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Tracking Climate Finance in the German Building Sector

A Landscape of finance flows for building decarbonisation in 2016

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Abstract

Germany's Energy Concept aims to reduce the building sector's primary energy demand by 80% compared to 2008 levels, of which 20% are to be achieved by 2020. This requires significant investment in integrated renewables and thermal. Public funds cannot finance such transition alone. Therefore, it is crucial to not only understand current investment levels and potential investment gaps, but also to analyse how public finance can leverage private investment. This thesis tracks public and private climate-specific investment in the German building sector in 2016. Finance flows are tracked from their source, through intermediaries and financial instruments, to the beneficiary measures and the building type. The thesis seeks to answer three questions. First, how is climate finance organised in terms of key funding sources, investors, financial instruments and mitigation activities. Second, what are the main trends in the last five years and how are they aligned to sector targets. The thesis concludes that in 2016, climate-specific investment in the German buildings sector almost reached EUR 30 billion, of which EUR 24 billion went to thermal and electrical efficiency with a 67% share to new buildings. Households invested the most, with close to EUR 19 billion. The development bank KfW plays the key role in facilitating private investment through its concessional loan programmes. The Ministry BAFA provides grants for innovative renewable and energy efficiency measures. Regional banks have proven to play a role in climate finance, yet due to data gaps, their contribution was not quantified. This thesis also finds that common climate finance reporting standards and tracking methodology are needed to enable accurate climate finance tracking and a fair comparison between different publications.

Keywords: Climate finance – Energy transition – Investment tracking – Climate finance Landscape

Executive Summary

How much money are we investing to protect the climate? Are current investment levels sufficient? Climate finance research seeks to answer these seemingly straightforward, but potentially very complex questions. To identify and measure investments directed towards climate mitigation requires overcoming many methodological and conceptual challenges. The think tank Climate Policy Initiative (CPI) introduced a new approach to climate finance by tracking it along its lifecycle providing an overview of finance flows from their source to their use. This method is called the climate finance Landscape approach. This thesis applies the method to the building sector in Germany. One of the most critical issues in the assessment and calculation of climate finance flows is the additionality principle. To differentiate business-as-usual investments from climate investments, this thesis takes a threefold approach establishing distinct baselines for the construction sector, existing building stock and efficiency of electric appliances.

The German building stock is rather old, has a low construction rate and long-lasting buildings of which most were erected in the post-war period before the first national Energy Ordinance in 1978. This means that there is a large potential to decrease energy demand in Germany's buildings. The German government has put in place a policy package to reach the climate target of reducing primary energy demand by 80% by 2050 compared to 2008 levels.

The results of this thesis show that in the building sector, climate investments as defined in this study, amounted to EUR 30 billion in 2016. Under the same assumptions as CPI's study "Landscape of climate finance in Germany for 2010", close to EUR 28 billion were invested in 2016 compared to EUR 16 billion in 2010. However, if we apply the incremental method to all energy efficiency measures, not merely thermal retrofits, the actual absolute amount of investment is slightly more than EUR 13 billion. The relative size of investment flows and destinations remains the same under different assumptions. Households are the main investor but their share has decreased from 85% in 2010 to 63% in 2016. The corporate sector, such as housing companies, has gained the most share and invested close to EUR 9 billion equivalent to 30% of total investments. The construction sector is still the main recipient of climate finance, with a 2/3 share in 2016. 68% of new residential dwellings received public support to have a primary energy demand 30% lower than the minimum standard, compared to 50% in 2010.

Climate finance tracking and landscaping methodologies should be further developed and harmonised and financial reporting could be aligned with national climate and energy transition targets. Ministries and public agencies could cooperate more closely to enable better climate finance tracking. Recently the Federal Ministry of Economic Cooperation and Development (BMZ) has established a new branch specifically for climate finance, which could have the capacity to do so. Furthermore, more standardised climate finance would enable a fairer comparison between studies assessing investment needs and the ones tracking climate finance.

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Abbreviations and acronyms

Abbreviation	Full text
BAFA	German Federal Office of Economics and Export Control
BAU	Business-as-usual
BMU	Federal Ministry of the Environment, Nature Conservation and Nuclear Safety
BMWi	Federal Ministry for Economic Affairs and Energy
BMZ	Federal Ministry of Economic Cooperation and Development
BNetzA	German Federal Network Agency
Destatis	Federal Statistical Office
EC	European Commission
EnEV 2014/2016	The Energy Savings Ordinance from 2014 with stricter standards for new buildings since 2016.
EU	European Union
EuCA	European court of Auditors
EUR	The Euro currency
GDP	Gross domestic product
GHG	Greenhouse gases
IEA	International Energy Agency
KfW	German government-owned development bank. Its name originally comes from Kreditanstalt für Wiederaufbau (credit agency for the reconstruction).
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
USD	The US dollar currency

Terms and definitions

For the purpose of this research the terms are defined as follow.

