Objectives of the report

This report is part of a wider study on the "Macroeconomics of the Energy Union", delivered for the European Commission (DG Energy). The study aims to **improve the macroeconomic modelling tools** (namely, GEM-E3[2] and E3ME[3]) used by the Commission to inform its decision-making around topics related to the energy transition. The report particularly focuses on model improvements related to **issues around financing** and aims to: (1) identify where and how issues around financing affect the progress of the energy transition; (2) assess to what extent the macroeconomic models capture these areas of influence; and, (3) propose model improvements to address the most important gaps. Together, these objectives contribute to an improved ability to capture the financial dimension of energy policies.

Analysis and suggested model improvements

Understanding the financing challenges of the energy transition begins with understanding what drives investment decisions. In this report, we emphasise the importance of **risk and return considerations** as primary drivers of investment decisions. This means that investors look for opportunities that balance both risks and returns, ensuring that returns are higher than their cost of capital. To improve financing conditions for projects that are relevant to the energy transition, policy makers can use levers that directly target risks, returns or cost of capital (thereby lowering the minimum required return on an investment). The impact of these levers (A, B and C, respectively) are illustrated in the figure below (Figure 0-1).

[1] EP (2017). *Financing the transition to clean energy in Europe*.

[2] For more information, see *GEM-E3*.

[3] For more information, see *E3ME*.

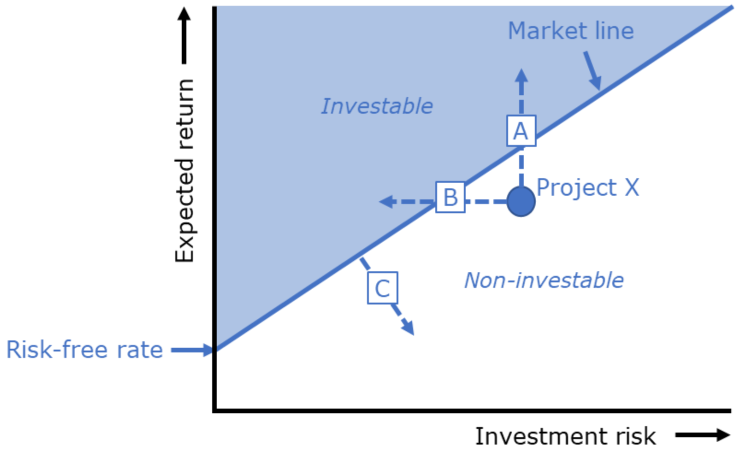

Figure 0-1: Making projects investable through various policies (levers)

Source: Own elaboration.

Beyond using various policy measures to improve financing conditions, it is important to understand that the factors that influence investment decisions (either directly or indirectly) are influenced by long-term trends. Some of these trends are captured in risk assessments, while others lead to different conditions for investment decisions in the future. In this report, we identified six trends that are likely to influence the financing of energy investments over the long term. Some of these trends, along with a series of policy options, were discussed with interviewees and considered as **potential model improvements** (see Table 0-2 below). For each suggested update below, the report describes potential approaches to improving the models.

Table 0-2: Assessment of potential model improvements

Potential model improvement	Relevance and significance	Decision
#1 Detail investments and investment decisions focused on energy efficiency in buildings	The relevance of the financial sector for energy efficiency investments is not so straightforward. Financing only become relevant once other, non-financial barriers (e.g. split incentives between landlords and tenants) are addressed.	Not a priority
#2 Reflect differences in risk per country and technology	Reflecting differences in risk per country and technology through differentiated discount rates can have significant effects on financing costs.	Update
#3 Reflect differences in sustainability of debt per borrower	The importance of the debt burden of utilities for financing investments in the power sector is less clear-cut than presumed due to the wide array of investors in the sector and the widespread use of project financing. Hence, the sustainability of the debt burden of utilities is not expected to affect financing conditions in a material way.	Not a priority
#4 Apply lower average sales prices for intermittent energy sources	The high penetration levels of intermittent energy sources such as wind and solar can significantly affect their sales prices (relative to wholesale prices). Increasing the flexibility of the energy system may offset part of this effect, but it is likely that a significant impact on sales prices will remain.	Update

#5 Incorporate the financial learning curve into the discount rate	The financial learning curve (although less significant than the technology learning curve) has been identified by practitioners in the financial sector as important. Research shows that gaining experience financing new technologies can lead to lower costs of capital for those technologies.	Update
#6 Broaden the range of policy options that can be modelled	The most important policy options for the financial sector (i.e. those most significantly affecting prices and costs) are already modelled.	Not a priority

Further insights with relevance for policy makers

Beyond the model improvements suggested above, our analysis led to a series of conclusions that are relevant for policy makers. It can be noted that the most important investment decisions for the energy transition are those that happen at the point of project development and financial closure (of new energy assets). Public policy can influence these decisions and the resulting financing conditions by targeting risks, returns and cost of capital. Practitioners in the financial sector consider policies that directly target risks and returns more important than policies addressing capital availability. Furthermore, the financial sector neither expects financing conditions to be affected by shortage of capital, nor by ‘sustainability’ considerations. Still, the cumulative effect of increasingly mature renewable energy technologies, increasingly stringent climate legislation and an overall more hostile environment for fossil assets has led to a situation where renewable energy investments have access to much cheaper capital than fossil investments.

1. Introduction

This report is a deliverable of the project ‘Study on the Macroeconomics of the Energy Union’ delivered for the European Commission, DG Energy. The overarching aim of the project is to improve the macroeconomic modelling tools used by the European Commission to inform its decision-making around topics related to the energy transition. The work focuses on improving the two main models used for this purpose (namely, GEM-E3 and E3ME) and treats different improvement areas in separate tasks.

This report is part of the task that concerns model improvements related to issues around financing the energy transition, in particular with respect to the role of the financial sector in financing investments in the energy sector (including energy efficiency, excluding transport). The specific objectives of this report are threefold:

1. Identify where and how issues around financing and the financial sector affect the progress of the energy transition most significantly;
2. Assess to what extent the macroeconomic models capture these areas of influence in a sufficiently realistic and detailed manner;
3. Propose concrete model improvements to address the most important gaps.

Together, these objectives contribute to an improved ability to evaluate policies that impact financing challenges and the financial sector.

Relevance

The financial sector is increasingly cited as an important pillar of the energy transition, and greater focus has been placed on mobilising **private capital flows**, following key climate and energy targets that have been established at both the EU and international levels (e.g. see targets in Figure 1-1).

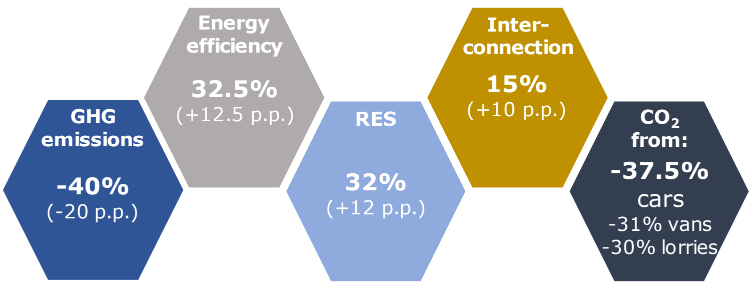

Figure 1-1 Agreed targets under the 2030 Framework for Climate and Energy, and percentage point (p.p.) change compared to 2020 targets

Source: Own elaboration, with data from EC (2019).[4]

[4] EC (2019). *Fourth report on the State of the Energy Union* [COM(2019) 175 final].

In EU policy, the importance of private investments has been highlighted in the 2020 Climate and Energy Package[5], and has since been re-emphasised in the 2030 Climate and Energy Framework[6], the Governance of the Energy Union Regulation[7] and the recent long-term decarbonisation strategy[8]. It is not without reason that discussions are shifting towards the financial sector, since this unprecedented transition of the energy sector will require **trillions of euros in investment** most of which will be sourced from the private sector.[9] As was stated in a European Commission (EC) memo from 2017, *"Public climate finance will continue to play a significant role. However, this is not enough. We need a broader range of contributions. To achieve our goals, we need to increase the flow of the private capital in green and sustainable investment."*[10]

Report structure

The report is structured into the following chapters:

1. **Introduction;**
2. **Understanding the financing challenge;**
3. **Current representation of the financing challenge in the models;**
4. **Suggestions on model improvements;**
5. **Conclusions and recommendations.**

The aim of **Chapter 2**, is to deliver an accurate view on how investments in the energy sector are made in the real world, drawing on insights from interviewees and relevant literature. This overview serves as the basis for identifying areas where the models' representation of the real world could be improved. The chapter starts by identifying and detailing where the financial sector has the most concrete influence on the progress of the energy transition: the investment decision. Next, we provide insight into the scale and type of investments that are needed and define the different types of capital providers. Afterwards, we present the policy options available to influence investment decisions in the energy sector and conclude with an overview on the main trends that affect investment decisions over time. Together, these inputs provide a comprehensive overview of the relevant aspects of the energy transition's financing challenge and the role of the financial sector.

In **Chapter 3**, we detail how the two models (GEM-E3 and E3ME) currently represent the financing challenge, and identify areas where improvements could be considered. For this, we compare findings from Chapter 2 with the current design of the models, specifically looking at their sectoral coverage, their representation of the investment decision, relevant

[5] EC (2008). *20 20 by 2020 - Europe's climate change opportunity* [COM(2008) 30 final].

[6] EC (2014). *A policy framework for climate and energy in the period from 2020 to 2030* [COM(2014) 15 final].

[7] EC (2016). *Proposal for a Regulation of the European Parliament and of the Council on the Governance of the Energy Union, amending Directive 94/22/EC, Directive 98/70/EC, Directive 2009/31/EC, Regulation (EC) No 663/2009, Regulation (EC) No 715/2009, Directive 2009/73/EC, Council Directive 2009/119/EC, Directive 2010/31/EU, Directive 2012/27/EU, Directive 2013/30/EU and Council Directive (EU) 2015/652 and repealing Regulation (EU) No 525/2013* [COM(2016) 759 final/2].

[8] EC (2018). *A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* [COM(2018) 773 final].

[9] EP (2017). *Financing the transition to clean energy in Europe*.

[10] EC (2017). *Questions and answers on EU and Climate finance*.

trends, and their ability to evaluate policy options. Any discrepancies between what is considered important in real life and what is treated in detail in the models are flagged as potential improvement areas.

In **Chapter 4**, we prioritise the improvement areas and provide inputs on relevant methods and data sources that can be used for addressing the improvement areas with the highest priority. For this, we draw on insights from literature, descriptions of other models, and interviews with model developers. Where feasible, datasets for model improvements are provided as an annex to this report.

Finally, in **Chapter 5** we first summarise the main findings and conclusions on the topic of financing the energy transition, and close with remarks on prioritisation of improvement opportunities.

2. Understanding the financing challenge

Since the vast majority of required investments will call for private-sector financing[11], it is important to understand **what drives the investment decisions of private actors**. An understanding of investment decisions is instrumental in further examining the dynamics of the financial sector in the context of the energy transition. Beyond looking at how investors make decisions, this chapter will also explore the investments that are required to meet the demands of the energy transition, the types of private-sector investors that can play an important role in the transition, the policy options available to encourage private capital flows, and the trends that influence investment decisions over time.

2.1. The investment decision

Investment decisions are to a large extent driven by **risk and return considerations**. In other words, investors want to balance the risks they face with the potential earnings on their investments. In addition to risks and returns, other factors can influence investment decisions, but they vary from investor to investor. As can be seen in Figure 2-1, other drivers of investment decisions include: project size, portfolio considerations, and corporate social responsibility (CSR) objectives.[12]

[11] EC (2018). *A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* [COM(2018) 773 final].

[12] For more background information and analysis on the range of influencing factors that drive investment decisions, see the prior study on the macroeconomics of energy and climate policies (Trinomics et al. (2017) - Assessing the European clean energy finance landscape, with implications for improved macro-energy modelling).

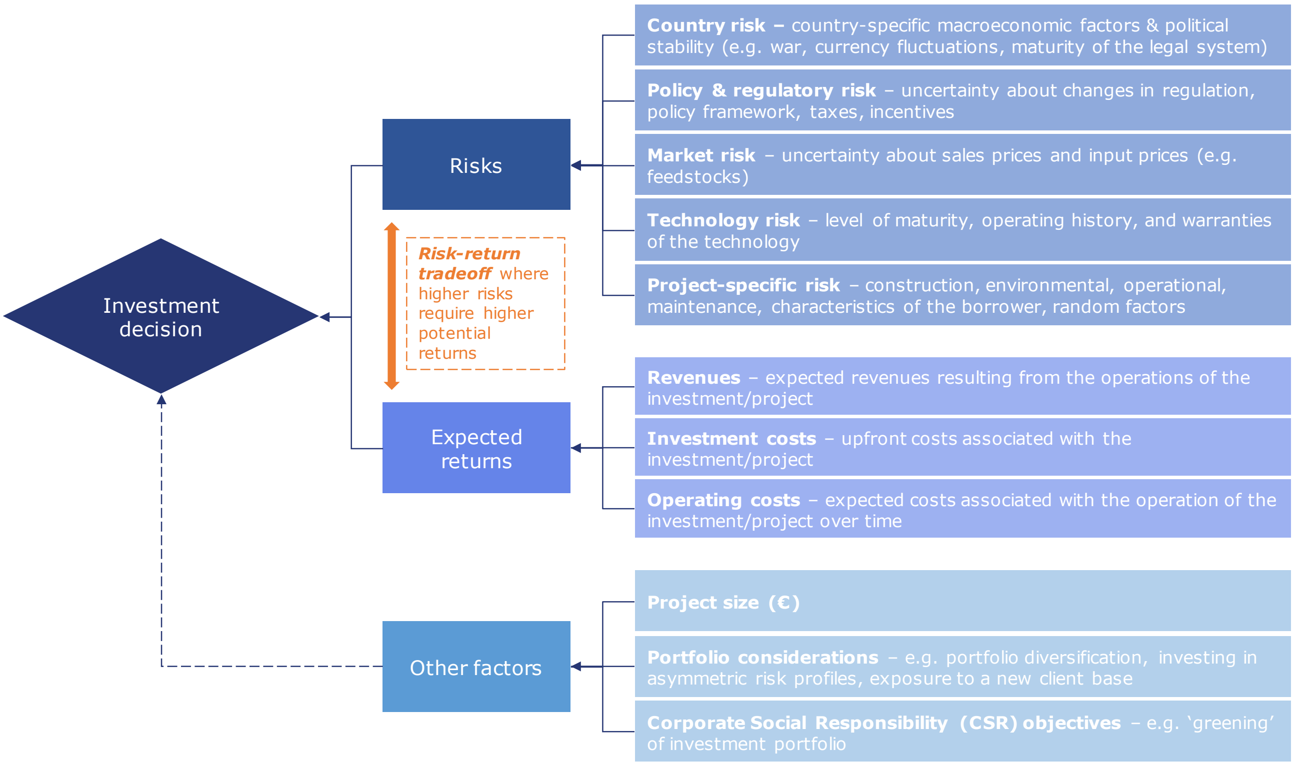

Figure 2-1: The investment decision

Source: Own elaboration.

Risks

Risk can be described as the potential deviation of an investment's actual returns from its expected returns. Risk therefore implies uncertainty about future outcomes. In economics and in finance, as well as in everyday life, humans aim to lower or to eliminate uncertainty. Our dislike for uncertainty is called **risk aversion**. For an investor, this means that when comparing two investments with equal expected returns, the investment with lower risks will appear more attractive. Although, risks imply both positive or negative deviations from expected returns, in practice, investors are primarily concerned with avoiding potential losses. Potential losses consist of the amount of money invested into the project and the cost of recouping the amount lost (i.e. the time value of money). Consequently, risk aversion is accompanied by loss aversion, whereby losses weigh heavier than gains.[13]

To compensate for the uncertainty of expected returns, investors may claim management costs, commercial margins and, most importantly, a **risk premium**. The latter is designed to compensate for potential losses, making an investment attractive despite existing risks. In practice, the risk premium is driven by the probability of default and the loss given default. The risk premium will thus vary according to the perceived risk (i.e. the perceived uncertainty) of an investment, and will result in a higher cost of capital. The risk premium is added to the 'risk-free' interest rate, which can be estimated in different ways. The risk-free interest rate is the rate of return of a hypothetical investment with no (or negligible) risk of financial loss. In practice, interbank rates such as the Euribor (i.e. the Euro Interbank

[13] Kahneman and Tversky (1984). Choices, Values and Frames. *American Psychologist*, *April 1984*, *39*, 341–350.

Offered Rate) or yields on government bonds are used as a proxy for the risk-free rate (as is shown in Table 2-1 below).