Term	Definition
Building envelope	The building envelope is the physical separator between the interior and exterior of a building. Components of the envelope are typically: walls, floors, roofs, fenestrations and doors. Fenestrations are any opening in the structure: windows, skylights, clerestories, etc.
Building sector	Residential and non-residential public and private buildings that do not fall under the agricultural or industry sector.
Climate Adaptation	Measures that aim to adapt to climate change (e.g. urban planning).
Climate finance	Finance (funding and investments) linked to climate mitigation of adaptation.
Climate mitigation	Measures that aim to reduce GHG emissions (e.g. renewable energy).
Concessional loans	Loans that are extended on terms substantially more generous than market loans.
Decarbonisation	The act of removing carbon from an activity.
Decoupling	The act of separating or diverging from an existing connection, for example decoupling GHG emissions from energy consumption.
Dwelling	One living unit, such as a house, flat, or other place of residence.
Energy Concept (*Energiekonzept*)	The German energy transition plan drafted in 2010 and adjusted in 2011 after Fukushima (sooner nuclear phase out).
Final energy consumption	Energy consumed minus energy consumption in the energy production and losses in distribution.
Free rider effect	It is a market failure that occurs when people take advantage of being able to use a common resource, or collective good, without directly paying for it. In this context, the free rider effect occurs when investors take advantage of financial subsidies, without the need for it. Thus, subsidies to not solely target those investors that would not be able to access finance without public support.
Incremental	Relating to or denoting an increase or addition, especially one of a series on a fixed scale. Here, the incremental cost of an investment is the additional cost that can be correlated with climate mitigation.
Landscape	A method to visualise climate finance flow along their lifecycle.
Primary energy consumption	All energy produced and consumed, including energy consumption in the energy production and losses in distribution.
Sensitivity analysis	Sensitivity analysis is performed with assumptions that differ from those used in the primary analysis. Sensitivity analysis addresses the questions such as "will the results of the study change if we use other assumptions?" and "how sure are we of the assumptions?" Sensitivity analysis is typically performed to check the robustness of the results. It involves a primary study, that is cross checked with one or more sensitivity analyses.
Thermal retrofitting	A retrofit is the addition of a new technology to older systems. Therefore, thermal retrofitting is the replacement of insulation and/or heating systems.
Tracking	Conduct the actual measurement.

1 Introduction

1.1 Background and significance

Energy is a core need for societies as it is a primary factor of economic development. Although Europe faces a steady decline in energy intensity, as the ratio of final energy consumption and gross domestic product (GDP) show trends towards decoupling economic growth and energy demand since 2005, it is not possible yet to fully decouple economic prosperity and the demand for energy (Moreau & Vuillec, 2018).

The current unsustainable pattern of energy production and use, and its release of greenhouse gas (GHG) emissions due to fuel combustion, has an impact on the environment. This leads to sharp temperature fluctuations, sea level rises, changes of borders of climatic zones, threats to biodiversity and human health, and more. Furthermore, energy production, even renewable energy, leads to resource depletion and is limited by planetary boundaries (Steffen et al., 2015).

Therefore, it is crucial to decouple GHG emissions from energy production and consumption. This is recognised in the seventh UN sustainability goal: "ensure access to affordable, reliable, sustainable and modern energy for all" (UN, 2015). In an attempt to decrease energy demand in this manner, the German government follows the "efficiency first" principle. The focus lies on increasing energy efficiency and producing the remaining energy through renewable sources.

Substantial investments are needed to reach climate targets and finance the energy transition. Yet, according to previous studies, climate mitigation investments, or in other terms investments that decrease GHG emissions, are insufficient. The European Commission (EC, 2017, p. 13) states that "currently, the EU is not on track to deliver the 11.2 trillion euros required to meet its 2030 energy policy targets" with the biggest gaps in energy efficiency in buildings followed by transportation. Therefore, the building sector play an important role.

Germany is an interesting country to analyse and learn from as it is a large and energy intensive economy. In 2017, there were 80,9 million inhabitants in the country, enjoying one of the highest GDP per capita of USD 48 000, ranked 9th worldwide (Destatis, 2017; OECD, 2017). In 2015, Germany's energy consumption accounted for 19,3% of the European Union (EU)[1] even though Germany represents less than 11% of the European population. As Germany's electricity consumption per households is far below the EU-28 average (Eurostat, 2017a, 2017b), it shows that thermal retrofitting is crucial to the country's energy transition.

Furthermore, Germany is an energy transition lab since several decades. Both oil crisis in the 1970s and the consequent concerns over energy security and increasing oil prices were the tipping point of national policies targeting the energy sector (Auer & Anatolitis, 2014). They mark the beginning of the ever-changing and diversifying German energy mix and energy policies to limit energy consumption, such as the first Energy Saving Ordinance introduced as part of the building code in 1978. Germany formalised its energy transition plan with the Energy Concept (*Energiekonzept*) that commits the country to ambitious climate and energy targets, especially in the building sector (Bundesregierung, 2010, 2011).

[1] EU-28

1.2 Problem definition

For Governments to boost the energy transition, in the building sector and other sectors, with proper policy instruments, such as tax or subsidies, it is important to understand the finance flows. In other words, understanding which actors invest in which type of investments and who provides funding to make these investments possible. In that way tracking climate finance enables evidence-based policy-making by providing an overview of the financial "playground" and provides insights of over- and underspending (Buchner, Falconer, Hervé-Mignucci, Trabacchi, & Brinkman, 2011).

For Germany specifically, the latest and the only complete research on climate finance flows dates from 2012. The study analysed climate finance flows in the year of 2010 (Juergens et al., 2012), which is the year the Energy Concept was introduced (Bundesregierung, 2010). Hence the study is outdated and there is a lack of knowledge of the current structure of climate finance.

1.3 Research questions

To address this lack in knowledge, this thesis aims to track investments of the German building decarbonisation. It seeks to answer the following questions:

Research question 1:

How much capital is invested in climate and energy transition measures in the German building sector in 2016?

1. using which type of capital and which financing instruments,
2. by which investors and through which intermediaries and facilitators,
3. for which technologies and practices,
4. for which type of buildings?

Research question2:

How has the climate finance Landscape evolved in the German building sector since 2010?

The paper answers where finance is concentrated and where the deficiencies are; contributes to framing the assessment of why and in how far investments for decarbonisation are sufficient or not; and finally, which actors could best help leverage more investment volume.

1.4 Scope and limitations

This paper analyses climate investments in the building sector flowing within Germany in the year 2016, or the portion thereof accounted on the 2016 balance. It tracks investments by all actors in the building sector, including residential and non-residential buildings. Outside the scope are buildings that are classified as industrial or agricultural.

Sometimes experts define building decarbonisation solely as energy efficiency measures. Here, it is defined as energy efficiency and integrated renewables in buildings. Energy storage is also included if it is on-site. Electrical appliances are also accounted for. Whereas data is sufficiently available for the residential sector, data is lacking on non-residential buildings. Moreover, the data that is available does not differentiate between industrial, agricultural, commercial or public buildings.

The most significant limitation to this thesis is the insufficient availability of relevant data, which is partially resolved by contacting intermediaries[2] of climate finance. In contrast to the 2012 study tracking climate finance in Germany (Juergens et al., 2012), expert interviews could not be conducted due to time and resource constraints. The use of assumptions and calculations to close data gaps critically limits the accuracy of the research.

In the face of these uncertainties, a conservative approach is taken on for data collection and analysis. It partly limits the "considerable risk" of over-estimation and double-counting in tracking climate finance (Caruso & Ellis, 2013).

Climate finance actors are typically public and commercial banks, that are known to do not divulge information lightly. This research is conducted for the Institute for Climate Protection, Energy and Mobility (IKEM), and is part of a wider research project on behalf of the German Federal Ministry of Education and Research (BMBF). This granted access to more data and contacts than a Master student alone would have access to. Since the respondents answered to IKEM and not me personally, only their institution or company's name is revealed while respondents remain anonymous.

1.5 Structure

This thesis is composed of six chapters. Chapter 1 introduces background information, the research' significance and its contribution to the topic of climate finance and energy transition financing. It also states the research aim, the investigated questions as well as the scope and limitations of this study. Chapter 2 is a literature review providing an overview of climate finance tracking approaches and state-of-art methods, background information on the German building sector and its climate targets, energy transition policy framework and investment needs and trends. Chapter 3 introduces the analytical framework, research design and methods used to answer the research questions and Chapter 4 presents the resulting findings and their analysis. Chapter 6 briefly discusses the research results in a broader context and finally, chapter 7 concludes with a summary of the thesis, provides policy recommendations and indicates further research opportunities.

[2] Intermediaries are the link between the source of capital and the investors and is further explained in the methodology chapter.

2 Literature review

The literature review consists of four sections. The first section explores the wider topic of climate finance in an international, European and national context. The second section provides a background to the German building stock, its energy and emission profile and barriers to its decarbonisation. The third section reviews the energy transition policies that regulate the German building sector. Finally, the fourth section reviews literature on investment needs to reach sector-specific energy and climate targets and reviews finance trends in the sector.

2.1 What is climate finance, who tracks it and how?

In order to track climate finance, one must first define what climate finance is. While it sounds self-explanatory, climate finance may in fact cover different expenditures depending on the context (Caruso & Ellis, 2013; Clapp, Ellis, Benn, & Corfee-Morlot, 2012). Therefore, definitions of climate finance are heterogeneous and no harmonised global standard exists so far (Caruso & Ellis, 2013). In general, the term 'climate finance' covers investments in either climate change mitigation or climate change adaptation. However, given political commitment of the EU and individual countries to spend a particular amount of money or a particular budget share on climate actions and to leverage private investments, the attribution of a particular expenditure to climate finance has become a political rather than a purely technical question, even more so for private climate finance (GIZ, 2014).

2.1.1 Climate finance in the international context

United Nations Framework Convention on Climate Change (UNFCCC)

Assessing and tracking climate finance started at the end of the 2000s. The purpose was to understand investment needs associated with climate mitigation and adaptation in developing countries and the finance flows towards those needs to address them better (UNEP, 2010; UNFCCC, 2007). Interest in climate finance tracking particularly grew after the adoption of the Cancun agreement (UNFCCC, 2010), when developed countries committed to jointly mobilise USD100 billion in climate finance annually by 2020 to address the needs of the developing world. This triggered the development of assessment methodologies as well as their application to track international climate finance flows (Brown, Buchner, Wagner, & Sierra, 2011; Buchner et al., 2011).

In the frame of the UNFCCC negotiations, climate finance usually refers to financial support of developed countries to developing countries. Interestingly, in spite of the significance of the USD 100 billion commitment, no universal definition of climate finance has been adopted yet (Caruso & Ellis, 2013; UNFCCC, 2016). The UNFCCC Standing Committee on Finance (UNFCCC, 2014) conducted a review of climate finance definitions adopted by international institutions. It concluded that these organisations usually provide the definitions of mitigation and adaptation finance, and refer to climate finance as a cumulative of these two. Accordingly, the Committee framed climate finance as "finance that aims at reducing emissions, and enhancing sinks of Greenhouse gas (GHG) and aims at reducing vulnerability of, and maintaining and increasing the resilience of, human and ecological systems to negative climate change impacts" (UNFCCC, 2014).