In order to finance a project, a firm will combine equity and debt in various proportions and from various sources. Equity and debt are different forms of finance that originate from different investors. ‘Equity’ represents ownership (or company shares), while ‘debt’ refers to borrowing capital from a lender (e.g. a bank). The overall cost of capital for the firm is expressed as the **weighted average cost of capital (WACC)**, which proportionately weights the cost of all sources of capital in the following way[14]:

$$WACC = \frac{E}{E+D} * R_e + \frac{D}{E+D} * R_d(1 - T_c)$$

The WACC is a metric that determines the amount of interest/dividends that a company will have to pay for each euro that it invests. Put differently, the WACC indicates the return that both lenders and equity holders expect to receive; and the (expected) rates of return of both equity and debt are influenced by the risk premium. The risk premium has an upwards effect on the cost of capital and it varies from project to project (and across technologies) since it is driven by a series of context-specific risk factors (see Figure 2-1). Although it is difficult to isolate the effect of specific risk factors on the risk premium, practitioners agree that the following main risk factors contribute to the risk premium:

- **Country risk** is a broad term that encompasses a variety of risks related to the macroeconomic conditions and political stability of the country in which the project will be implemented. As part of this analysis, a variety of variables may be looked at: e.g. inflation, exchange rate risks, currency controls and devaluation, the stability and durability of the political regime, the maturity of the legal system, and general instability due to wars, famine and strikes;[15]
- **Market risk** refers to the volatility of sales and input prices (e.g. feedstock prices), which have the potential to negatively affect the profitability of a given investment;
- **Policy and regulatory risk** is also assessed at country level. Policy and regulatory risk relates to the general stability of the policy regime and the legal basis on which it stands. Volatile or uncertain regulation, or changes in taxes, tariffs and other incentive structures are all factors that may pose a threat to a project’s profitability. Administrative burdens related to permits, authorisations or licenses may also increase regulatory risk, as they can impact the timeline and costs of a project;[16]
- **Technology risk** refers to the risk of a technology not performing as expected and includes both the risk of unexpectedly high periods of downtime and maintenance requirements as well as higher than expected degraded performance over time. This risk is driven by the technology’s characteristics and maturity. Technology risk is

[14] In the WACC formula, ‘E’ represents equity, and ‘D’ denotes debt; ‘R_e’ refers to the cost of equity (or return on equity), ‘R_d’ refers to the cost of debt (or return on debt), and ‘T_c’ is the corporate tax rate.

[15] Country risk is often evaluated based on the ‘sovereign credit ratings’ issued by international rating agencies such as Standard & Poor’s (S&P), Moody’s and Fitch. These agencies are expected to provide impartial and rational estimates of a country’s general investment atmosphere, thus guiding investors in their decisions. The ratings are an indication of the creditworthiness or the level of risk associated with investing in the debt of a particular country. For example, S&P provides an investment grade for bonds rated “AAA” to “BBB-“, but any bond rated lower than that is considered ‘junk’. Table 3 (p.35) in the *Finance Guide for Policy-makers: Renewable Energy, Green Infrastructure* by Bloomberg New Energy Finance (BNEF), Chatham House, the Frankfurt School of Finance & Management, and UNEP (2016) provides further explanation on the credit ratings of different agencies.

[16] Country, policy and regulatory risks can also be assessed from a regional perspective, especially when it comes to cross-border projects.

sometimes also associated with public acceptance risk, because investing in certain technologies may be met with public disapproval (as can be the case with nuclear or carbon capture and storage (CCS) projects, for example);

- **Project-specific risk** identifies any costs or possible liabilities incurred during the development, construction and operational phases of a project. The earlier a project is in its development process, the higher the risk. Project-specific risks may include risks associated with the build, the interfacing of different contracts, the degree of protection from liquidated damages for project delays, environmental and social risks, contracts required during the operational period and provisions required for decommissioning. As part of the project-specific risk evaluation, the characteristics of the borrower (e.g. existing indebtedness, financial capacity/size, experience/track record) and the project team are also looked at. With respect to the construction stage of the project, the quality of materials may also be taken into account. For RE plants particularly, grid connection, secure transport and delivery of electricity can be seen as project-specific risks.[17]
- Another subcategory of risks that are evaluated on a project by project basis are 'random factors' that fall out of the hands of both project developers and investors. A readily available example of such factors are weather conditions, which can present an important risk to RE projects. In this case, past weather trends are looked at to determine the probability of weather trends changing in the future.

Box 2-1 Climate risk versus traditional risk factors

How about climate risk?

Over the past years, the topic of climate risk has gained increased attention in the financial sector.[18] Consequently, how banks are dealing with climate risk was often on the top of the interviewee's mind during our interviews. Still, we chose not to introduce a separate climate risk category in our representation of the investment decision. The primary reason for this is that a separate climate risk category would overlap with the other risk categories as climate change affects the likelihood and impact of various risks rather than being a discrete, separate risk.

In the literature, climate risk is often separated into physical risk and transition risk.[19] Physical risks concern the impact of the increased likelihood of floods, droughts, storms and other natural phenomena. The extent to which these risks may impact an investment depend on the location of the investment and are therefore very project-specific. Hence, we consider that such risks are part of what we labelled 'project-specific risks'. Transition risks refer to the impact of climate policy, technological developments and changing consumer preferences as a result of climate change and the response to it. In our representation of the investment decision, such risks are primarily covered in policy/regulatory risk (in case of climate policy for instance) and market risks (in case of faster than anticipated technology development or changing consumer preferences).

[17] Greenpeace (2015). *Energy [R]evolution. A sustainable world energy outlook 2015*.

[18] See for instance S&P (2015) – *Climate risk: rising tides raise the stakes*.

[19] See for instance DNB (2017) – *Waterproof: an exploration of climate-related risks for the Dutch financial sector* and Oliver Wyman (2019) – *Climate Change: Managing a new financial risk*.

Some risk factors can be assessed quantitatively, and others only qualitatively; but ultimately, the risk premium combines all risk factors according to a subjective set of expectations regarding the future[20], as part of the **risk analysis and due diligence process**. As underlined above, the risk premium adds to the cost of capital. This means that riskier investments require higher returns to attract and compensate investors. This also means that higher returns are offered on projects that are at an earlier stage in the development process, rather than in operation, due to the fact that there are more risks that may materialise at an early stage.

An example of the impact of country risk on the risk premium is shown in Table 2-1, but other risk factors can further contribute to the risk premium, and consequently, to the cost of capital. The example below shows that, for an identical debt-to-equity ratio of 70%, a firm in the US has an annual cost of capital of 6%, while a firm in South Africa has a cost of 15%. This difference in WACC means that a similar investment in South Africa needs to have higher returns than in the US for it to be financed. In the table below, the country risk is captured by the government bond yields individual to each country.[21]

Table 2-1 Example of the impact of country risk premium on the cost of capital

Country	UK	US	India	South Africa
Risk-free rate (based on 10Y government bond yield 01.09.15)	1.91%	2.41%	8.56%	8.52%
Assumed spread on loans	2.50%	2.50%	2.50%	2.50%
Cost of debt	**4.41%**	**4.91%**	**11.06%**	**11.02%**
Total equity risk premium (including default spread and country beta)*	6.20%	5.75%	9.13%	8.75%
Cost of Equity	**8.11%**	**8.16%**	**17.69%**	**17.27%**
Assumed debt-to-equity ratio	70%	70%	70%	70%
Marginal tax rate**	20%	40%	35%	28%
WACC	**8%**	**6%**	**14%**	**15%**

*Country risk premium based on data inputs provided by Damodaran, 2014[27]. **Corporate tax rate according to KPMG, 2015.

Source: Imperial College London (2016).[22]

Returns

While risks are captured by the WACC via the risk premium, the expected gains of an investment are captured by the **internal rate of return (IRR)**. This is the metric most often used in capital budgeting to estimate the expected rate of return on potential investments.

[20] Imperial College London (2016). *The cost of capital and how it affects climate change mitigation investment.*

[21] In some cases, the risk-free rate can already incorporate a measure of country risk, if government bond yields are differentiated per country. Another way to measure the risk-free rate would be to use the government bond yield of a relatively risk-free country (e.g. Germany), and to add a country risk premium to that. These methods of representing country risk can also be observed in the different methods of calculating the cost of equity, either unconditionally (whereby the country risk is included in the risk-free rate) or conditionally (whereby the country risk is included in the market risk premium). These methods are described in Deloitte (2017) – *Overview of business valuation parameters in the energy industry*.

[22] Imperial College London (2016). *The cost of capital and how it affects climate change mitigation investment.*

In practice, the IRR is the *discount rate* that makes the net present value (NPV) of all cash flows (CFs) from a particular project equal to zero, as follows:

$$NPV = 0 = -I_0 + \frac{CF_1}{1+IRR} + \frac{CF_2}{(1+IRR)^2} + \cdots + \frac{CF_t}{(1+IRR)^t} = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t}$$

As Figure 2-1 shows, returns are driven by costs, including initial investments costs (represented by 'I_0' in the IRR calculation above), as well as revenues. In a first instance, an IRR may need to pass a certain threshold to catch the attention of certain investors. However, to deepen their analysis on the actual added value of a given investment, investors will compare the IRR to the WACC. This analysis provides information on the difference (positive or negative) between the cost of capital and returns. A company which invests in projects with an IRR lower than its cost of capital (i.e. IRR<WACC) will lose money in the long run and will ultimately not be able to pay its capital providers the return they expected. However, an investment with a higher IRR than cost of capital (i.e. IRR>WACC) signals 'added value', i.e. the ability to pay the interest rate on debts and dividends higher than initially expected by investors. This entails that the WACC is actually the **minimum required return** on a project. Hence, the WACC is also commonly used as a hurdle rate against which companies can benchmark return on invested capital (ROIC) performance and as the discount rate for future cash flows in discounted cash flow (DCF) analyses.

Other factors

Some additional factors that impact investor decision-making have been listed inFigure 2-1. However, these factors vary depending on *who* is investing. Investors of different profiles will look to invest in projects of varying **sizes** (in terms of value). For example, large investors such as pension funds, will look to invest in large (and typically less risky) projects, while venture capital firms will target smaller and riskier investments. The risk and size of projects undertaken by investors are often linked to their **portfolio considerations**. The role of pension funds, for instance, is to invest money in assets that will provide stable cash returns over a long period of time (e.g. to be able to provide sufficient income to retirees). To guarantee stable returns, pension funds and other institutional investors therefore need to invest in assets whose risks are as far as possible insulated from potential shocks in the stock market (i.e. assets with asymmetric risk profiles). Other investors may seek shorter term profits, or they may target projects that require their technical know-how and thereby allow them to add value. Additionally, certain investments may prove attractive because they open the door to new potential clients and markets.

CSR objectives make up another driver of investment decisions. Such objectives may be defined by managers or shareholders who wish to 'green' their investment portfolio for strategic reasons. In the case of utility companies, decisions to invest in greener technologies can be encouraged by customers demanding more green energy. Similarly, public-sector investors are motivated by social and environmental objectives, in line with the public agenda.

These additional factors can sometimes over-ride one another depending on what is most important for the investor. Likewise, these factors can sometimes over-ride risk-return considerations. This may be the case when PR-driven motivations become more important; investors may then accept lower returns or higher risks to invest in socially or environmentally desirable projects. That being said, in the long run an investor can only take on projects that match their available budgets and allow them to retain a healthy and profitable position over time. In some cases, an investor (for example, a pension fund) may be prevented by law from trading off returns against CSR objectives. Hence, risk and return considerations will always remain key drivers of investment decisions.

2.2. The investment needs for the energy transition

The relevance of understanding how investment decisions are made in the context of the energy transition can only be fully appreciated when looking at the investments that are needed to reach a fully decarbonised energy system. Hence, in this chapter we will provide an overview of the scale of investment that is needed and what different types of investments this entails.

Investment needs

As highlighted at the beginning of this chapter, there is a growing interest in the financial sector's contribution to the energy transition, and the ways in which policy-makers can support investors. This growing interest stems from the estimated volume of capital required to meet the EU's strategic objectives with respect to the energy transition. Table 2-2 below attempts to bring together available figures on the order of magnitude of investment needs. As shown in the table, cumulative investment needs in the coming decade (2021-2030) are estimated to reach almost **EUR 6 trillion** in the EU alone, and approximately **EUR 12 trillion** over the following two decades (2031-2050), excluding transport.[23,24] On a global level, total investment needs (excluding transport) have been estimated to reach around EUR 35 trillion up to 2030[25,26] and EUR 100 trillion up to 2050[27,28].

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[23] EC (2018). *In-Depth Analysis in Support of the Commission Communication COM(2018) 773. A Clean Planet for All. A European long-term strategic vision for a prosperous, modern, competitive and*

climate neutral economy.

[24] In constant 2013 €.

[25] Energy Transformation Commission (2017). *Better Energy, Greater Prosperity*.

[26] In constant 2010 €.

[27] IRENA (2018). *Global Energy Transformation A Roadmap to 2050*.

[28] In constant 2015 €.

Table Error! No text of specified style in document.**-1 Order of magnitude of total investment needs up to 2050 in the EU, in constant € (excluding transport)**

Source	Period	Constant prices	Total investment needs (€)		Share of GDP (%)[29]	Target
			Cumulative	Annual		
Current investments						
IEA (2019) World Energy Investment 2019	2018	USD 2018 (converted to EUR 2018)	N/A	*€180 bn*	1.1% GDP	N/A
Up to 2030						
Trinomics and Öko-Institut (2018) Energy and the MFF	2021-2030	EUR 2013	€3,790 bn	€379 bn[30]	2.3% GDP	2030 climate and energy targets
In-depth analysis accompanying COM(2018) 773[31]	2021-2030	EUR 2013	€5,730 bn	€573 bn	3.4% GDP	2030 climate and energy targets
Up to 2050						
IRENA (2018) Global Energy Transformation A Roadmap to 2050	2015-2050	USD 2015 (converted to EUR 2015)	*€7,756 bn*	*€172 bn*	0.8% GDP	2°C
In-depth analysis accompanying COM(2018) 773	2031-2050	EUR 2013	€8,780-11,520 bn	€439-576 bn	2%-2.6% GDP	2°C for the lower bound, 1.5°C for the upper bound

Source: Own elaboration based on a review of sources (as listed in the first column).

Note: Figures in *italics* have been converted from USD to EUR based on the average exchange rate of the constant prices in question. According to ECB statistics, the average USD-EUR exchange rate in 2015 was 0.9019, and in 2018, 0.8796.

According to the IEA (2019) World Energy Investment report[32], the current level of investment in the energy sector (including investments in energy efficiency) amounted to EUR 180 billion in 2018, or 1.1% of GDP. This number needs to increase at least threefold in order to meet the demand of the energy transition and the more ambitious 1.5°C scenarios. This estimate is in line with the IPCC special report[33], which estimated that

[29] Share of GDP has been calculated as the annual total investment needs divided by the projected GDP (in 2030 or in 2050, depending on the timeline of investment needs), where relevant. The projected GDP figures were retrieved from the EU Reference Scenario 2016, while the 2018 GDP figure was retrieved from Eurostat.

[30] Figure calculated based on the EUCO30 scenario from the impact assessment accompanying the revision of the Energy Efficiency Directive.

[31] The in-depth analysis accompanying COM(2018) 773 looks at eight scenarios (in addition to the baseline scenario). The investment needs shown for the period 2031-2050 cover a range between the least expensive (CIRC) and the most expensive scenario (1.5 TECH). The analysis also includes the investment needs for the baseline scenario for the period 2021-2030 (€396 bn/year), and makes note of the additional investment needs in this period (€177 bn/year), based on the figures from the impact assessment accompanying the revision of the Energy Efficiency Directive. Additional investment needs in this period could also decrease by 15% due to the revised 2030 targets.

[32] IEA (2019). *World Energy Investment 2019*.

[33] IPCC (2018). Special Report on Global Warming of 1.5 °C [SR15]. *Chapter 4: Strengthening and Implementing the Global Response*.

approximately 2.5% of global GDP in investments are required in the energy system between 2016 and 2035 to limit global warming to 1.5°C.

While the investment needs of more than EUR 500 bn/year may look daunting compared to current investment levels of EUR 180 bn/year, it is important to keep in mind that current investments in the EU energy sector are relatively low historically due to overcapacities in the electricity market and little opportunity for new fossil fuel developments. Furthermore, the EU import bill of fossil fuels is still high with annual imports exceeding EUR 300 bn[34], part of which would become available in a low carbon future. Moreover, investment would be needed even in a future which failed to decarbonise energy use: the gross figures cited here are not the *additional* investment cost of decarbonisation (although investment costs will be higher in a decarbonising future). However, in a relatively more recent assessment of *additional* investment needs, the European Commission's modelling of the EU32-32.5 scenario demonstrates that an additional EUR 260 bn/year[35] are needed to meet the objectives of the 2030 climate and energy targets.[36,37]

Areas of demand

At EU level, the most recent and comprehensive overview of investment needs comes from the in-depth analysis on the **long-term decarbonisation strategy** released in 2018.[38] The analysis constructs eight pathways (or scenarios) leading to a decarbonised Europe by 2050. These eight pathways focus on different technologies and can be compared to a baseline scenario across both energy supply and energy demand. The extent to which supply or demand sectors require investments depends on the pathways and on the technologies that are prioritised. However, it is still worthwhile to note that demand-side investments make up an important share of investment needs across all pathways (between 54% and 71%). The latter are most significant in the Energy Efficiency (EE) pathway, which requires less investment in power generation (supply) relative to investments in energy efficiency measures (across all sectors). The Power-to-X (P2X) pathway, which prioritises e-fuels in industry, buildings, (and transport), requires heavier investments in power generation relative to other pathways. The Electrification (ELEC) pathway emphasises the electrification of all sectors, and thus, power-grid investments are most significant in this scenario.