Given the scope of the commitment, tracking towards its compliance has become an issue. Under UNFCCC (Decision 19/CP.18 and Decision 9/CP.21), developed countries Parties adopted the biennial report common tabular format (BR CTF) for biennial reporting guidelines (UNFCCC, 2018). These tables are designed to facilitate the provision of information and include the tracking of GHG emission trends, the description of quantified economy-wide emission reduction target, the progress in achieving this target, and the provision of financial,

technological and capacity building support (ibid.). There is a strong focus on public international funding with a differentiation between "new and additional" financial resources from other public funding.

Organisation for Economic Co-operation and Development (OECD)

In the OECD context, climate finance has a similar definition to that used by the UNFCCC. It refers to bilateral aid finance with the same purpose of tracking progress towards "mobilising" USD 100 billion annually until 2020 (GIZ, 2014). Across all sectors, OECD DAC[3] statistics encompass public and private flows, from concessional and non-concessional loan finance (Clapp, et al., 2012). These databases on official development assistance (ODA) finance can be filtered by the so-called "Rio markers", introduced at the 1992 Rio Earth Summit, to tag and therefore relate a particular expenditure to the Convention on biodiversity, desertification or climate change. The marker on the climate change Convention was later split into climate mitigation and adaptation (ibid.). There are three levels to the climate mitigation Rio marker depending on the intention of a given project: the reduction of GHG emissions as principal objective (Score 2), emission reduction is a significant objective (score 1) or climate mitigation is not the target at all (score 0).

After many lessons had been learned from the first reporting wave to the UNFCCC in 2014 (biennial reports for 2010-2012), the OECD stated that climate finance accounting standards in the context of development aid has significantly improved (OECD & CPI, 2015). Despite this progress, the broad definition of climate finance still leads to unclear reporting practices, which is most likely inconsistent across public and private donors (Clapp, et al., 2012). Tracking methodologies and climate finance definitions are still undergoing changes, especially in the private finance sector (OECD & CPI, 2015).

Climate Policy Initiative (CPI)

In 2011, the international think tank Climate Policy Initiative (CPI), a key actor in tracking climate finance, developed a methodological approach to tracking climate finance and has since published annual Global Landscapes of Climate finance (OECD & CPI, 2015, p. 32). Core of the publications is a diagram that visualises the flow of capital from its source to its use, which is called the Landscape of climate finance (Buchner et al., 2017a). In contrast to climate finance tracked by the UNFCCC and OECD, CPI does not have its own reporting and statistics platform, but uses "empirical data drawn from a wide range of primary and secondary sources" (Buchner et al., 2017b). Whereas the basic definition of climate finance is like UNFCCC and OECD, the methods are clearly outlined, assuring transparent and comparable results. CPI's approach to climate finance is further depicted in the methodological section of this thesis (see 3.1.2).

The scope of climate finance, or in other words the amount of expenditures that can be tracked, has increased since 2011, as methodologies and definitions develop. In 2017, Buchner et al. (2017a) tracked public investments in renewables, energy efficiency, transport, land use and adaptation. Private climate-related capital flows tracked were solely renewable energy and estimated energy efficiency spending. The authors take on a conservative approach, in which uncertain climate finance flows are not tracked so to avoid double-counting (ibid., p.9)

CPI's 2011 Global Landscape of Climate Finance study established a playground methodology to track climate finance. In recent years, OECD has collaborated with CPI to improve climate finance tracking standards (OECD & CPI, 2015) and the EU and several countries have tracked climate finance building on its methods.

[3] OECD Development Assistance Committee (DAC)

Annex A summarises climate finance definitions provided by several international organisations. Some similarities across the definitions are noticeable, especially when one institution relies on definitions provided by another institution. Overall, climate finance is defined in broad terms and is often complemented with a long list of examples (UNFCCC, 2016).

2.1.2 Climate finance in the European context

European Member States are part of the UNFCCC and report on their climate actions in financial terms and in GHG reduction terms. Therefore, EU official documents adopt UNFCCC and OECD climate finance definitions. Yet, to harmonise and strengthen climate finance reporting under UNFCCC and tracking achievements towards the target to spend 20% of the EU budget on climate action, the EU released several regulations[4]. In 2014, the EU set a methodology for the calculation of support by the five European Structural and Investment Funds (ESIF) for climate change objectives (REGULATION (EU) No 215/, 2014). For each measure supported by the funds, it sets coefficients for the calculation of measures' contribution to climate change objectives at 100% (significant support), 40% (moderate support) and 0% (insignificant support). It is aligned with the OECD's tracking of the 'Rio markers' (IEEP et al., 2014; REGULATION (EU) No 215/, 2014).

While the EU sets a framework for reporting, climate finance is tracked separately by each of its Member States. Rademaekers et al. (2017) attempted to track clean energy finance across the EU, however the authors mainly relied on national publications of climate finance. Overall European contributions to the UNFCCC are available on Eurostat, but here again, it is a summary of national commitments, rather than an EU level tracking of climate finance.

Currently, discussions are ongoing about the new (post-2020) EU budget, for which the climate target and the tracking approach will need to be either confirmed or refined. In particular the European court of Auditors (EuCA) has provided a detailed assessment and identified scope for improving the current approach (EuCA, 2016). Despite efforts by the EU and its Member States to harmonise reporting methodologies in the recent years, differences in reporting and in the scope of the data still exist and defining climate finance is mainly determined by Member States (EC, 2016).