Demand-side investments are strongly driven by the needs of the residential sector, as can be seen in Table 2-3. Higher investment needs in the residential sector highlight a stronger reliance on energy efficiency measures in contrast to supply-side investments. As such, there is a substitutability between energy efficiency and supply-driven investments. Furthermore, the modelling illustrates the potential of the circular economy and lifestyle

[34] Eurostat (2019). *EU imports of energy products – recent developments*.

[35] This includes additional investment needs in transport, which amount to around €25 bn/year in comparison to the business-as-usual scenario. This number was taken from Figure 5 in COM(2019) 285.

[36] EC (2019). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. United in delivering the Energy Union and Climate Action – Setting the foundations for a successful clean energy transition.* [COM(2019) 285 final].

[37] EC (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Sustainable Europe Investment Plan. European Green Deal Investment Plan.* [COM(2020) 21 final].

[38] EC (2018). *In-Depth Analysis in Support of the Commission Communication COM(2018) 773. A Clean Planet for All. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*.

changes to reduce additional investments overall, with the Circular Economy (CIRC) scenario requiring the least amount of additional yearly investments out of the eight scenarios (EUR 62 billion). Nonetheless, even in the CIRC scenario, additional supply-side investments amount to EUR 41 billion, representing 66% of the scenario's additional investment requirements.

Table: Average annual investment needs over the 2031-2050 period, per scenario (% of total, excluding transport)

	Base-line '21-'30	Base-line '31-'50	EE	CIRC	ELEC	H2	P2X	COMBO	1.5 TECH	1.5 LIFE
Supply	**29%**	**30%**	**28%**	**35%**	**40%**	**41%**	**46%**	**40%**	**43%**	**39%**
Power grid	14.95%	18.91%	17.24%	20.73%	23.22%	20.07%	18.91%	19.04%	17.85%	17.40%
Power plants	13.61%	10.66%	10.79%	13.74%	16.17%	19.07%	21.41%	17.93%	20.89%	18.09%
Boilers	0.43%	0.34%	0.24%	0.41%	0.40%	0.22%	0.12%	0.13%	0.14%	0.12%
New carriers	0.03%	0.08%	0.19%	0.21%	0.21%	1.21%	5.73%	3.10%	3.80%	3.18%
Demand	**71%**	**70%**	**71%**	**65%**	**60%**	**59%**	**54%**	**60%**	**57%**	**61%**
Industry	4.57%	2.94%	7.61%	3.01%	2.86%	2.91%	2.74%	5.04%	4.88%	4.30%
Residential	50.23%	52.89%	50.24%	48.20%	45.14%	43.81%	39.31%	41.82%	39.22%	43.87%
Tertiary	16.25%	14.24%	13.63%	13.74%	12.00%	12.78%	11.81%	12.85%	13.19%	13.06%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Total (€)[39]	**396 bn**	**377 bn**	**468 bn**	**439 bn**	**475 bn**	**454 bn**	**504 bn**	**522 bn**	**576 bn**	**519 bn**

Source: Own elaboration based on the PRIMES scenarios of the In-Depth Analysis in Support of the Commission Communication COM(2018) 773.[40]

Supply-side investments represent, on average (across all scenarios), 39% of total annual investment levels in 2031-2050 (when excluding transport). Amongst the latter, investments in power generation and in the grid make up the largest share of investments. The required investment efforts in power generation and the grid increase further with the rise in ambition level of the 1.5°C pathways (i.e. 1.5 TECH and 1.5 LIFE). On the supply-side, investments in power generation also imply investments in the transmission and distribution (T&D) network. Investments in trans-European energy infrastructure alone are estimated to total EUR 229 bn in the coming decade.[41] These T&D investments include electricity transmission, gas transmission, storage, oil supply connections, carbon networks and power-to-gas grid injections; the most significant share of T&D investments resulting from electricity transmission (65%).[42] The increase of regional integration and interconnection of electricity markets is crucial to the energy transition. Equally, it is the key to integrating localised energy production.[43] Other studies also point to a large share of investments going into renewable energy infrastructure (for power and end-uses), energy efficiency, and

[39] In EUR 2013.

[40] EC (2018). In-Depth Analysis in Support of the Commission Communication COM(2018) 773. A Clean Planet for All. A European long-term strategic vision for a prosperous, modern, competitive and

climate neutral economy.

[41] Ecofys (2017). Investment needs in trans-European energy infrastructure up to 2030 and beyond.

[42] Ibid.

[43] ECF (2010). Roadmap 2050.

energy flexibility to integrate renewables in the power sector.[44] Figure 2-2 shows the spread of investment needs in the 2020-2030 period across different RES sectors in the EU.

Research and development (R&D) investments are not explicitly covered in these estimates but will also be required to enable the energy transition. These investments are of a much smaller scale, however, with EU public R&D budgets for renewables in the order of EUR 1 bn/year. Hence, the specificities and challenges around R&D funding are not covered in this study, which focuses on the larger macroeconomic financing challenges.

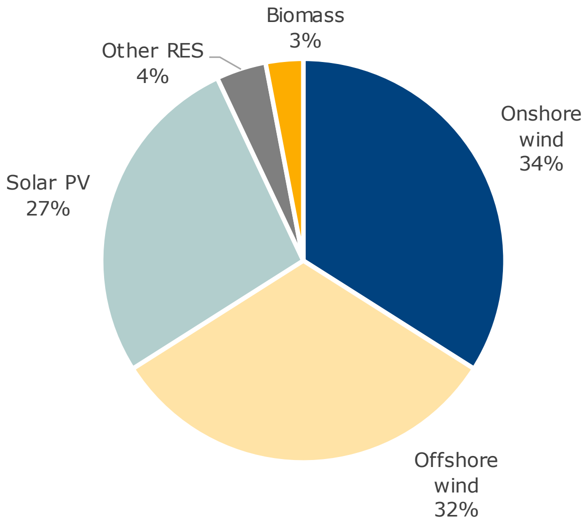


Figure 2-2 Share of required annual investments across different RES sectors, 2020-2030

Source: Own elaboration based on data from EC (2016).[45]

2.3. Private sources of finance and their risk appetite

To tackle the financing challenge of the clean energy transition and to match the different characteristics of the kinds of investment that need to be funded, financing is needed from investors of different sizes, origins, and risk attitudes. This subsection will introduce the different private sources of finance, and will underline what role they have in the clean energy transition.

The main source of private funding can be grouped into the following categories:[46]

- **Institutional investors** are organisations that invest on behalf of their members (e.g. pension funds, insurance companies, and sovereign wealth funds). Institutional investors are generally considered 'large' investors that look for steady and safe returns to provide a stable income flow to their members;

[44] IRENA (2018). *Global Energy Transformation. A Roadmap to 2050*.

[45] EC (2016). *Commission SWD Impact Assessment Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (recast)*.

[46] BNEF, Chatham House, and the Frankfurt School-UNEP Centre (2016). *Finance Guide for Policy-makers: Renewable Energy, Green Infrastructure*.

- **Commercial banks** are a type of financial institution that accepts deposits, makes loans, and offers other services, such as checking account services, to individuals and businesses. Commercial banks earn income (that they can further re-invest) from the interest on the loans they provide and other management fees, as well as potential assets that they buy from consumers;
- **Venture capital (VC)** is financing that investors provide to start-ups and new, young and/or small businesses that are believed to have long-term growth potential. VC can also take the form of technical or managerial expertise. Within the realm of VC, investors can focus on the 'seed stage' to get a company or project off the ground, 'early stage' to help accelerate a company's sales and marketing efforts, or 'growth stage' to help companies grow beyond a certain point to become truly successful. Other seed or early-stage investors are 'seed' and 'angel investors'. VC funds raise capital from a wide range of sources, including institutional investors and high-net-worth individuals, but early stage capital can also be provided by financial institutions such as investment banks;
- **Private equity (PE)** consists of funds and investors that directly invest in private companies (through equity) or that acquire the controlling interest in public companies. PE funds also raise capital from a variety of sources such as high-net-worth individuals and institutional investors, but they take on less risk than VC funds. PE funds target companies and projects with more mature technologies, including companies that are preparing to raise capital on public stock exchanges; and,
- **Public equity** refers to the capital that is invested in firms via stock (share) offerings.

A comparison of these investors can be found in Table2-4. In the table below, the figures on expected returns provide an indication on the **risk preferences** of each investor. As was highlighted in subsection 2a, the higher the expected returns, the more open investors are to taking risks. Given this reasoning, VC firms are willing to take on the most risk, but have high return expectations, resulting in a high cost of capital. Institutional investors are the largest investors with typical transaction sizes up to €500 million. However, as their low expected returns indicate, they are the most risk averse. Somewhere in the middle, PE firms can be characterised as having a 'medium' risk profile.

Table 2-4: Main private-sector financial actors

Investor	Type	Stage of intervention	Expected returns[47]	Typical investment size ('ticket size')
Institutional investors	Equity	Late stage	6-15%	€10m-€500m
Commercial banks	Debt	Mid stage, late stage	1-7%	€20m-€100m
Venture capital (VC) and other early-stage investors	Equity or 'convertible' debt	Seed stage, early stage	>50%	€300k-€5m
Private equity (PE)	Equity	Early stage, mid stage	15-25%	€30m-€200m
Public equity	Equity	Mid stage, late stage	6-8%	N/A[48]

Source: Own elaboration, with insights from BNEF et al. (2016)[49], Trinomics (2017)[50], Trinomics and adelphi (2017)[51], Trinomics (2018)[52], European Private Equity & Venture Capital Association (2014)[53], Preqin (2019)[54], and Bain & Company (2019)[55].

When interpreting these figures it is important to realise that most investments benefit from a mix of sources of capital.[56] Hence, even when investors with relatively high expected returns are involved, the overall cost of capital (i.e. the WACC) may be much lower due to high shares of cheaper capital.

Important to realise is that not all investor types make direct investments in new energy assets at the stage of project development and financial closure, which is represented by the investment decision at the start of this chapter. In particular institutional investors and public equity do not feature as potential investors at this stage. In the case of institutional investors this is due to the too small size of the investment, combined with a too high risk profile. In the case of public equity this is due to the fact that stock markets only offer company stock and not project stock. Hence, these investor types are not involved in the investment decision as presented at the beginning of this chapter. They do play a role in the energy transition, however, for instance by taking over equity stakes in realised projects, thereby freeing up risk-capital for new projects.

[47] Expressed as IRR for equity (except for public equity) and interest rates for debt.

[48] Company shares are bought and traded in any quantity. Hence, there is no 'typical investment size'.

[49] BNEF, Chatham House, and the Frankfurt School-UNEP Centre (2016). *Finance Guide for Policy-makers: Renewable Energy, Green Infrastructure*.

[50] Trinomics (2017). *Assessing the European clean energy finance landscape*.

[51] Trinomics (2017). *Task 1: Improving the investment community to facilitate increased investments*.

[52] Trinomics (2018). *The Entrepreneur's Guide to Growing and Financing Innovative Energy Technology Companies*.

[53] European Private Equity & Venture Capital Association (EVCA) (2014). *Accelerating Innovation & Delivering Growth: Using the Jobs, Growth and Investment Package to Attract Private Sector Investors to the European Venture Capital Industry*.

[54] Preqin (2019). Database on the number and value of infrastructure deals in the world (1988-2019).

55 Bain & Company (2019). *Global Private Equity Report 2019*.

56 This can be either directly, in case of project finance, or indirectly, in case of corporate finance.

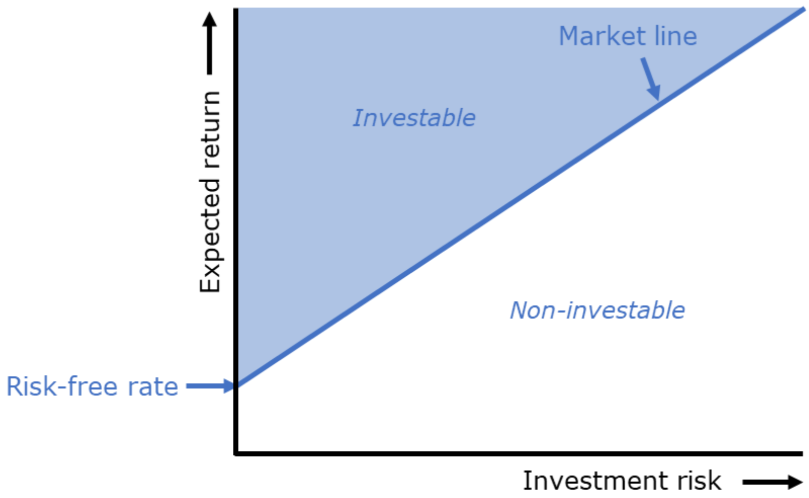
2.4. Policy options to address financing challenges

After having looked at the investment needs, the sources of finance and the variables that influence investment decisions, this section continues with a discussion on how the public sector can influence the investment decisions of the private sector, ultimately aiming to mobilise more investments in the energy transition. For this, we start by identifying the levers that influence investment decisions to pinpoint where influence can be had. Afterwards, we identify the most relevant policy options that can be used to influence these levers.

Levers to influence the investment decision

As described earlier, the investment decision is primarily influenced by the risk and return of an investment opportunity, with higher returns and/or lower risks leading to a higher likelihood of attracting capital. This concept is summarised in Figure 2-3.

Figure 2-3 Graphical representation of how risk and return influence investment decisions



Source: Own elaboration based on Higgins (2007).[57]

The *shaded area* in the figure depicts investment opportunities with sufficiently high returns compared to their risks, and are therefore considered ‘investable’. The ‘risk-free rate’ (introduced in subsection 2a) informs the expected return of investors for investments without any risks and thereby determines where the line crosses the y-axis. The slope of the line is dictated by market actors’ requirements for increased returns at higher risk levels. Hence, this line is also known as the ‘market line’ in literature.

Based on this visualisation, there are two obvious levers that can be targeted with policies: (1) the risks and (2) the returns of a project. This is illustrated in Figure 2-4, which shows how a project that is not considered investable can move to the investable area through better returns (lever A) or lower risks (lever B).

[57] Higgins, R. C. (2007). *Analysis for financial management.*

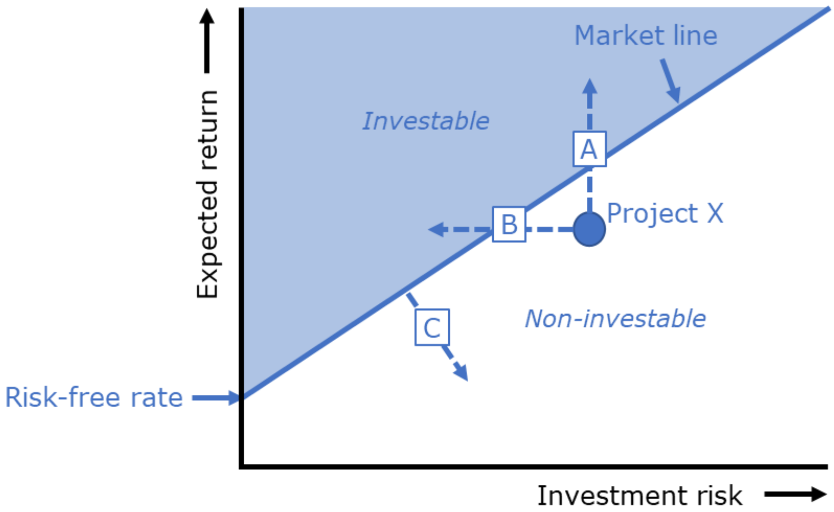


Figure 2-4: Making a project investable through increasing revenue or reducing risks

Source: Own elaboration based on Higgins (2007).[58]

Additionally, a third lever (lever C) can be identified, which is to move the market line downwards and thereby increases the area of investable projects. This can occur when the cost of capital of the investors or the investment vehicle is reduced (see Box Error**! No text of specified style in document.**-1 for further background on investment vehicles). As mentioned earlier, investors look for investment opportunities that have returns higher than their weighted average cost of capital (WACC), provided risks are similar to their current activities. Hence, a reduction in the WACC of the investor(s) should lead to a lower minimum required return (hurdle rate) and thereby increase the range of investable projects.

Box Error! No text of specified style in document.**-1 Project versus balance sheet financing**

Different methods of financing

When evaluating the relevant cost of capital for an investment opportunity, it is important to distinguish between balance sheet financing and project financing. Balance sheet financing occurs when a single investor finances the full project from their balance sheet (e.g. when a utility company decides to develop and finance a windfarm by itself). In this case, the capital is provided by the utility company, and the relevant costs of capital to measure against is the WACC of the utility company. The utility company is in turn financed by a mix of capital providers including, for instance, banks and shareholders, which together affect the company's WACC. There is no direct allocation between the capital attracted and the capital used for the new wind farm. In other words, the capital attracted is added to the company's pool of capital, which it later uses to finance the new wind farm as well as other investments and operational expenses.