2.1.3 Climate finance in the national context

So far, five countries have tracked climate finance using CPI's Landscape method in a national level,: Germany (Juergens et al., 2012), Indonesia (Ampri, et al., 2014), France (Hainaut, Morel, & Cochran, 2015a), Belgium (Rademaekers, Debeer, De Kezel, & Van Nuffel, 2016) and the Ivory Coast (Falconer, 2017). Climate finance was also tracked in South Africa, yet using a different method (Montmasson-Clair, 2013). Because the aim of each study varies, so does the type of climate finance tracked.

Based on the conducted studies in Europe, a report called "Assessing the State-of-Play of Climate finance Tracking in Europe" (Eichler, Rademaekers, van den Berg, van der Laan, & Bolscher, 2017) has provided the following definition of the term "climate finance tracking".

[4] (REGULATION (EU) No 215/, 2014; REGULATION (EU) No 525/, 2013; REGULATION (EU) No 1232/, 2014; REGULATION (EU) No 1293/, 2013)

"Climate finance Landscapes are comprehensive studies mapping finance flows dedicated to climate change action and the energy transition. Covering both end-investment and supporting finance flows from public and private stakeholders, Landscapes draw the picture of how the financial value chains link sources, intermediaries, project managers and the end investment."

Indeed, the three European studies take the same approach to defining the end investment, as shown in In line with the definition of a Landscape, the research focuses on additional investments beyond the BAU baseline that are in line with Germany's Energy Concept. Table 5 illustrates the boundaries applied to the thesis. There are three layers to defining climate finance measures..

Table 5 and discussed further in methodologies (3.1.1). Therefore, the differences lie across the scope of which elements are tracked in quantitative terms and how the baseline is defined. Figure 1 is a visual representation of what is tracked as climate finance, which defers depending on the context of each study. Typically, climate finance lies within the range of business-as-usual (BAU) investment levels and investment needs to reach certain targets, that vary across publications depending on the context. Several studies and how they applied CPI's concept of climate finance Landscapes are explored further.

Figure 1 Climate finance, investment needs and business-as-usual investments. Source: Author.

The German Landscape of climate finance in 2012 was the first national Landscape. It used national climate targets as a baseline to define climate finance flows, in line with those targets. The study aimed to understand investment levels and potential investment gaps, as well as the effect of public finance on private investments (Juergens et al., 2012, 2013). In a second step, BAU investment levels were subtracted. The methodology used to define BAU investments was defined differently for each sector and depended on the nature of the financed measures.

The Indonesian Landscape tracked climate-relevant public funds in Indonesia in 2011 so to understand how climate finance was flowing through the economy. Therefore, the study supported ongoing efforts by the Government of Indonesia with information on areas on which it could focus on but did not assess investment gaps (Ampri, et al., 2014).

The French Landscapes, from 2011 on, create two baselines, one that assesses general funding of the French economy (BAU) and one on investment needs to reach national GHG reduction and energy transition targets (investment needs). Sector-specific finance flows related to these targets are quantified. The studies aim to understand the role of public and private climate finance and their relevance to the energy transition and to assess investment gaps (Hainaut et al., 2015a).

The Belgian Landscape explores climate finance throughout the country using its own definition of climate finance (not aligned to climate targets). The study does not clearly state an aim behind the tracking, but it seems that the authors focused on providing first insights into Belgian climate finance flows and assessing the state of climate finance tracking so to generate recommendations on how to proceed further (Rademaekers et al., 2016).

The Ivory Coast Landscape creates a baseline of needed investments to achieve estimated annual minimum needs to meet the 2030 20% forest cover target and specifically tracks public REDD+[5] related finance flows in the year 2015 and. Therefore, the Landscape measures

[5] The United Nations Collaborative Programme on « Reducing Emissions from Deforestation and Forest Degradation in Developing Countries» REDD was launched in 2008. REDD+ programs are nationally-led and are supported by the UN REDD, with the support of the FAO, UNDP and UNEP (UN, 2018).

progress towards the levels of investment required to drive sustainable agriculture and reforestation and identifies opportunities to increase available finance (Falconer, 2017).

2.2 The German Building Sector

This section discusses the building sector in Germany from the perspective of climate finance. First, it explains what the German building stock constitutes of and then assesses its impact on the climate. Thirdly, typical barriers to the sector's decarbonisation are reviewed, which then leads us to how the Government uses policies to overcome these challenges. The last section briefly explores literature on climate finance trends in the building sector, which is further discussed in the results and analysis.

2.2.1 Structure of the building sector

Germany has a rather old building stock (see Figure 2 and Figure 4), as well as a low construction rate and long-lasting buildings, which is why it is expected that even by 2050, these buildings will still represent 85% of the total building stock[6] (Amecke et al., 2013; OECD/IEA & IRENA, 2017). Most buildings have very old and inefficient envelopes that are very costly to upgrade, which leads to the risk of stranded assets[7] (Amecke et al., 2013; Bollmann, von Mallinckrodt, & Röttmer, 2018).

The residential sector has the highest share of buildings, its structure mostly comprises of detached houses, and most buildings were constructed in post-war times but before the first energy efficiency ordinance of 1978 as shown in Figure 2. In 2016, German authorities administered building permits for 23 760 dwellings renovations and 189 836 apartment construction projects (AGEB, 2018).

Despite the relevance of non-residential buildings, less research and therefore less literature is available for it. The German government has launched a large-scale building structure research project to counter this gap in knowledge, yet only preliminary results are available (March 2018): production, office space and trade buildings bear the highest share and most buildings are not retrofitted (Hörner, Schwarz, & Busch, 2018). German statistics differentiate between residential or non-residential buildings, but not between the industry, agricultural, tertiary or public sector.

[6] Hence, in 2050, only 15% of the building stock will consist of new buildings, construvted after 2010.

[7] These buildings bear the risk of partial or total devaluation (stranding).

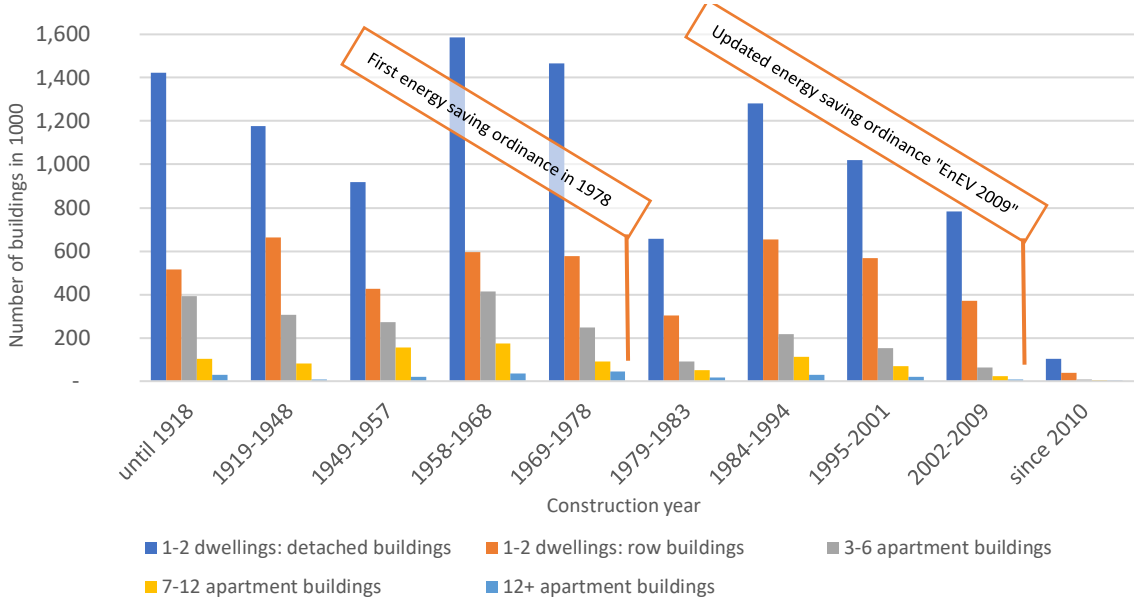


Figure 2 Structure of the German building sector as of 2016. Data Source: (Bürger et al., 2016). Residential buildings are split into five dwelling types. The amount of each building type is represented in 5-year intervals. Many buildings were erected before the first Energy Saving Ordinance of 1978.

2.2.2 Energy and emission profile

In 2016, the German residential sector accounted for 26,2% of the final energy consumption out of which roughly 69,4% was used to heat buildings (BMWi, 2018). Furthermore, households accounted for 25% of electricity consumption and 42,4% of district heating in 2015 (AGEB, 2017). Although evolving energy efficiency standards for new buildings and retrofit rates push energy consumption down, heat consumption is not seen to decrease, due to an increasing number of households, larger living space and decreasing inhabitants per household (BMWi, 2018).

Non-residential buildings account for only 13% of the building stock but consume 38% of the building sector's final energy consumption, which results in 47% of the sector's GHG emissions (Bollmann et al., 2018)[8]. As described in the previous section, not all non-residential buildings are relevant to this thesis, as buildings from the industrial and agricultural sector are not considered.

Energy efficiency standards in the building stock do not solely address the building envelope, but also appliances and heating systems. Figure 3 shows the development of heating systems by source of energy in construction[9] and in the existing building stock in five-year timeslots. In Germany, heating pumps and district heating have slowly been increasing, pushing energy supply from oil and gas down. We can see that newly-built buildings adapt faster to technological advances (e.g. faster uptake of new heating systems such as heating pumps or pellets), whereas the heat transition on the existing building stock is much slower (e.g. slower decrease of fossil fuels).

[8] Including space and water heating, lighting, air conditioning. These numbers were calculated by the authors based on seven German data sources from 2011 to 2015.

[9] Newly constructed buildings are acconted as „construction" only once per timelsot, therefore a newly constructed building in 2000 is reflected as the building stock in the next timeslot (2002-2009).