Project financing occurs when a separate legal entity with a separate financial structure is created for the project. In this way, capital can be attracted solely for the project that is under consideration and capital providers can make a more direct assessment of the

[58] Higgins, R. C. (2007). *Analysis for financial management.*

risks and returns of the investment opportunity. This could occur when a project developer is realising a wind farm, and manages to attract equity capital from a private equity fund and debt capital from a bank, together funding the entire project. Interest rates and dividends are then paid directly and only from the revenues of the wind farm. In this case, there is a direct link between the capital attracted and the capital used for the new wind farm, as this is the only activity of the legal entity that was created.

In practice, both ways are used to finance projects in the energy sector and both have their advantages and disadvantages, which we will not revisit in this report.[59] For the purpose of this project, it is important to understand, however, that the WACC for a project may either be the WACC of the company financing it (in case of balance sheet financing), or may be the WACC of the capital provided directly to the project.

Policy options that can influence investment-decision levers

Building on the discussion in the previous section, it can be derived that for policies to have an influence on investments they need to address one of three investment-decision levers. This section will identify which policies are available for doing this and will detail their mode of operation (see Table 2-5). This will lead to a comprehensive list of policy options that can be considered by policy makers, and would ideally be represented in the macroeconomic models (which will be evaluated in Chapter 3) to better evaluate the impact of any new policies or policy changes. It is important to note that policy options can have a direct impact on one or more of the three levers discussed above, however, the three levers are themselves interconnected (as explained in subsection 2a). Therefore, a direct impact on one lever will spill over to other levers. Note that in the table below, we only capture the *immediate* effect of policy options.

Table 2-5 Policy options and their impact on risks, returns, and/or the cost of capital

Policy options	Description of impact	Impact area and direction of impact		
		Returns (↑)	Risks (↓)	Cost of capital (↓)
Feed-in-tariffs (FITs)	By setting a tariff that is higher than the market price, the revenues of the project are increased, and the risk of market price volatility is mitigated.	✓	✓	
Feed-in premiums (FIPs)	Adding a premium on top of the market price increases project revenues, guaranteeing a certain level of profitability.	✓		
Net metering	By allowing to deduct energy generated from energy consumed, the owner of the equipment effectively receives a sales price for its energy equal to its purchasing price. Because the purchasing price is always higher than the sales price due to the impact of taxes and grid tariffs, this results in a higher sales price for energy generated (up to the consumption level of the owner). If the owner buys his/her energy at a fixed rate, market price risk is also mitigated for this volume. Hence, the impact is both increased returns and reduced risk.	✓	✓	

[59] See for instance *IEA* – *World Energy Investment 2018* for a more elaborate discussions.

Policy options	Description of impact	Impact area and direction of impact		
		Returns (↑)	Risks (↓)	Cost of capital (↓)
Renewable portfolio standards, green certificates and other (concrete) regulatory obligations	By obliging market players (e.g. utility companies) to, for instance, have a minimum share of renewable energy in their portfolio, the government creates a larger market for renewable energy and, depending on the design, a market for renewable energy certificates. This results in higher sales prices and returns, and lower commercial risks (with a guarantee of a minimum market size).	✓	✓	
Capacity remuneration mechanism	To address adequacy and security of supply problems, the government remunerates existing power plants to stay active. The remuneration generally ensures a minimum level of stable/predictable revenues to cover fixed costs.	✓	✓	
Tax cuts, rebates, favourable tax regime/ instruments	By shifting the tax regime in favour of certain technologies or sources of energy, their economic case becomes more attractive. Lower costs (due to tax cuts) result in improved returns. (In the case of a decrease in corporate taxes, the result is also a lower WACC.)	✓		(✓)
Exemptions from permitting requirements and one-stop shops for permitting	Exemptions from permitting requirements and one-stop shops for permitting lower the financial cost and time associated with administrative processes. Permitting can sometimes slow down the approval or development of the project, which is a risk for project developers. Exemptions and one-stop shops can also lower this risk.	✓	✓	
Carbon taxes	By taxing carbon generating technologies (and thus reducing their profitability), investing in alternatives becomes more attractive from a financial perspective.	✓		
Emissions Trading System (ETS)	By limiting the amount of carbon that can be emitted, companies are forced to think of alternatives, thus developing a new market (and demand for that market). This also means that carbon emitting practices become relatively more expensive, and less financially attractive.	✓		
High-level targets, commitments, plans and strategies (e.g. Paris commitments, National Energy and Climate Plans)	Setting targets, making commitments, and drafting plans/strategies creates signals on what will be supported or penalised by government actions in the future and reduces the risk of sudden policy changes in an opposite direction. However, more ambitious policies for renewable energy may also increase the risk of price erosion for intermittent renewables, adversely affecting the investment decisions.		✓ (↑ & ↓)	
Government-backed guarantees on loans	By covering part of the losses in case of default, the risks for capital providers are reduced, which should lead to a lower cost of capital for the project.			✓
Co-investment through grants	Grant provision lowers the total amount of capital that the project developer needs to raise or to put in, thereby improving the business case of the project.	✓		
Co-investment through (soft) loans or equity	Public loans or equity investments are accompanied by more favourable conditions and lower costs, so the total cost of capital improves.			✓

Policy options	Description of impact	Impact area and direction of impact		
		Returns (↑)	Risks (↓)	Cost of capital (↓)
Fund of funds (FOF) and other policies targeting availability of capital issues	By increasing the availability of capital exactly where it is lacking (e.g. early-stage investments in energy projects), investors have more capital and incentives to invest, thereby reducing their expected returns and the cost of capital.			✓

Source: own elaboration based on interviewee inputs and literature, with particularly relevant inputs from Polzin et al. (2019).[60]

It is worth noting that this overview of policy options is limited to those that directly influence the investment decision made by capital providers. In particular for energy efficiency investments, several barriers exist that may prevent projects from being developed in the first place. For example, issues around split incentives between landlords and tenants may obstruct the development of projects which could have passed the risk/return evaluation of capital providers but do not reach that stage. Policies to address such issues and generate a bigger pipeline of investments are outside of the scope of this report, which is focused on the role of the financial sector in the energy transition.

2.5. Trends affecting the financing challenge over time

The interplay of the factors that influence the investment decision is not a static situation but changes over time due to several long-term trends. Parts of these trends are captured in risk assessments (e.g. the market risk) while others create new conditions for investment decisions in the future (e.g. technological learning curves). Ideally, such developments are well understood and represented in the models to evaluate the impact of policy options over time. In this section, we introduce the main trends that we identified and indicate how these trends affect investment decisions in the energy sector. Here, we differentiate between impacts on investment decisions that are made *now* and impacts on investment decisions in the *future* (so that the outcome of decisions may be path-dependent). In the following chapters, we analyse to what extent such trends are captured in the current macroeconomic models and if there are opportunities to better reflect such trends in the models.

Trend 1: Technological learning

A well-documented trend is the effect that the increased deployment of a technology leads to lower costs of the technology, also known as the technology learning curve (learning by doing). Or, more technically stated, that the "cost of a technology decreases with a constant fraction with every doubling of installed capacity or exercised activity".[61] Such learning curves have been shown to exist for important energy technologies such as solar PV and wind power and have contributed to increased market uptake of the technology.

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[60] Polzin et al. (2019). *How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective.*

[61] See for instance JRC (2012). *Technology Learning Curves for Energy Policy Support*.

The technology learning curve does not feature directly into the investment decision as the technology is procured now at current market prices. Hence, the development of the technology's cost over time is not particularly relevant.[62] What is relevant, however, is that future investments benefit from the learning that is driven by current investments which lead to lower technology costs over time. This effect should particularly be reflected in models that simulate how the energy transition may evolve.

The literature also distinguishes a 'learning by research' relationship, in which higher expenditure on R&D brings about a reduction in technology costs. In practice, commercial R&D funding is likely to be committed when a technology is close to market or has begun to be deployed and so there is a close relationship with the scale of deployment. But for early-stage technologies, the influence of R&D is likely to be stronger that the impact of deployment.

Trend 2: Financial learning

A more recently discovered trend is the effect that increased deployment of a technology, and increased familiarity of the financial sector with that technology, also reduces the cost of capital for that technology. This concept states that experience with deployment and financing leads to lower safety margins applied by financial institutions, which for instance leads to lower debt margins on loans.[63] Our interviews with the financial sector confirm the existence of this effect. Interviewees explain it as a phenomenon where risks are initially overstated due to a lack of familiarity with the technology and a lack of a track record in evaluating these risks. Hence, the perceived risks are higher than the actual risks of the technology at that stage and capital is provided at less favourable rates (or not at all).

The effect of the financial learning curve on the investment decision is similar to that of the technological learning curve – i.e. for the investment decision that has to be made now, the financial learning that is expected to happen in the future is of little relevance. However, for investment decisions in the future, the financial learning curve is relevant and should be represented in the models.

Trend 3: Increasing importance of sustainability of investments

In the last couple of years, an increased importance of sustainability considerations in investment decisions can be seen. Examples include the movement towards divesting from fossil fuel assets, the development of criteria and a taxonomy to define what sustainable investments are[64], and the efforts of financial institutions to align their portfolios with sustainability goals (including the Paris targets). Through such developments, more capital should become available for sustainable energy investments and less for fossil energy investments. In theory, such an increase in supply should lead to lower prices (e.g. lower debt margins) for sustainable investments. In practice, however, financial institutions state that they cannot provide discounts beyond what risk and return considerations allow due to

[62] Apart from the effect that project developers may choose to delay projects to benefit from lower costs over time. However, this is a relatively minor effect in the long-term energy transition.

[63] Egli, F., Steffen, B., & Schmidt, T. S. (2018). *A dynamic analysis of financing conditions for renewable energy technologies*. Nature Energy, 3(12), 1084-1092.

[64] EU Technical Expert Group on Sustainable Finance (2019). *Taxonomy Technical Report.*

financial prudence legislation. Hence, they cannot fully endorse the hypothesis that this trend should to cheaper capital for sustainable investments.

The effect of the sustainable finance trend features in our representation of the investment decision as 'CSR objectives' under 'other considerations' (see Figure2-1). If this effect is assumed to be significant, it would have to feature in the model's evaluation of current investment decisions as a factor that improves the risk/return evaluation for sustainable investments due to the desire to maintain/develop a sustainable portfolio of investments over time. This effect could then be amplified for future investment decisions due to the trend of increasing importance of sustainability considerations.

Trend 4: Lower sales prices for intermittent renewable energy sources

Due to the successful development of solar PV and wind power, these technologies are expected to play a large role in the future energy system. Both technologies generate power intermittently, however, and have marginal costs that are close to zero. Hence, these technologies generate power whenever it is windy and sunny and sell at any price that the market is willing to offer, which leads to increased volatility in wholesale prices with very low prices at times with strong winds or high solar irradiation.[65] While flexibility options can partly mitigate this risk, the expectation is that average sales prices for solar PV and wind will deteriorate at higher penetration levels. Our interviews with the financial sector confirmed this development as a substantial risk for investments in solar PV and wind power.

The effect of this trend on the investment decision should be captured in the assessment of market risk as well as the expected revenues of the project. This effect will not only impact investment decisions in the future, but also investment decisions that are made now, as the effect will influence the revenues of the project over its lifetime. To what extent the impact of this effect will become larger for investments that are made further ahead will depend strongly on the effectiveness of flexibility options in mitigating this effect. The current expectation is that the occurrence of very low wholesale prices will become much more prevalent in 2050, indicating a continuing trend of price erosion for intermittent RES.[66]

Trend 5: More stringent climate legislation

Even though the efforts to stop climate change have not been able to stop the rise of greenhouse gas emissions, there is a clear trend in increasingly stringent legislation to stop climate change. Examples include more prevalent and higher carbon taxes and emission trading schemes across the world, higher efficiency requirements and stricter air pollution limits. With ambitious commitments like the Paris agreement and the EU long-term strategy in place, this trend is expected to continue.

The effect of this trend should be captured in current investments decisions as part of the policy and regulatory risk assessment, particularly leading to additional risks for fossil assets. Additionally, the expectation of increased ETS prices may be factored into the evaluation of the project's returns. Over time, this trend should lead to further worsening of

[65] Metis Studies (2018). *Wholesale market prices, revenues and risks for producers with high shares of variable RES in the power system*.

[66] Ibid.

investment decisions for fossil assets and may also lead to actual bans on certain technologies, forcing their withdrawal from the technology mix.

Trend 6: Fossil fuel depletion and fuel price developments

Expectations on increasing fossil fuel prices due to depletion of reserves have always existed and are generally part of models and scenarios for analysing how the energy transition will unfold.[67] However, long-term price developments do not necessarily signal a trend of increasing prices, when looking at oil price developments for instance.[68] Furthermore, the urge to sell fossils now that they are still profitable and the reluctance of investing in additional fossil fuel production capacities due to the fear of stranded assets may lead to opposing pressures on fuel prices.[69] Still, the interaction between the evolution of the energy mix and the prices of fossil fuels is an important development, which may also lead to lower fuel prices in case of rapid decarbonisation and corresponding reduced demand for fossil fuels.[70]

The effect of this trend should be captured in current investment decisions as part of the expected revenues calculation for fossil fuel-based assets. Over time, this trend may alter the outlook of expected fuel prices (and revenues) in investment decisions, based on the development of the demand for fossil fuels in the model run.

[67] See for instance Fraunhofer (2018) – *Levelized cost of electricity renewable energy technologies*, which assumes rising prices for hard coal and natural gas; and IEA (2018) – *World Energy Outlook* which assumes rising oil and gas prices in both the new policies and the current policies scenarios, but not in the sustainable development scenario.

[68] Helm, D. (2017). *Burn-out – The endgame for fossil fuels*.

[69] Bauer, N., McGlade, C., Hilaire, J., & Ekins, P. (2018). Divestment prevails over the green paradox when anticipating strong future climate policies. *Nature Climate Change*, 8, 130-134.

[70] As for instance assumed to be the case in the IEA's sustainable development scenario.

3. Current representation of the financing challenge in the models

In this chapter, we compare the way that the macroeconomic models of interest (GEM-E3 and E3ME) represent financing issues with our findings about the financing challenge of the energy transition from the previous chapter. More specifically, we assess to what extent the models cover the main investment categories (sectors), the elements of the investment decision, the trends affecting the investment decision over time and the policy options available to influence the availability of finance for the energy transition. Areas where the models do not cover these aspects or not at an appropriate level of detail are identified as potential improvement areas and feed into the subsequent chapter where we review potential improvement areas in detail.

3.1. Sectoral breakdown and coverage

The literature review on the investment needs revealed that the largest volumes of capital are required in the power supply (mainly power generation and grid) and the energy demand sectors (energy efficiency investments, primarily in the residential sector). Hence, the dynamics in these investment categories should be accurately captured in the macroeconomic models, while for other investments a more general and aggregated assessment could suffice. Table 3-1 provides an overview of the categories that are defined in the models for each main investment category.

Table 3-1 Representation of main investment categories in GEM-E3 and E3ME

Investment category	Level of detail in GEM-E3	Level of detail in E3ME
Supply – Power generation	Coal fired Oil fired Gas fired Nuclear Biomass Hydro electric Wind onshore Wind offshore PV CCS Biomass CCS coal CCS gas Geothermal (soft link with PRIMES model)	**Model: FTT:Power** Nuclear Oil Coal PC Coal IGCC Coal PC + CCS Coal IGCC + CCS Gas CCGT Gas CCGT + CCS Solid Biomass Solid Biomass + CCS Biomass IGCC Biomass IGCC + CCS Biogas Biogas + CCS Tidal Large Hydro Wind onshore Wind offshore Solar Photovoltaic Concentrated Solar Power

Investment category	Level of detail in GEM-E3	Level of detail in E3ME
		Geothermal Wave Fuel Cells CHP
Supply – Grid	Transmission and distribution is a separate sector. Infrastructure (incl. grid) is separately modelled. *Other grid investments are not represented (e.g. gas). The gas sector undertakes investments that relate both to capacity and grid expansion.*	*Not represented as investment category. Fixed mark-up assumed between generation costs and final prices to represent grid costs.*
Demand - Residential	The model includes a representation of consumption where durable goods are consumed in combination with non-durable goods using the ratios derived from consumption matrices (link between consumption by purpose and consumption by product). Biomass Oil Gas Conventional and advanced electric appliances Conventional and advanced heating and cooking appliances Conventional and advanced transport equipment (soft link with PRIMES model)	**Model: FTT: heat** Coal District heating Electric Gas Gas condensing Heat pump air-air Heat pump air-water Heat pump ground Oil Oil condensing Solar thermal Wood boiler Wood stove
Demand - Tertiary	*The services sector purchase fuels and electricity as part of their production process. Investments to further (beyond the limits of the elasticity of substitution) improve energy efficiency can be introduced through a satellite energy efficiency module.*	*Investments in energy efficiency not distinguished from other kinds of investment. An impact of higher R&D on energy consumption / savings is captured.*
Demand - Industry	*Substitution of energy with other production factors.* *Energy efficiency cost curve with expenditures allocated to sectors as demand for their products (e.g. for building insulation).*	*FTT: Steel identifies different stages and technologies in the steelmaking process. Fuels include intermediate energy carriers such as coke and pellets. 'Raw' energy carriers are:* • *Coking coal;* • *Other coal;* • *Natural gas;* • *Biogas;* • *Electricity;* • *Hydrogen;* • *Solid biomass.* *For other industry sectors, econometric equations determine total energy use (depending on average energy prices and sector output) and then a disaggregation*

Investment category	Level of detail in GEM-E3	Level of detail in E3ME
		by fuel types (depending on relative prices).

Source: Own elaboration.

This assessment shows that investments in power generation assets are modelled at a high level of detail. Furthermore, investments in residential heating are treated explicitly, while investments in the grid and demand (other than residential heating) are either not explicitly modelled or only at a high level of aggregation.

3.2. Investment decision elements

As shown in the previous section, primarily the investment decisions in the power sector are modelled in detail in GEM-E3 and E3ME. E3ME also has a detailed treatment of investment in technologies for car transport and for residential heating. GEM-E3 has a detailed model for the transport sector where agents can choose among conventional, hybrid and electric vehicles of different vintages and a detailed module for heating/cooling and cooking appliances. For most other sectors, the investments are either part of broader sector development trends or not modelled at all.

The next question is to understand if and how each element of the investment decision is modelled in the power sector. Table 3-2 provides a summary of which elements are represented and how.

Table 3-2 Representation of investment decision elements for power generation technologies in GEM-E3 and E3ME

Element	Sub-element	GEM-E3	E3ME – FTT:Power
Risk	Country risk	The model is calibrated on exogenously defined country interest rates (10-yr bonds) that reflect the base year risk. Interest rates can vary over time during the construction of the reference scenario, exogenously. Under development: Endogenous differentiation on the basis of risk-free rates per country.	Model can apply different discount rates per country but does not do so yet.
	Policy & regulatory risk	Not included endogenously. Exogenous mark-ups on interest rates apply.	Not included.
	Market risk	Not included endogenously. Exogenous mark-ups on interest rates apply.	Not included.
	Technology risk	Discount factors are differentiated per technology.	Model can apply different discount rates per technology but does not do so yet.
	Project-specific risk	Adjustment for borrower risk based on indebtedness /	Experimenting with inclusion of each country's electricity sector's

Element	Sub-element	GEM-E3	E3ME – FTT:Power
		sustainability of debt is considered.	indebtedness in discount rate for borrowing.
Returns	Revenues	Same price of electricity sold for each technology except when a specific incentive is in place (e.g. a FiT). Each power generation technology prices at marginal cost. The final consumer price includes any taxes that may apply.	Same price of electricity sold for each technology, except when a specific incentive is in place (e.g. a FiT). Decreasing load factors for intermittent RES to account for impact of deployment at less favourable sites.
	Investment costs	Specified for each technology.	Specified for each technology.
	Operating costs	Specified for each technology.	Specified for each technology.
Other factors	Project size, portfolio considerations, CSR objectives	Not included.	Not included.
Availability and cost of capital		Cost of capital is determined through demand and supply. Capital stock is updated using a stock-flow investment driven motion equation. The cost of capital depends on demand/supply, its mobility considerations (across sectors and countries) and on financing availability (i.e. the mix of domestic and international savings used to finance investments – impact on interest rate). A closure where infinite financing at prevailing interest rates is also available. The current discount rate for all power generation technologies is 8%.	Basis of post-Keynesian models is assumption that banks create bank deposits to the extent required to make capital available to projects that pass their lending criteria at a cost that reflects their assessment of risk. Currently, cost of capital (discount rate) is entered by assumption. The current rate is 10% for all power generating technologies. A planned development is to model the cost of capital that power utilities have to pay as mark-up on policy interest rate. NB In practice, the policy interest rate does not change much in the long term, so any constraints on availability of finance would have to be represented in risk factors that affect the mark-up.
Choice between power generation technologies		Driven by costs and some technical parameters to account for difference between baseload and flexible generation, for instance. Investment is triggered by demand for power. If an element of conventional generation changes (e.g. ETS price or fuel costs), the	Bottom-up technology model based on choice equation.[71] LCOE and existing global market shares are key factors in choosing technology. Heterogeneity between actors in assessment of risks and willingness to adopt new technology.

[71] This is only used for sectors of specific interest, which are power generation, household energy use for heating and road transport. For other sectors an accelerator function approach is used.

Element	Sub-element	GEM-E3	E3ME – FTT:Power
		model may choose for a different, more competitive technology to satisfy the demand. (Soft Link with PRIMES)	Heterogeneity is reflected in a weight that depresses take-up of a new technology when its market share is small. Intermittent RES only up to maximum share of capacity (more sophisticated method under development, based on supply-duration curves).

Source: Own elaboration.

Risk

With respect to country and technology risk, the above overview shows that E3ME does not differentiate between countries or technologies yet. GEM-E3 does differentiate per technology but not per country yet (this is under development). Both models can apply different risk premiums per country and/or per technology, so there is no lack of technical capability but rather a lack of data collected so far as well as the lack of mechanisms to endogenise the development of these risks. As country and technology risk can differ substantially, we identify this as a clear opportunity for improving the models' representation of reality. A suggestion for data sources and a dataset is included in Chapter 4 and Annex A.

Policy and regulatory risk is not explicitly included, although one may argue that this is partly covered by country risk. In any case, variation in risk levels per country seems desirable and could include differences in policy and regulatory risk.

Market risks are not explicitly modelled by the models. This risk category is clearly distinct from country and technology risk and is considered an important risk category by the financial sector, however. Hence, we will discuss the possibilities for improving the representation of this risk category in the remainder of this report.

Project-specific risks are, to a large extent, not specifically treated by the models, which makes sense as their project-specific nature does not match with applying generalised assumptions. What is important, however, is the fact that these project-specific risks lead to heterogeneity in the projects that are developed. Incorporating a certain level of heterogeneity in the models would, therefore, be a sensible way to represent this risk category.

A development that is ongoing in both models is to reflect the indebtedness of borrowers and in particular the sustainability of the debt as a risk that affects the cost of capital available to them. This could for instance be based on the indebtedness of a country's electricity sector and their ability to repay these debts from their revenues.[72] Based on our interviews with the financial sector, the debt profile of the borrower is confirmed as an important factor but also as a very project-specific factor where the track record of the project developer and their ability to invest their own capital are key determinants of the investment decision. The question is whether or not this risk factor can be generalised to a whole sector in a country as one may argue that in case a project developer is not

[72] Also known as the debt service coverage ratio (DSCR).

considered credible enough, there will be other project developers who seize the opportunity. We discuss this in more detail in section 4c.

Returns

The (expected) returns of an investment opportunity are influenced by the revenues, investment costs and operating costs of the project. The investment and operating costs clearly differ per technology, which is captured in the parameters of the models. The revenues are not differentiated per technology, assuming each receives the same electricity prices. This does not fully reflect reality however, as the revenues for intermittent technologies such as solar PV and wind energy are negatively affected by eroding wholesale prices at times of high wind speeds or high solar irradiation. Based on current trends, average sales prices for these technologies may drop to values of 20% to 40% below average wholesale prices.[73] The financial sector does include this phenomenon in their risk/return assessments and consider this an important factor for the profitability of the investment. Hence, there may be room to improve the models by better reflecting differences in average sales prices for the different technologies.

Other factors

Other factors that affect investment decisions such as the project size, portfolio considerations and CSR objectives are not captured in the models. For project size and portfolio considerations this makes sense as these are investor-specific requirements which dictate which investor types may be interested in certain investments, but generally do not lead to an overall lack of interest in certain investments.

With respect to CSR objectives, the effect is not clear cut. On the one hand, the high interest in sustainable investments should lead to high availability of capital for these investments. And with high levels of supply, increased competition should lead to lower prices (in theory). Interviewees from the financial sector did however not confirm that sustainable projects get cheaper capital as the capital providers still need to fulfil their risk/return requirements. Hence, there is no strong evidence that CSR objectives lead to a substantial effect on the investment decision (yet) which justifies not representing this element in the models.

Availability and cost of capital

The availability of financial capital could in theory lead to a barrier for the energy transition. However, there is little evidence nor expectations by the market that such a barrier may materialise. For post-Keynesian models such as E3ME, the basis assumption is that in ‘normal’ (non-crisis) times the constraint on capital availability is due not to any exogenous money supply limits but to the impact of the risk factors discussed above on the financial investor’s assessment of project viability, which is consistent with the experience of market actors in the interviews carried out for this report. The GEM-E3 allows for different financial closures and, hence, constraints on financial capital availability. This is particularly relevant in a large-scale model where different countries and households that are at different stages of economic development, and are, thus, characterised by different financial easiness.

The cost of capital in the market also plays a role in the investment decision as higher interest rates favour less capital-intensive technologies due to their lower need for borrowing capital for upfront investments. Hence, higher interest rates favour technologies

[73] See more elaborate discussion in Chapter 4.

that have relatively high operating costs (e.g. due to fuel costs) while lower interest rates favour technologies that have relatively high investment costs (e.g. for buying and installing the technology). Both GEM-E3 and E3ME include developments in cost of capital over time.

Choice between technologies

The final decision in which technology to invest is driven by a cost comparison , technical and preference aspects. The cost comparison utilises the levelised cost of electricity (LCOE) of technologies as the basis for comparison. The LCOE calculation incorporates investment and operating costs explicitly while risks can be captured in the discount rate. Differences in revenues are not part of this comparison as LCOE is a cost metric.

Both models incorporate other factors to choose between technologies, including whether the technology generates baseload or intermittent electricity.

3.3. Incorporation of trends

As introduced in Chapter 2, there are several trends that affect parameters of investment decisions over time. Ideally, the models should represent the impact of these trends, at least when they have a significant impact. In this section we explore if and how these trends are incorporated in GEM-E3 and E3ME. For trends that are not captured, we also discuss how significant their impact is thought to be.

Table 3-3 provides a summary of which trends are represented and how.

Table 3-3: Representation of trends in GEM-E3 and E3ME (power sector only)

Trend	Representation in GEM-E3	Representation in E3ME
1. Technological learning	Technology-specific learning curves.	Technology-specific learning curves.
2. Financial learning	Not included yet – development considered.	Not included.
3. Increasing importance of sustainability of investments as a choice criterion for financial investors	Could be represented as a lower borrowing rate for green technologies.	Could be represented as a lower borrowing rate for green technologies.
4. Lower sales prices for intermittent renewable energy sources	Not included.	Not included.
5. More stringent climate legislation	Development of carbon prices included. Increasing policy risk for polluting technologies not included.	Development of carbon prices included. Increasing policy risk for polluting technologies not included, although the model has been used to calculate the value of stranded fossil fuel assets.

6. Fossil fuel depletion and fuel price developments	Prices can be either: i) endogenous without resource depletion, ii) endogenous with resource depletion and iii) exogenous (fixed among scenarios).	Fossil fuel depletion model used in E3ME.[74]

Source: Own elaboration.

The overview shows that technological learning is incorporated in both models. Financial learning is not, however, while our interviewees all recognised the concept and considered it a significant factor. Hence, a potentially relevant improvement is to capture financial learning in the models.

The trend of increasing importance of sustainability considerations in investment decisions is currently not modelled, but could be incorporated relatively easily. Our interviewees recognised this trend but were very sceptical on whether it would lead to different financing conditions, commenting that an investment being 'sustainable' wouldn't remove the need for a proper assessment of risks and returns. So while the trend has been confirmed, we conclude that it's impact is not significant enough to warrant changes in model parameters.

The trend of lower sales prices for intermittent renewables is recognised by our interviewees. Their opinions on the importance of this trend vary, with some mentioning it as their main concern for renewable energy investments while others merely consider it one of many risk factors to consider. In any case, we conclude that it is relevant enough to consider as a potential improvement area.

Both models can evaluate increasingly stringent climate legislation through inserting higher carbon prices. Increasing policy risk is not modelled yet but may be included as an increasing technology risk premium for polluting / fossil technologies as part of the improvement of differentiating discount rates per technology as mentioned in the previous section.

Fossil fuel depletion and price developments are captured in both models.

3.4. Ability to evaluate policy options

In Chapter 2, the main options for policy makers to influence investment decisions are described, detailing which lever they use to alter the investment decisions made in the market. Table 3-4 summarises these policy options (consolidating similar options) and shows to what extent the macroeconomic models are able to evaluate the impact of such policies.

[74] Mercure et al. (2018). Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE. *Energy Strategy Reviews*, 20, 195-208.

Table 3-4: Ability of GEM-E3 and E3ME to model the impact of policy options with relevance for investment decisions

Policy option	Representation in GEM-E3	Representation in E3ME
Feed-in-tariffs (FITs) & feed-in premiums (FIPs)	Included (price effect, but no risk effect).	Included (price effect, but no risk effect).
Net metering	Not included.	Not included.
Renewable portfolio standards, green certificates and other (concrete) regulatory obligations	Not included.	Not included.
Capacity remuneration mechanism	Included.	Not included.
Tax cuts, rebates, favourable tax regime/ instruments	Included.	Included.
Exemptions from permitting requirements and one-stop shops for permitting	Not included.	Not included.
Carbon taxes & Emissions Trading System (ETS)	Included.	Included.
High-level targets, commitments, plans and strategies (e.g. Paris commitments, National Energy and Climate Plans)	Announced long-term goals are reached in the model. No direct impact on components of the investment decision.	No direct impact on components of the investment decision.
Government-backed guarantees on loans & Co-investment through (soft) loans or equity	Exogenously specified lower cost of capital (exogenous change in mark-up).	Not included, although they could be represented as a cut in the cost of capital if the risk impact can be quantified.
Co-investment through grants	Direct subsidies or separation of ownership and source of capital financing.	Direct subsidies can be modelled.
Fund of funds (FOF) and other policies targeting availability of capital issues	Not yet included. Could be represented if the impact on perceived risk and hence cost of capital can be quantified.	Not yet included. Could be represented if the impact on perceived risk and hence cost of capital can be quantified.

Source: Own elaboration.

The table above shows that the models can evaluate several key policy options but lack the ability for some. In the next chapter, we provide a more in-depth review to discuss the significance of the policy options that cannot be evaluated at present, and how the most significant policy options could be included.

3.5. Summary of potential improvement areas

The assessment in this chapter compared the findings of Chapter 2 on the relevant dimensions of the financing challenge with the current representation of the financial sector and the investment decision in the macroeconomic models. This assessment revealed various areas where the models can be improved to better represent financing decisions in real life.

First, should be mentioned that it is only in *power generation capacity* that investment decision factors (risks, returns, cost of capital) are treated at a sufficient level of detail to talk about the role of the financial sector and the investment decision levers. Investments in the grid and in energy demand (e.g. energy efficiency) are not captured at a level that considers the investment decision levers (risks, returns and capital costs). Whereas financing challenges are less relevant for investment decisions in the grid because such assets are typically regulated, they may be more relevant for investments in energy efficiency. Hence, further elaboration of the investments in energy efficiency measures is a first potential improvement area.

The investment decisions in the power sector are represented in more detail in the models and capture the influence of risks through a discount rate. This discount rate is currently not differentiated based on differences in the risks per country and technology, however, which is not in line with reality. Hence, better considering different risk profiles is a potential model improvements to be considered.

A currently ongoing development in both models is to better reflect the impact of borrower-risk driven by the sustainability of the indebtedness of the borrower. This risk category is recognised as a relevant risk category by the market, justifying developments in this area.

With respect to the revenues of the investments, both models do not differentiate between technologies unless a specific support measure is in place (e.g. a FiT). In reality, however, average sales prices for intermittent renewables deviate significantly from those of baseload generation due to oversupply at times of high wind speeds / solar irradiation, driving prices down at times of high generation for these technologies.

The effect of the financial learning on the discount rate has been shown to exist in the literature and is recognised by the financial sector, but is not captured in the models. Hence, this could be a further improvement area.

Finally, there are several policy options that cannot be evaluated in detail in the current set-up of the models. Adding the most relevant policy options could be another improvement to consider.

A summary of potential improvement areas is provided in Table 3-5. In the next chapter, we assess these potential improvement areas in detail.

Table 3-5 Overview of potential improvement areas

#	Improvement area
1	Detail investments and investment decisions in energy efficiency
2	Reflect differences in risk per country and technology
3	Reflect differences in sustainability of debt per borrower
4	Apply lower average sales prices (and revenues) for intermittent energy sources
5	Incorporate impact of financial learning curve
6	Broaden range of policy options that can be modelled

4. Review of potential model improvements

In this chapter, we **review** the potential model improvements identified in the previous chapter with the aim to provide more detailed insights on the relevance of the improvement areas, the significance of the impact on the model results and potential approaches to address the improvement areas. Based on this assessment, improvements can be prioritised along the lines of **importance and feasibility**.