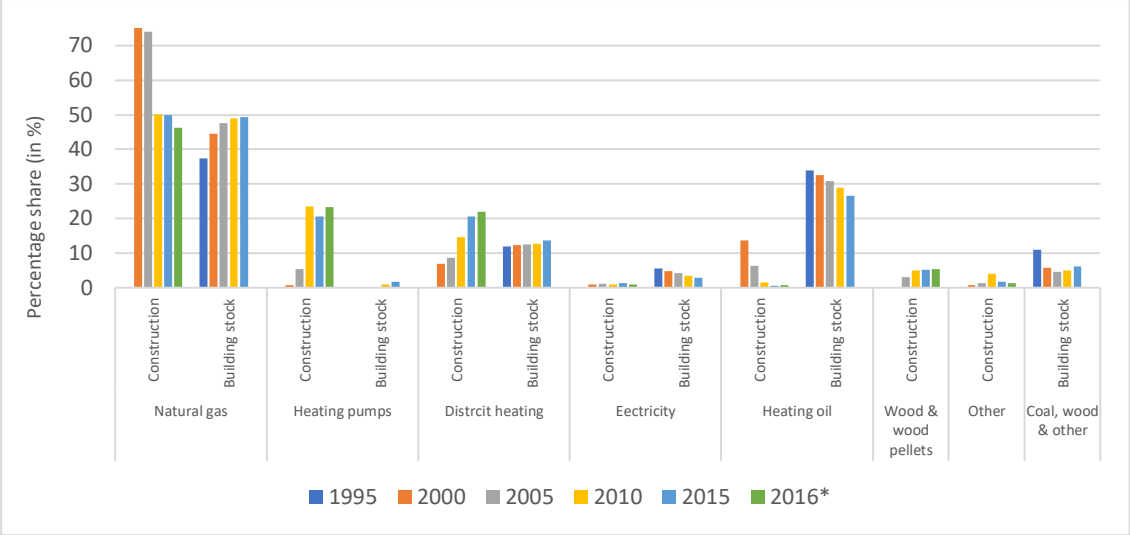


Figure 3 Heating systems for new and existing buildings in percentage share. Data source: (AGEB, 2018). Eight categories of heating systems are represented, each split into the construction sector and the existing building stock. The transition to low carbon heating systems is faster in the construction sector than in the building stock

As could be expected, energy consumption levels vary across Germany's building stock depending on the construction year of any given building. As mentioned before, most of the building stock dates from post-war times but before the first Energy Saving Ordinance in 1978. Figure 4 shows the magnitude of the building stock in million square meters on the x-axis and the average energy consumption of the given section in annual kilowatt-hour per square meter (kWh/m^2a). Energy consumption per square meter drastically dropped each time after the introduction of three major Energy Saving Ordinances, in 1978, 2009 and 2015. Figure 4 also illustrates that buildings constructed between 1948 (post-war reconstruction boom) and 1978 (first Energy Saving Ordinance) represent the biggest potential, as they are the dominant class in square meters of housing space and have the highest primary energy consumption per square meter.

Several pilot projects across Europe demonstrate that it is technically possible to achieve so called-passive buildings or nearly zero-energy buildings by implementing efficiency measures and renewable energy production. For example, the Wuppertal University[10] developed a comprehensive database with more than 330 real buildings from 1993 to 2013 aiming at a (nearly) equalised energy balance. The European Energy Performance Building Directive (EPBD) defines nearly zero-energy building' as buildings that have a very high energy performance, complemented to a very significant extent by renewable energy, preferably on-site.

2.2.3 Barriers to the decarbonisation of the building sector

There are several barriers to decarbonise the building sector. The most relevant ones to this research are listed below.

<u>High upfront costs and uncertain energy prices</u>

The cost-effectiveness of retrofit measures is methodologically not easy to calculate, because among other things, the future development of energy prices is difficult to predict (BMWi, 2014, pp. 12 & 13). Furthermore, energy subsidies disrupts the cost benefit analysis of an energy

[10] The study was part of the International Energy Agency (IEA)'s project "Towards Net Zero Energy Solar Buildings".