4.1. Detail investments and investment decisions focused on energy efficiency in buildings

Relevance and significance

As mentioned earlier, investments in energy efficiency (particularly investments in the building stock) are an important part of the total investments needed for the energy transition, with shares above 50% of the total investment need. Hence, there is no doubt about the significance of energy efficiency investments within the energy transition.

However, the relevance of energy efficiency investments for the financial sector and issues around mobilising these investments are not so straightforward. On the one hand, there are many issues specific to financing energy efficiency investments in buildings, as well as policies and instruments that address these. Examples of issues include the heterogeneity of energy efficiency measures, which causes a challenge for the standardisation of financial evaluation models; the relatively small scale of energy efficiency projects which lead to relatively high transaction costs; and the lack of clear, tangible assets that can be used as collateral. Furthermore, regulation around energy performance contracts and energy service companies plays a role in what financing models are available. Consequently, financial issues *do* play an important role in energy efficiency investments. On the other hand, energy efficiency investments also face many challenges that do not specifically relate to financing. Issues around split incentives between landlords and tenants, lack of knowledge and capacity to initiate energy efficiency projects, and a lack of awareness of funding options may all contribute to the lack of development of project pipelines in the first place. Hence, any model developments need to recognise that financing only becomes relevant for projects that overcome other barriers first and that addressing **non-financial barriers** may be more important for progress on energy efficiency.

Potential approaches to improve models

A general prerequisite for improving how models address financing issues is that investments need to be modelled as discrete decisions where financing conditions can be inserted as a separate parameter (e.g. as a discount rate). Currently, energy efficiency investments are not modelled in this level of detail, and doing so would require an elaborate exercise, including establishing investment categories, technological options and cost and performance parameters for each technological option. A focus on buildings would require the development of data to represent the quality of different types of buildings. Since such an exercise is beyond the scope of this report, we have not included recommendations on improving the models for this improvement area.

4.2. Reflect differences in risk per country and technology

Relevance and significance

Literature on the influence of country and technology-specific factors on the overall risk of energy investments indicates that the level of risk differs substantially between countries and technologies. Moreover, differentiating such risks in macroeconomic models could alter model outcomes significantly, resulting in energy prices that are 5% to 15% lower[75] in an energy transition scenario.[76] In other words, the lack of differentiated discount rates could **overestimate the costs of the energy transition** substantially. This overestimation occurs because the discount rate is part of the LCOE calculation. In the case of solar PV, for example, a discount rate (or WACC) of 7% or more already implies that financing costs exceed hardware and technical installation costs (see Figure 4-1).[77] Similarly, Egli, Steffen and Schmidt (2019) argue that differences in the cost of capital between countries can significantly alter the results of LCOE calculations in different countries, which can have an impact on policy recommendations.[78] The authors find that by differentiating the cost of capital between countries (therefore accounting for differences in country risk), solar PV LCOEs could be up to 30% lower in industrialised countries and up to 180% higher in developing countries (in comparison to a case where a uniform cost of capital of 7% is used across all countries). Hence, we conclude that accounting for differences in risk per country and technology is very relevant and has a significant impact.

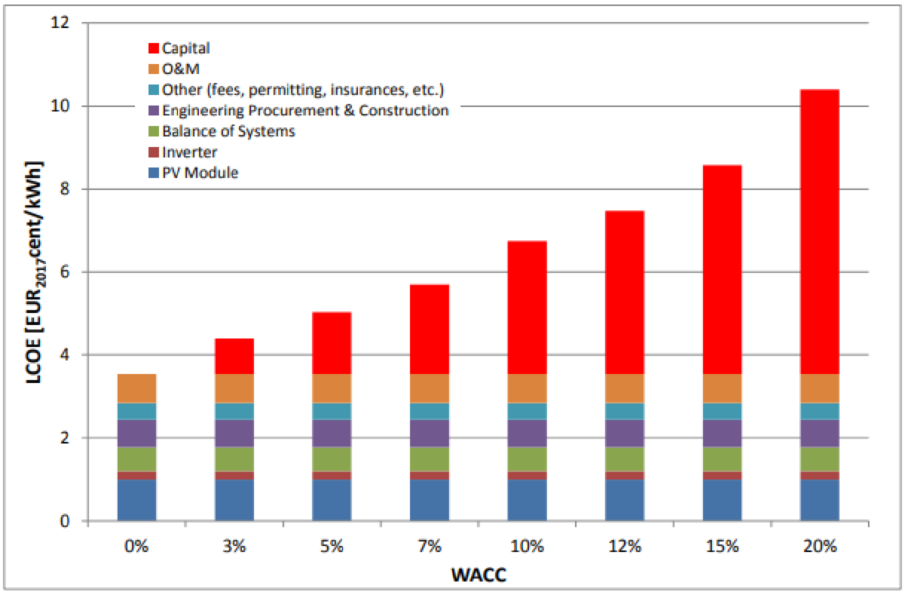

Figure 4-1 Influence of WACC on LCOE – the case of PV

Source: JRC (2018).[79]

[75] In all modelled regions and countries, except Greece, where costs are approximately 2% higher.

[76] Bachner et al. (2019). *Costs or benefits? Assessing the economy-wide effects of the electricity sector's low carbon transition – The role of capital costs, divergent risk perceptions and premiums.*

[77] JRC (2018). *PV Status Report 2018*.

[78] Egli, F., Steffen, B. & Schmidt, T.S (2019). Bias in energy system models with uniform cost of capital assumption. *Nature Communications* 10, 4588.

[79] JRC (2018). *PV Status Report 2018*.

When differentiating risks per country and technology, it is important to establish which risk factors are country and technology-specific. In our representation of the investment decision (Figure 2-1) we identify five main risk factors: country, policy/regulatory, market, technology, and project-specific risks. Out of these, country risk is clearly a country-specific risk factor which should be part of the basis for differentiating discount rates across countries. Policy and regulatory risk is, however, country-specific too. Historically, policy and regulatory risk has been a very relevant risk factor for renewable energy investments, with industry experts commonly referencing infamous retroactive policy changes (e.g. for solar PV in Spain) which damaged investor confidence. Our series of interviews indicated that the perceived risk of unexpected policy changes has become small in Western Europe, but is still much larger in Eastern Europe and other parts of the world. Hence, differences in policy and regulatory risk may still result in clear differences in the costs of energy technologies between countries. An important caveat with treating policy risk is that it partly overlaps with country risk, because country risk also covers the stability of the country's regime and policies. To avoid double counting, policy and regulatory risk should therefore be treated as a correction of the country risk based on differences between the general stability of the country and the specific stability of its energy and climate policies. We have not identified a dataset that can be used to perform such corrections for the EU28. Hence, we propose to not treat policy & regulatory risk separately and to consider country risk as the best proxy for policy & regulatory risk that is currently available.

Technology risk is the most obvious technology-specific risk factor and could therefore be the basis for differentiating risks per technology. Market risk (related to intermittent RES technologies) could also be considered a technology-specific risk factor. Market risk can be understood in two ways. First, it may be understood as the phenomenon that intermittent RES technologies (i.e. solar and wind) have a lower average sales price due to oversupply at times of peak generation. While this is a real and relevant phenomenon, we consider this not as an uncertainty (i.e. risk) in itself but rather as a fact that affects the returns and business case of investments in intermittent RES technologies. This effect is treated in more detail in a separate improvement suggestion. The second interpretation of market risk is that the higher penetration of intermittent technologies leads to higher volatility and uncertainty (and, therefore, risk) of the sales prices of these technologies, affecting their discount rates. However, the impact can be lower in countries where the energy system is more flexible. Flexibility is shaped by multiple factors: demand/use of energy, storage capacity/potential, interconnections with other markets, and the mix of energy supply (whereby hydropower provides the highest level of flexibility, and nuclear the least). As such, the magnitude of market risk is not only technology-specific but also partly country-specific, and can be mitigated if countries effectively manage to make their energy systems more flexible.

With respect to market risk, there are no studies on the magnitude of its impact, in quantitative terms. Nevertheless, findings on the relative importance of market risk versus other risks for renewable energy technology investments indicate that market risk has become the most important risk for solar PV and wind energy, ahead of country and technology risk.[80] Additionally, some of the interviewees for this study confirmed that market risk has become their most important risk category, at least in the more developed markets where regulatory risk is small. We conclude that market risk for intermittent technologies is an important risk factor that is primarily technology-specific (e.g. more impactful for solar PV than for gas-fired power), but the degree to which it affects the discount factor also depends on the country/market in which the technology is used. Due to a lack of data on

[80] Egli (2019). *The dynamics of renewable energy investment risk: A comparative assessment of solar PV and onshore wind investments in Germany, Italy, and the UK.*

this impact, we consider that the best approach is to consider it to be included in estimates of the technology risk premium, for now.

Potential approaches to improve models

The common way to account for different risk profiles is to differentiate the discount rate used in the appraisal of investment opportunities. Both E3ME and GEM-E3 already have the technical capability to insert different discount rates in the evaluation of investments in the power sector, so this does not require any model developments. What is required, however, is to establish a methodology for estimating the discount rates per country and technology, collect data, and determine if and how the discount rates should be modelled to evolve over time.

In capital budgeting and investment appraisals, the minimum rate that a company expects to earn when investing in a project (i.e. the required rate of return) is referred to as the hurdle rate. As was described in Chapter 2, to understand whether a project is profitable, a company compares the IRR to its WACC (i.e. a blend of equity and debt). The IRR must exceed the WACC in order for the project to be profitable. Hence, the WACC is often used as the hurdle rate. This rate is usually used to discount a project's cash flows in the calculation of the net present value (NPV), to account for the time value of money and the uncertainty of future cash flows.

To simplify these definitions, the **discount rate** can be understood as a figure that represents the desired return on an investment and the perceived uncertainty about future cash flows (i.e. risks); so, any indicators (e.g. WACC, hurdle rate) that could be used to discount future cash flows have been considered as relevant data inputs for this part of the study.

Differentiating discount rates across countries and technologies could be done on the basis of a simple formula incorporating the risk-free rate (Rf), the country risk premium (CRP), and the technology risk premium (TRP), namely:

$$Discount\ rate = Rf + CRP + TRP.$$

Table 0-3 (Annex A) provides an overview of our calculations. For each of the sub-components of the discount rate, we used the following data:

- **Risk-free rate (Rf):** As is done in other studies[81,82], we used the average (nominal) yield of the German government bond (10-year maturity) over the year 2019 to estimate the Rf. The long-term average of the German bond rate is also the lowest in the EU, thus representing the lowest risk;[83]
- **Country risk premium (CRP):** The CRP is based on the work of Damodaran (2019), who uses the data from sovereign credit rating agencies (Moody's and Standard and Poor's) to calculate default spreads, and, ultimately, country-specific

[81] E.g. Ecofys (2014). *Subsidies and costs of EU energy (Annex 4-5)*.

[82] GREEN-WIN (2017). *Green growth and win-win solutions for sustainable climate action*.

[83] ECB (2019). *IRS – Long-term interest rate statistics*. The data refers to long-term interest rates for convergence purposes, denominated in national currency and expressed in percentage per month. According to Article 4 of the Protocol (No 13) on the convergence criteria referred to in Article 140(1) of the Treaty on European Union, "observed over a period of one year before the examination, a Member State has had an average nominal long-term interest rate that does not exceed by more than two percentage points that of, at most, the three best performing Member States in terms of price stability" (see ECB (2020) *Convergence criteria*). As such, we assume that the long-term interest rates (and, therefore, the risk-free rate), as provided by the ECB, are nominal.

risk premia.[84] Credit rating agencies cover a wide array of country-specific risks, including political risk, economic structure, fiscal flexibility, and monetary flexibility. These risks impact investments in any given sector, and will affect the credibility of policies, which are important for energy investments (where policy risk has been identified as especially relevant in certain parts of Europe[85]);[86]

- **Technology risk premium:** Data on the TRP has been extracted from a number of studies.[87] The main study used was by Fraunhofer (2018).[88] When this study lacked data on certain technologies, other studies were used to extract differences in TRPs (using onshore wind as a baseline, present in all studies). More detail on the methodology behind the TRPs can be found in Annex A.

The table below discusses the main risk factors identified in Chapter 2 related to differences in risk per country and technology, and highlights how we propose to incorporate them into the discount rate. In addition, we provide some insights on the expected evolution of these risks over time, based on underlying drivers. The development of the risk parameters over time provides some insight into whether their evolution needs to be modelled over time (i.e. endogenised). In most cases, we consider that modelling such developments is not feasible or not needed, while for technology risk we recommend to include some function to model its evolution over time.

Table 4-1: Incorporating various risks into the models

Type of risk (as defined in Ch. 2)	How we propose to incorporate it into the models	Evolution of the risks over time and conclusions on the feasibility and need to endogenise the evolution
Country risk	Directly included in the discount factor calculation as the country risk premium (CRP).	The Rf will depend on monetary policies affecting Germany, particularly the development of short-term interest rates.[89] According to ECB data, the yearly average German government bond yield (10-year maturity) has decreased from 1.16% in 2014 to -0.25% in 2019, with yearly fluctuations ranging from +0.2 to -0.7 percentage points over the six-year period.[90] Forecasting how this rate will evolve in the future is very difficult, however. Our conclusion is that there is no sufficiently reliable approach to model the evolution of the Rf endogenously, and suggest to update the Rf periodically as the best alternative option.

[84] Damodaran calculates rating-based default spreads and scales them by a factor of 1.22 (as of 2019) to adjust for the for the higher risk of equities.

[85] DiaCore (2016). *The impact of risks in renewable energy investments and the role of smart policies*.

[86] Damodaran (2019). *Country Risk: Determinants, Measures and Implications – The 2019 Edition*. See Appendix 7 of the study.

[87] Ecofys (2014). *Subsidies and costs of EU energy (Annex 4-5)*; Grant Thornton (2019). *Renewable energy discount rate survey results – 2018*; Fraunhofer (2018). *Levelized Cost of Electricity Renewable Energy Technologies*; NERA (2015). *Electricity Generation Costs and Hurdle Rates*; and Tax Foundation (2019). *Corporate Income Tax Rates in Europe*.

[88] Fraunhofer (2018). *Levelized Cost of Electricity Renewable Energy Technologies.*

[89] Akram and Das (2017). *The Dynamics of Government Bond Yields in the Eurozone.*

[90] ECB (2019). *IRS – Long-term interest rate statistics*.

Type of risk (as defined in Ch. 2)	How we propose to incorporate it into the models	Evolution of the risks over time and conclusions on the feasibility and need to endogenise the evolution
		The CRP depends on country developments which influence sovereign credit ratings. Damodaran (2019)[91] largely uses Moody's ratings to calculate the CRP, and the latter's ratings are considered to be relatively stable over time[92], while hard to forecast exactly.[93] Hence, we advise not to endogenise developments in the CRP.
Policy & regulatory risk	Due to potential overlaps with country risk and the lack of data to identify differences between countries, we propose to consider country risk as the best proxy for policy & regulatory risk currently available.	N/A.
Market risk	We consider that the TRP captures market risk on an average basis and that there is currently a lack of data on the isolated impact of market risk and differences between countries, as well as its evolution over time. Hence, we suggest to consider that the TRP incorporates market risk.	N/A.
Technology risk	Directly included in the discount factor calculation as the technology risk premium (TRP).	Technology risk reflects a risk of project cost overruns, lower performance, reduced lifetime, higher maintenance costs, and other similar technology-specific considerations, of some technologies over others. This risk exists due to the level of maturity of the technology (which decreases with higher deployment) and the characteristics of the technology. For example, technologies with moving parts such as wind turbines have a higher inherent risk of breaking down in comparison to technologies without moving parts (e.g. solar PV). The reduction of this risk over time could be modelled similar to the reduction of the technology's costs over time (i.e. per the technological learning rate).

Source: Own elaboration.

[91] Damodaran (2019). *Country Risk: Determinants, Measures and Implications – The 2019 Edition*.

[92] Rabobank (2012). *Sovereign credit ratings*.

[93] Egli et al. (2019). *Bias in energy system models with uniform cost of capital assumption.*

4.3. Reflect differences in sustainability of debt per borrower

Relevance and significance

The scale of investment needed in the energy sector warrants the question of who is going to provide this capital and whether the financing conditions are affected by the large demand of capital from investors in the energy sector. To better address this issue, model developments that evaluate the sustainability of the debt of the power sector are considered. Such developments could assume an increasing cost of capital for investments in the power sector if the indebtedness of the power sector and their ability to repay loans deteriorates. This would then effectively function as a brake on the speed with which the power sector can decarbonise and/or a higher cost passed through to electricity prices.

In our interviews and literature review, we evaluated the hypothesis that higher investments in the power sector would lead to higher costs of capital for new investments as a result of the higher indebtedness of the power sector. There was consensus among interviewees that such an effect was not likely to happen in practice. There was less consensus on the reasons for this effect not to happen. The reasons mentioned included:

1. Financing is not dependent on a limited number of investors. Instead, there are many parties (beyond the local utility companies) that can make the investment. Potentially relevant investors include project developers, private equity firms and international utility companies. As long as the business case can yield returns in excess of its cost of capital, it will be financed, regardless of the overall level of capital sunk into the sector already;
2. Utility companies are too important for society to go bankrupt, so, in many cases, governments will back them up in case of financial distress. Therefore, banks attach little relevance to the debt burden of utility companies and do not significantly alter interest rates for loans to major utility companies based on it;
3. Project financing makes the debt burden of the investing companies irrelevant, as the investment is set up as a separate investment vehicle. Hence, in cases where the debt burden of utility companies becomes prohibitive, they may use project financing structures for future investments. While this may lead to slightly higher discount rates due to the debt providers not having recourse to assets beyond those included in the special purpose vehicle, this effect is limited as evidenced by the prevalence of project finance structures in the energy sector.[94, 95]

Based on these inputs, the hypothesis can be questioned at different levels. First, the importance of utilities for financing investments in the power sector is less clear-cut than presumed, as general investors may provide the capital as well. Secondly, a higher debt burden for the power sector would not necessarily lead to a higher cost of capital for the sector (due to the limited risk of bankruptcy). Finally, even if the costs of capital for the power sector would increase, the impact on investments can be largely mitigated by applying a project finance structure. Overall, we conclude that modelling a link between the debt burden of the power sector and the financing conditions of investments in the power sector is not in line with reality.

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[94] Steffen (2018). The importance of project finance for renewable energy projects.

[95] IEA (2018). *World Energy Investment 2018.*

Potential approaches to improve models

Based on the lack of evidence on a relation between the debt burden of the power sector and the financing conditions of investments, we recommend no changes to the models.

4.4. Apply lower average sales prices for intermittent energy sources

Relevance and significance

The concept that high penetration levels of intermittent energy sources such as wind and solar lead to price erosion for these energy sources has been proven in several studies.[96, 97] Recent contributions show that the number of hours in which wholesale electricity prices drop below €1/MWh could reach 500 up to 2,000 hours/year for countries with large solar capacities (20-50% of demand) and 700 to 1,400 hours/year for countries with large wind capacities (15-25% of demand).[98] In other words, sales prices for wind and solar PV may decline to less than 25% of average wholesale electricity prices for 25% of the time, underlining the significance of this effect. The overall magnitude of its impact is in the order of a reduction in average sales prices of 1% (wind) and 4% (solar[99]) for each 1% increase in market share of the respective technology.[100] With current penetration levels of 14%[101] (wind) and 4.5% (solar PV)[102] which are expected to increase to more than 20% (wind) and 10% (solar PV) in 2030[103], the effect of price erosion may result in sales prices that are 20% up to 40% lower than average wholesale prices. It should be noted that part of this effect may be offset by increased flexibility of the system (including flexible generation, storage, interconnections and demand response), but how effective flexibility measures will be is hard to foresee.

Potential approaches to improve models

The effect of price erosion could be captured in the models through a value factor (VF) which declines with increased penetration of the energy source. The VF for wind power is defined as:

$$VF_{wind} = \frac{\bar{P}_{wind}}{\bar{P}}$$

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[96] For an overview of relevant studies, see Hirth (2016). *The market value of wind energy*.

[97] For a more recent modelling exercise on the topic, see CERRE (2018). Europe's electricity market design. 2030 and beyond.

[98] METIS studies S14 (2018). *Wholesale market prices, revenues and risks for producers with high shares of variable RES in the power system*.

[99] Note that the average sales price for solar PV at low penetration levels (<1%) exceed the market average with up to 30%. So the large decline in average prices for solar PV starts from a higher basis.

[100] Hirth (2016). *The market value of wind energy*.

[101] Wind Europe (2019). *Wind energy in Europe in 2018*.

[102] JRC (2018). *PV Status Report 2018*.

[103] JRC (2017). *Renewable technologies in the EU electricity sector: trends and projections. Analysis in the framework of the EU 2030 climate and energy strategy – Study*.

Where P_{wind} is the wind-weighted average electricity price (i.e. the average price at which wind energy sells) and P is the average electricity price.

The decline of this value factor would then be represented by the following formula:

$$VF_{wind} = a + bx$$

Where *a* represents the value of the energy source at a market share close to zero, *b* is the rate at which the value declines at higher penetration, and *x* is the market share of the energy source in the total electricity mix. Such a formula could be developed for both solar PV and wind energy based on the work of Hirth (2016).[104]

A refinement to this formula that may be considered is to differentiate the rate at which the value declines (*b*) based on the availability of (large) hydropower capacities in the power mix of the country. Hirth (2016) shows that the availability of large hydro capacities reduce the value decline of wind power by two thirds, thanks to the ability for hydropower to be turned on and off when needed.[105]

Further refinements that may be considered are to account for the effects of other options for offering flexibility than using traditional hydropower capacities, such as interconnections, storage and demand response.

4.5. Incorporate the financial learning curve into the discount rate

Relevance and significance

The financial learning curve (or experience curve) is a novel concept which was introduced in 2018.[106] Before, the impact of financial learning was not separated from technological learning when assessing LCOE reductions of realised projects over time. When confronted with the concept during our interviews, practitioners in the financial sector recognised it directly, indicating that the term may be rather new but its existence is not.

The magnitude of its impact is estimated to be in the order of a 8% reduction in debt margin for every doubling of cumulative investments made and accounted for 1% (solar PV) and 4% (wind onshore) of the LCOE reductions between the early 2000s and 2017.[107] The effect is relatively small compared to the technology learning curve which accounted for 95% (solar PV) and 77% (wind onshore) of the cost reductions in this period, due to a combination of lower upfront investment in itself and the reduced capital costs due to the lower upfront investment. The remainder of the cost reduction is due to the sharp decline in general, economy-wide interest rates during this period.

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[104] Hirth (2016). The market value of wind energy.

[105] Hirth (2016). The market value of wind energy.

[106] Egli, F., Steffen, B., & Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. *Nature Energy*, *3*(12), 1084-1092.

[107] The learning rates estimated by Egli et al. (2018) are between 10% and 11% for solar PV and 11% and 16% for onshore wind. When performing a sample calculation with 12% as a mid-point in the range of values, the resulting decline in debt margins is 8%. Egli et al. (2018) define debt margin as the mark-up above the risk-free rate (i.e. the yield on a German government bond), reflecting the investor's compensation for taking risk.

It is important to note that the financial learning curve concept likely also applies to equity investments, but is not researched as such due to the lack of data on equity costs and returns.

Potential approaches to improve models

Capturing the financial learning curve in the models could be done through incorporating a one-factor experience curve as presented in the formula below, where *I* is the cumulative investment in the respective technology and *b* is the learning rate.[108]

$$DebtMargin(I_t) = DebtMargin(I_0)(\frac{I_t}{I_0})^{-b}$$

Subsequently, the debt margin could be fed into a calculation of the weighted average cost of capital for the technology which is then used as the discount rate for the technology.

One caveat when incorporating the financial learning curves in the models is to properly distinguish the effects of technological learning and financial learning. In principle, technological learning leads to investment and operating cost reductions which are separate terms in the LCOE calculation and are therefore easily distinguishable from the financial learning curve which only affects the discount rate. However, the technological learning may also lower the technology risk of an investment. Since risks are generally reflected in a higher cost of capital and discount rate, there is a risk of double counting the effects of financial learning and technological learning when reducing discount rates at higher deployment. Specifically, the technology risk premium (TRP) introduced in the section on reflecting differences in risk per country and technology, would include the effects of financial learning so far. Any attempts to endogenise the development of the TRP in the models would therefore need to account for both technology risk reductions and the effects of financial learning.

4.6. Broaden the range of policy options that can be modelled

Relevance and significance

Table 3-4 in Chapter 3 showed the range of policy options that are currently represented by E3ME and GEM-E3. Feedback from stakeholder interviews showed that some of the most important policies affecting investment decisions are renewable energy support policies (such as FITs and FIPs), fiscal measures directly impacting the cost of capital (such as tax rebate options), renewable portfolio standards/green certificates, carbon taxes, and any policies pushing for flexibility options. The bulk of these policies are already included in the models, namely FITs and FIPs, tax cuts/rebates, and favourable tax regime/instruments, as well as carbon taxes and the ETS. Renewable portfolio standards and green certificates were brought up by certain interviewees; so, we consider them to hold significance for the financial sector. However, only four countries in the EU have such a quota system in place[109]

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[108] Egli, F., Steffen, B., & Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. *Nature Energy*, *3*(12), 1084-1092.

[109] RES Legal (n.d.). *Legal sources on renewable energy* (database). According to the database, only Belgium, Romania, Sweden and Poland have a quota system in place.

and the impact of such a system is relatively similar to a feed-in-premium because it effectively increases the revenues for electricity sold. Hence, for the limited cases where such a system is applied, the effect can be evaluated as a feed-in-premium and would therefore not require a separate model development.

Based on interviewee responses, we consider that certain policies do not impact investment decisions to a relatively high degree and would therefore not require additions to the macroeconomic models. Interviewees generally agreed that high-level targets, plans, and strategies provide a view on the priorities of a government, but they do not necessarily impact investment decisions unless they translate into concrete actions or regulatory obligations. When asked about availability of capital concerns, many interviewees agreed that the financial sector disposes of sufficient capital and that policies to increase capital availability and financing conditions (e.g. guarantees, government-backed loans, fund of funds) are not as relevant as other measures. This is also in line with the mixed evidence on the effectiveness of such policies reported in literature.[110] Given this context, we do not recommend adding any instruments or measures addressing such concerns to the models at present, since their impact is perceived to be limited. The only exception is co-investment by governments through grants as this could impact the investment decision in a material way. This is, however, not so much a measure to address financing conditions but rather a direct subsidy for projects, which could easily be modelled as a reduction in investment costs. Therefore, we do not advise any separate model developments for this policy option.

Net metering schemes were brought up by certain interviewees. According to REN21, 10 EU MS appear to have some kind of net metering system in place.[111] However, some countries such as the Netherlands, are phasing the system out. Furthermore, net metering is an instrument targeting households, as opposed to larger investors. Reflecting the investment decisions of households in energy generating assets (e.g. solar panels) requires a separate development incorporating many different factors beyond financing, and would therefore be beyond the scope of this report.

Lastly, it was noted by several interviewees that the EU taxonomy for sustainable activities is likely to impact the day-to-day decisions of investors in the future; but that its impact is not yet tangible, making it unclear whether its implementation will ultimately lead to materially different financing conditions.

Table 4-2: Conclusions on policy updates

Policy option	Relevance, significance and conclusions on required model updates
Feed-in-tariffs (FITs) & feed-in premiums (FIPs)	Already included and significant.
Net metering	Not included. Somewhat significant but the trend appears to be towards phasing out net metering schemes. Developments to better reflect household investment in local generation (primarily solar PV) could be investigated as a model improvement, but would be beyond the scope of this report.
Renewable portfolio standards, green certificates and other (concrete) regulatory obligations	Not included and limited significance. Although they have been cited by a few respondents, the system is not prevalent in the EU. The effect of such a system can be evaluated in a similar way as a feed-in-

[110] Polzin et al. (2019). *How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective.*

[111] REN21 (2019). *Renewables 2019 Global Status Report*.

	premium and would therefore not require separate model developments.
Capacity remuneration mechanism	Not included and not significant. This was not brought up by any interviewee. The mechanism can be found in a few EU MS[112], but its future remains a source of debate.[113]
Tax cuts, rebates, favourable tax regime/instruments	Already included and significant.
Exemptions from permitting requirements and one-stop shops for permitting	Not included and not significant. This was not brought up by any interviewee.
Carbon taxes & Emissions Trading System (ETS)	Already included and significant.
High-level targets, commitments, plans and strategies (e.g. Paris commitments, National Energy and Climate Plans)	Not considered to significantly influence financing conditions by interviewees.
Government-backed guarantees on loans and co-investment through (soft) loans or equity	Not included and not significant. Not prevalent in the EU. Approximately eight MS have some loans in place as support for RES development, but few countries appear to provide guarantees on these loans.[114]
Co-investment through grants	Not included and significant. Although this measure was not considered important by the interviewees, many countries in the EU provide grants through various investment support programmes.[115] Such support measures could however be represented as a reduction in the investment cost of a technology and would therefore not require separate model developments.
Fund of funds (FOF) and other policies targeting availability of capital issues	Not considered significant by interviewees. Availability of capital is not considered a relatively important concern.

Source: Own elaboration.

Potential approaches to improve models

Based on the considerations mentioned above, we conclude that the models are already able to evaluate the most important policy options affecting financing decisions. These include direct subsidies and policy actions that directly affect prices and costs (including taxes). Other policies are considered to have a less critical impact on financing decisions. Hence, we do not recommend model developments to broaden the range of policy options that can be modelled.

[112] FSR (2019). *The Clean Energy Package and Capacity Remuneration Mechanisms*.

[113] EURACTIV (2018). *Electricity Market Reform: A European Tour* (Special Report).

[114] RES Legal (n.d.). *Legal sources on renewable energy* (database).

[115] RES Legal (n.d.). *Legal sources on renewable energy* (database).

5. Conclusions and recommendations

In this report we started by developing an understanding of the financing challenge of the energy transition, identifying where the financial sector and issues around financing play the most important role and how public policy can address those. We then evaluated how the macroeconomic models of interest (E3ME and GEM-E3) treat these points of influence and developed concrete recommendations to model these in a more realistic way. While this analysis focused on delivering recommendations to improve the models, several relevant insights for policy makers emerged, which we summarise in this conclusions section. We then summarise our conclusions on the priorities for improving the models and underlying parameters.

5.1. Key insights with relevance for policy makers

The primary financial issue of the energy transition is setting the financing conditions when the investment decision is made

Through our research, we concluded that the primary financial issue of the energy transition is at the stage of the final investment decision for new energy assets. At this point, investors determine whether or not capital is provided and under which conditions (e.g. interest rates). In case a project financing structure is applied, the financial sector (primarily banks and private equity) is directly involved. In case a corporate financing structure is applied, the role of the financial sector is more indirect through influencing the cost of capital for the corporate investor (e.g. a utility).

Public policy can influence the investment decision and resulting financing conditions by targeting risks, returns and cost of capital

Whether or not investments get financed and under which conditions depends on an evaluation of the risks and returns of the project versus the hurdle rate of the investors. Public policies such as feed-in-tariffs and carbon taxes can influence the risk and return evaluation directly, whilst policies that target the availability of capital can lead to lower hurdle rates. Hence, policies aimed to stimulate the required investments for the energy transition should target at least one of these dimensions.

The financial sector considers policies that directly target risks and returns most effective

When discussing the range of policy options that influence the investment decision, representatives from the financial sector attached most value to policies that directly affect risks and returns of investment opportunities (such as feed-in-tariffs) and policies that affect the relative competitiveness of technologies (such as carbon taxes / trading systems). Conversely, policies that target availability of finance and financing conditions such as cheap loans, guarantees and public investment funds were considered less impactful, in particular with the abundance of cheap capital that is currently available on the market.

Another interesting finding was that high-level energy and climate targets and policy ambitions such as the Paris Agreement and the EU 2030 and 2050 targets have little impact on day-to-day investment decisions. In some cases, even a negative impact on investment decisions may occur, for instance due to the expected price erosion for intermittent renewables at higher penetration levels.

The scale of the required investments is not expected to lead to materially different financing conditions

While there is no doubt that the energy transition requires large investments (in the order of 2-3% of GDP annually) the financial sector does not foresee that this would adversely affect financing conditions due to reasons such as a shortage of capital, high debt burdens for the energy sector or too high exposure to a single sector. So, when actual investments lag behind the investments required, the most likely reason is a lack of investment opportunities with a sufficiently attractive risk/return ratio, rather than a lack of capital in the market.

The increasing importance of sustainability concerns is also not expected to lead to different financing conditions

In spite of the hype around divestment and climate-alignment of investment portfolios, the financial sector was clear that they cannot provide lower interest rates to sustainable investments, because the same risk/return evaluation and requirements still apply, and their financial stability is their primary objective. Several investors have implemented policies that prohibit investments in non-sustainable sectors (e.g. coal), but this does not necessarily affect financing conditions as other parties may still provide capital.

Still, the cost of capital for renewables is much lower than for fossil investments

Over the past decade, renewable energy investments (in particular solar PV and wind) have developed from risky investments to low-risk investments, with an associated sharp decline in the cost of capital. The reasons include the development of the technologies leading to lower technology risk, the increasing stringency and stability of climate policies (leading to lower policy risk), and economy-wide reductions in the cost of capital. At the same time, the environment has become increasingly hostile to fossil assets, with rising carbon prices, risk of premature closing of power plants and reduced opportunity to sell electricity at profitable wholesale prices due to the effect of zero marginal cost renewables. Overall, this has led to a situation where the cost of capital for solar PV and wind are approximately three percentage points lower than that of coal and gas-fired power, which has a large impact on the cost competitiveness of the technologies.

5.2. Prioritisation of model improvements

The primary goal of this study was to identify and detail improvements to the macroeconomic models GEM-E3 and E3ME. Based on this, we identified three concrete model improvements and some suggestions for further research.

The most important improvement that we identified was to differentiate discount rates per country and technology. This improvement will have a large impact on the model outcomes, as the discount rates currently used in the model (e.g. 10% for all technologies and countries in E3ME and 8% in GEM-E3) are significantly different from the discount rates that we recommend in Annex A of this report (with values as low as 3% in specific cases). Furthermore, the improvement seems relatively easy to incorporate as both models already have the technical capability to work with differentiated discount rates. A slightly more challenging element is to endogenise the development of the technology risk premium as technologies mature, but an approach similar to the technological learning curve for investment costs could be envisioned. Overall, we conclude that this improvement is relevant, highly impactful and feasible, and should be prioritised.

We consider the improvement opportunity to apply lower average sales prices for renewables as the second most important improvement that we identified. The order of magnitude that we estimated is 20% up to 40% lower prices than average, which would have a significant impact on the appraisal of investment opportunities. Additionally, the improvement seems feasible to incorporate in the models.

The improvement opportunity around the concept of financial learning is fully supported by the interviewees and literature and possible approaches to update the models are available. The impact on the model outcomes is, however, expected to be relatively small compared to other factors such as technological learning and the reduction in technology risk. The most practical approach to account for financial learning would probably be to integrate it into the function for the development of the technology risk premium, which is part of the recommendation to insert and endogenise differentiated discount rates.

Further work (outside the scope of this report) could be considered to better reflect how energy efficiency investment decisions are made and which factors play a role, including but not limited to financing conditions. Additionally, options to better reflect decision-making around residential investments in local generation (e.g. solar PV) may be explored.

Annex A – Data on discount rates

Energy policy evaluation studies show that the cost of capital or the discount rate is a crucial determinant of model results (primarily via LCOE calculations) and recommendations for policy design.[116] As such, the discount rate is an important indicator of the financial burden that will have to be passed on to consumers in the low-carbon energy transition. The table below provides our estimations of discount rates, differentiated per technology and per country (Table 0-3). The numbers are based on a simple formula combining the **risk-free rate** (Rf), the **country risk premium** (CRP) (based on sovereign credit ratings)[117], and the **technology risk premium** (TRP). To calculate the TRP, we used (nominal) WACC data from Fraunhofer (2018)[118]. For those technologies that were not included in the study, we used the TRP found for onshore wind as a baseline and complemented it with additional premia as found in other studies (further description of the methodology is provided in Table 0-1). The TRP for onshore wind was used as a baseline because this was a technology that was common to all studies. Furthermore, the risk-free rate used to calculate the discount rate in this study is based on the yield of a German government bond (10-year maturity), averaged over the period January-December 2019.[119]

Table A-1: Technology risk premia

Technology	Risk premium	Methodological notes
Biomass fired plants	4.7%	Fraunhofer (2018) calculated a (nominal) WACC of 4.6% for onshore wind. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 3.6%. Furthermore, the government bond yield in 2018 in Germany was 0.4%.[120] We assumed this to be the Rf and subtracted it from the WACC to obtain a TRP for onshore wind. In the Grant Thornton (2018) study, the (unlevered) discount rate for onshore wind was 4.5% and the (unlevered) discount rate for biomass was 6% in Germany. The difference between the two technologies was added to the TRP found for onshore wind in Fraunhofer (2018) to obtain a **TRP for biomass fired plants.**
Coal fired plants	6.3%	Fraunhofer (2018) calculated a (nominal) WACC of 7.7% for hard and brown coal. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 6.7%. Furthermore, the government bond yield in 2018 in Germany

[116] E.g. Bachner et al. (2019). *Costs or benefits? Assessing the economy-wide effects of the electricity sector's low carbon transition – The role of capital costs, divergent risk perceptions and premiums*; JRC (2018). *PV Status Report 2018*; ICL (2016). *The cost of capital and how it affects climate change mitigation investment*.

[117] Damodaran (2019). *Country Risk: Determinants, Measures and Implications – The 2019 Edition*.

[118] Fraunhofer (2018). *Levelized Cost of Electricity Renewable Energy Technologies*. See Table 2, p. 11. This study was the primary source of data for the TRPs. After validation with the authors of the study, it appears that the WACC rates do not account for the effect of corporate tax, so the rates have been adjusted based on a corporate tax rate of 29.8% (as found in Tax Foundation (2019). *Corporate Income Tax Rates in Europe*).

[119] ECB (2019). *IRS – Long-term interest rate statistics*. The data refers to long-term interest rates for convergence purposes, denominated in national currency and expressed in percentage per month. The risk-free rate has been calculated as the average monthly long-term interest rate for Germany, over the period January-December 2019. According to Article 4 of the Protocol (No 13) on the convergence criteria referred to in Article 140(1) of the Treaty on European Union, "observed over a period of one year before the examination, a Member State has had an average nominal long-term interest rate that does not exceed by more than two percentage points that of, at most, the three best performing Member States in terms of price stability" (see ECB (2020). *Convergence criteria*). We, thus, assume that the long-term interest rates, as provided by the ECB, are nominal.

[120] The data used for the 2018 German government bond yield was the *IRS – Long-term interest rate statistics* database of the ECB. Same notes apply as in the previous footnote.

Technology	Risk premium	Methodological notes
		was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a **TRP for coal fired plants.**
Gas fired plants	5.9%	Fraunhofer (2018) calculated a (nominal) WACC of 7.3% for CCGT and GT. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 6.3%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a **TRP for gas fired plants.**
Solar PV	2.9%	Fraunhofer (2018) calculated a (nominal) WACC of 4.1% for utility-scale PV (> 2 MWp). This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 3.3%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a **TRP for solar PV.**
Wind onshore	3.2%	Fraunhofer (2018) calculated a (nominal) WACC of 4.6% for onshore wind. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 3.6%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a **TRP for onshore wind.**
Wind offshore	5.3%	Fraunhofer (2018) calculated a (nominal) WACC of 6.9% for offshore wind. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 5.7%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a **TRP for offshore wind.**
Nuclear	8.2%	Fraunhofer (2018) calculated a (nominal) WACC of 4.6% for onshore wind. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 3.6%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a TRP for onshore wind. In the Ecofys (2014) study, the TRP for onshore wind was 3% and the TRP for nuclear (new plant) was 8%. The difference between the two technologies was added to the TRP found for onshore wind in Fraunhofer (2018) to obtain a **TRP for nuclear.**
Hydropower	2.5%	Fraunhofer (2018) calculated a (nominal) WACC of 4.6% for onshore wind. This was adjusted to account for the effect of a corporate tax rate of 29.8% in Germany in 2018, resulting in a (nominal) WACC of 3.6%. Furthermore, the government bond yield in 2018 in Germany was 0.4%. We assumed this to be the Rf and subtracted it from the WACC to obtain a TRP for onshore wind. In the Grant Thornton (2018) study, the (unlevered) discount rate for onshore wind was 4.5% and the (unlevered) discount rate for hydropower was 3.8% in Germany. The difference between the two technologies was added to the TRP found for onshore wind in Fraunhofer (2018) to obtain a **TRP for hydropower.**
Technologies with low deployment and high risk	6.0%	Additional technologies that are covered by the E3ME and GEM-E3 models are: geothermal, tidal, wave, fuel cells, and concentrated solar power. The NERA (2015) study includes data on the nominal (post-tax) hurdle rates for **geothermal, tidal, and wave.** Apart from certain CHP variations of biomass fired plants and waste-to-energy plants, the hurdle rates for the three technologies are amongst the highest of the list. We calculated the median hurdle rate based on the hurdle rates of the following technologies: geothermal, geothermal CHP, tidal stream (both shallow and deep), and wave. This resulted in a hurdle rate of 12%. Comparing this hurdle rate to that of onshore wind (9.2% in the same study), provided us with a premium to be added to the TRP found for onshore wind in the Fraunhofer (2018) study. We assume that this can serve as a proxy TRP for all technologies that currently have **limited deployment**, and, therefore, face higher

Technology	Risk premium	Methodological notes
		perceived risks. This group of technologies could also include **fuel cells** and **concentrated solar power** (since they have similar characteristics).
Biomass fired plants + CCS	6.2%	NERA (2015) provided a nominal (post-tax) hurdle rate for dedicated biomass plants: 10.6%. In the same study, a biomass plant + CCS has a hurdle rate of 12.1%. Taking the difference between the two values and adding it to the TRP calculated for biomass fired plants in this study (above), allowed us to generate a **TRP for biomass fired plants with CCS.**
Coal fired plants + CCS	8.6%	NERA (2015) provided a nominal (post-tax) hurdle rate for gas (CCGT) of 9.6%. The same study calculated a hurdle rate of 12% for gas (CCGT) with CCS. Taking the difference between the two values and adding it to the TRP calculated for gas fired plants in this study (above), allowed us to generate a **TRP for gas fired plants with CCS.**
Gas fired plants + CCS	8.3%	NERA (2015) provided a nominal (post-tax) hurdle rate for coal plants of 9.9%. The same study calculated a hurdle rate of 12.2% for coal (ASC) with CCS. Taking the difference between the two values and adding it to the TRP calculated for coal fired plants in this study (above), allowed us to generate a **TRP for coal fired plants with CCS.**

Source: Own elaboration based on data from Fraunhofer (2018)[121], NERA (2015)[122], Ecofys (2014)[123], Grant Thornton (2018)[124], and for data on Germany's corporate tax rate in 2018, Tax Foundation (2019)[125].

Note: All values have been rounded to the nearest tenth.

[121] Fraunhofer (2018). *Levelized Cost of Electricity Renewable Energy Technologies*.

[122] NERA (2015). *Electricity Generation Costs and Hurdle Rates*.

[123] Ecorys (2014). *Subsidies and costs of EU energy. Annex 4-5*.

[124] Grant Thornton (2019). *Renewable energy discount rate survey results – 2018*.

[125] Tax Foundation (2019). *Corporate Income Tax Rates in Europe.*

Table A-2: Country risk premia

Country	Risk premium
Austria	0.5%
Belgium	0.7%
Bulgaria	2.2%
Croatia	3.4%
Cyprus	3.4%
Czechia	0.8%
Denmark	0.0%
Estonia	0.8%
Finland	0.5%
France	0.6%
Germany	0.0%
Greece	5.1%
Hungary	2.5%
Ireland	1.0%
Italy	2.5%
Latvia	1.4%
Lithuania	1.4%
Luxembourg	0.0%
Malta	1.4%
Netherlands	0.0%
Poland	1.0%
Portugal	2.5%
Romania	2.5%
Slovakia	1.0%
Slovenia	1.8%
Spain	1.8%
Sweden	0.0%
UK	0.6%

Source: Damodaran (2019).[126]

Note: All values have been rounded to the nearest tenth.

[126] Damodaran (2019). *Country Risk: Determinants, Measures and Implications – The 2019 Edition*. See Appendix 7 of the study.

Table A-3 Estimated country- and technology-specific discount rates

Country	Technology											
	Biomass fired plants	Coal fired plants	Gas fired plants	Solar PV	Wind onshore	Wind offshore	Nuclear	Hydro-power	Technologies with low deployment and high risk	Biomass fired plants + CCS	Coal fired plants + CCS	Gas fired plants + CCS
Austria	4.9%	6.5%	6.1%	3.1%	3.4%	5.5%	8.4%	2.7%	6.2%	6.4%	8.8%	8.5%
Belgium	5.2%	6.7%	6.3%	3.3%	3.7%	5.7%	8.7%	2.9%	6.5%	6.7%	9.0%	8.7%
Bulgaria	6.6%	8.2%	7.8%	4.8%	5.1%	7.2%	10.1%	4.4%	7.9%	8.1%	10.5%	10.2%
Croatia	7.9%	9.5%	9.1%	6.0%	6.4%	8.4%	11.4%	5.6%	9.2%	9.4%	11.8%	11.5%
Cyprus	7.9%	9.5%	9.1%	6.0%	6.4%	8.4%	11.4%	5.6%	9.2%	9.4%	11.8%	11.5%
Czechia	5.3%	6.9%	6.5%	3.4%	3.8%	5.8%	8.8%	3.0%	6.6%	6.8%	9.2%	8.9%
Denmark	4.5%	6.1%	5.7%	2.6%	3.0%	5.1%	8.0%	2.2%	5.8%	6.0%	8.4%	8.1%
Estonia	5.3%	6.9%	6.5%	3.4%	3.8%	5.8%	8.8%	3.0%	6.6%	6.8%	9.2%	8.9%
Finland	4.9%	6.5%	6.1%	3.1%	3.4%	5.5%	8.4%	2.7%	6.2%	6.4%	8.8%	8.5%
France	5.1%	6.6%	6.2%	3.2%	3.6%	5.6%	8.6%	2.8%	6.4%	6.6%	8.9%	8.6%
Germany	4.5%	6.1%	5.7%	2.6%	3.0%	5.1%	8.0%	2.2%	5.8%	6.0%	8.4%	8.1%
Greece	9.6%	11.1%	10.7%	7.7%	8.1%	10.1%	13.1%	7.3%	10.9%	11.1%	13.4%	13.1%
Hungary	7.0%	8.5%	8.1%	5.1%	5.5%	7.5%	10.5%	4.7%	8.3%	8.5%	10.8%	10.5%
Ireland	5.5%	7.0%	6.6%	3.6%	4.0%	6.0%	9.0%	3.2%	6.8%	7.0%	9.3%	9.0%
Italy	7.0%	8.5%	8.1%	5.1%	5.5%	7.5%	10.5%	4.7%	8.3%	8.5%	10.8%	10.5%
Latvia	5.8%	7.4%	7.0%	4.0%	4.3%	6.4%	9.3%	3.6%	7.1%	7.3%	9.7%	9.4%
Lithuania	5.8%	7.4%	7.0%	4.0%	4.3%	6.4%	9.3%	3.6%	7.1%	7.3%	9.7%	9.4%
Luxembourg	4.5%	6.1%	5.7%	2.6%	3.0%	5.1%	8.0%	2.2%	5.8%	6.0%	8.4%	8.1%
Malta	5.8%	7.4%	7.0%	4.0%	4.3%	6.4%	9.3%	3.6%	7.1%	7.3%	9.7%	9.4%
Netherlands	4.5%	6.1%	5.7%	2.6%	3.0%	5.1%	8.0%	2.2%	5.8%	6.0%	8.4%	8.1%
Poland	5.5%	7.0%	6.6%	3.6%	4.0%	6.0%	9.0%	3.2%	6.8%	7.0%	9.3%	9.0%
Portugal	7.0%	8.5%	8.1%	5.1%	5.5%	7.5%	10.5%	4.7%	8.3%	8.5%	10.8%	10.5%
Romania	7.0%	8.5%	8.1%	5.1%	5.5%	7.5%	10.5%	4.7%	8.3%	8.5%	10.8%	10.5%
Slovakia	5.5%	7.0%	6.6%	3.6%	4.0%	6.0%	9.0%	3.2%	6.8%	7.0%	9.3%	9.0%
Slovenia	6.3%	7.9%	7.5%	4.4%	4.8%	6.9%	9.8%	4.0%	7.6%	7.8%	10.2%	9.9%
Spain	6.3%	7.9%	7.5%	4.4%	4.8%	6.9%	9.8%	4.0%	7.6%	7.8%	10.2%	9.9%
Sweden	4.5%	6.1%	5.7%	2.6%	3.0%	5.1%	8.0%	2.2%	5.8%	6.0%	8.4%	8.1%
UK	5.1%	6.6%	6.2%	3.2%	3.6%	5.6%	8.6%	2.8%	6.4%	6.6%	8.9%	8.6%

Source: Own calculations based on multiple sources of data (as listed in previous tables).

Annex B – Stakeholder interviews

Table B-1: Interviewee list

Name of the interviewee(s)	Name of organisation	Role(s) within the organisation	Type of organisation
Lieven Vanstraelen	Energinvest	Senior Partner	Private consulting firm specialised in energy efficiency and EPCs
Jurjen Algra	Meewind	Commercial Director	Renewable energy investment fund
Stephen Hibbert and Gerben Hieminga	ING Global	Managing Director/ Global Lead Energy Transition and Senior Economist Energy Markets and Sustainability, respectively	Bank
Paul Koutstaal	Dutch Planning Bureau (PBL)	Deputy Head of Climate, Air and Energy Sector	Public (data-driven) modelling organisation
Lisa Eichler	Ortec	Co-Head Climate and ESG Solutions	Financial advisory firm
Niek Schumacher	Green Giraffe	N/A	Financial advisory firm
Alex Van Steenbergen	Belgian Federal Planning Bureau	Expert in Environmental Economics	Public (data-driven) modelling organisation
Darius Biekša	Lithuanian Energy Agency	CEO	Public (data-driven) modelling organisation
Bjarne Steffen and Florian Egli	ETH Zürich, Energy Politics Group	Senior researcher and lecturer, and PhD candidate, respectively	Academic institution
Sébastien Soleille	BNP Paribas Global	Global Head of Energy Transition and Environment	Bank
Nadia Ameli	University College London (UCL), Bartlett School of Environment, Energy and Resources	Principal Research Fellow	Academic institution

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