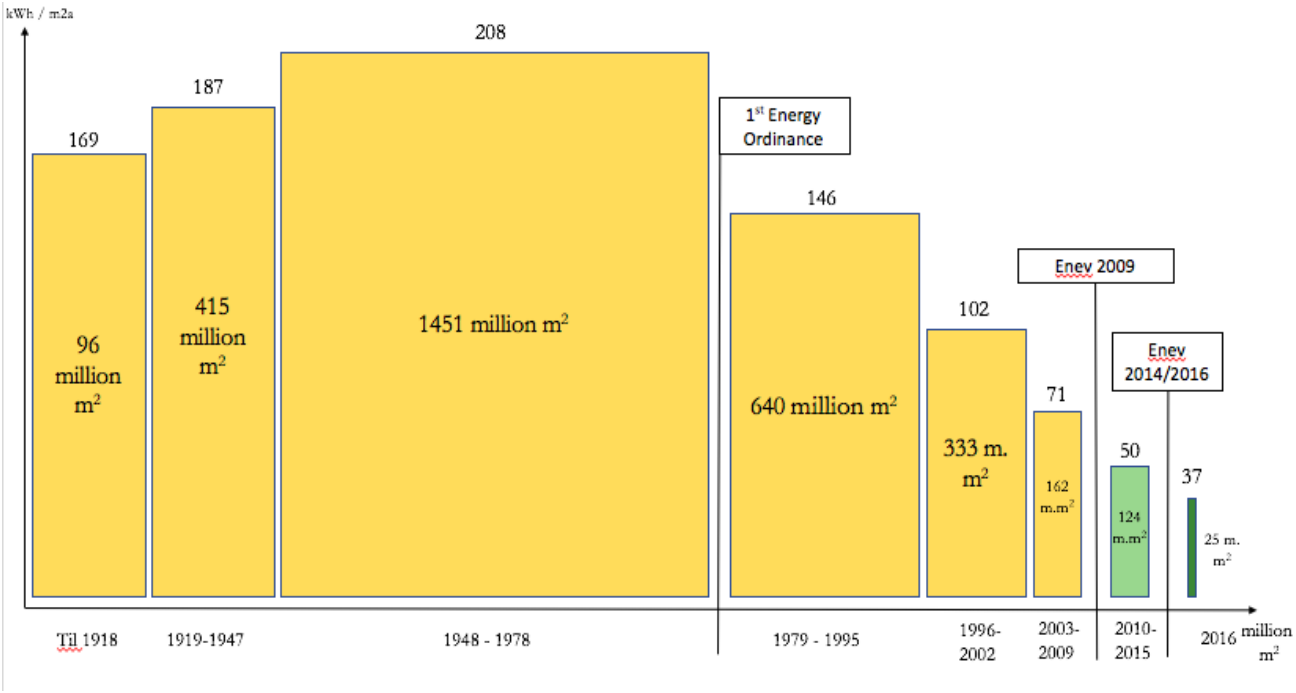


Figure 4 Energy consumption of the building stock by time classes. Data source: (BMWi, 2014; Destatis, 2018; Kersten, 2014; Loga, Diefenbach, Stein, & Born, 2012). The magnitude of the building stock in illustrated in million square meters on the x-axis and the average energy consumption of the given section in annual kilowatt-hour per square meter (kWh/m²a). Buildings from 1948 to 1978 show the largest energy saving potential.

retrofit measure, or in other words the ratio between investment costs and the value of energy savings (Ürge-Vorsatz et al., 2012, pp. 698–703).

Private households with low or middle income may not be able to afford high investments in energy retrofits. Besides, the typical high upfront cost is usually too high for tenants, which are most likely to move out before the investment return (Forni & Zajaros, 2014). In contrast, building owners that rent out do not benefit from the high investment (more in the split-incentive section). Companies prioritise investments in their core business more than energy-saving measures and in general, return on efficiency measures is rated less attractive than other business measures (Ürge-Vorsatz et al., 2012, pp. 698–703).

Information and training deficit

Another barrier to a proper cost-benefit analysis is the insufficient transparency of present and future energy cost and energy consumption. Building owners often have little experience in project management of larger investment projects such as energy renovation. Together with the above-mentioned methodological difficulties in assessing economic efficiency, investors are generally risk averse to energy retrofits (BMWi, 2014, pp. 12 & 13). Although heating and insulation the insulation techniques and products continue to evolve, the high degree of innovation leads to the lack of qualified planners, architects or technical workers (ibid.).

Split-incentive

The renter-tenant dilemma is a particular case of the investor-user dilemma that can also be called split-incentives, principal-agent, agency dilemma, or misaligned financial incentives (Forni & Zajaros, 2014). There is a lack of incentive for tenants to reduce consumption or invest in energy efficiency measures when utility bills are included in the rent (ibid.) On the other hand, owners also have little incentives to pursue energy efficiency retrofitting when renting out as they do not benefit from the energy savings and it is uncertain whether they are not able to

recoup the cost through asking for higher rents (BMWi, 2014, pp. 12 & 13). This is particularly a problem because in Germany 60% of owners rent out their properties (Forni & Zajaros, 2014; Li & Grießhaber, 2013). In general, tenant-occupied homes are less well insulated than owner-occupied ones and have lower energy efficiency appliances (Papineau, 2015).

Lack of motivation

Beyond solely financial arguments, aspects such as tradition, behaviour, lack of awareness, and lifestyle, health concerns, or risk aversion of less known products leads to reservations about new energy-efficient techniques (BMWi, 2014, pp. 12–13; Ürge-Vorsatz et al., 2012, pp. 698–703). From a behavioural economic point of view, house owners or tenants may prioritise investments with direct social status benefit (e.g., new bathroom, car, big trip) instead of energy saving measures (BMWi, 2014, pp. 12 & 13).

2.3 Sector-relevant energy transition policies

The German government has taken over the responsibility to fight climate change and reduce its own GHG emissions. Therefore, it has set up a climate strategy for its energy transition, the Energy Concept (Bundesregierung, 2010, 2011). Furthermore, due to the above-mentioned barriers to the building sector's decarbonisation, the German government steps in with a wide range of policies to overcome these barriers (BMUB, 2017, pp. 398–400). These policies in turn impact investment flows tracked in this thesis, which is why the policy framework is depicted and explained.

Climate targets

Germany has formalised its energy transition with the Energy Concept that commit the country to ambitious climate and energy targets: to reduce GHG emissions 80-95% below 1990 levels by 2050, to phase out nuclear energy by 2022, and to reduce primary energy consumption 50% below 2008 levels by 2050 (Bundesregierung, 2010, 2011). The building sector bears even more ambitious targets, such as reducing primary energy demand by 80% in the building sector compared to 2008 levels, of which 20% are to be achieved by 2020 (Bundesregierung, 2010, pp. 5, 27). The thermal retrofit rate is aimed at 2% annually, more than double than the current rate (ibid.). Following the Energy Concept, the Climate Action Plan 2050 depicts GHG emissions reduction targets by sector, and the building sector bears the highest[11], with a 67-68% reduction target by 2030, below 1990 levels (BMUB, 2016). Finally, all new buildings are to be climate neutral by 2020 and all buildings, including the existing building stock are to be climate neutral by 2100.

To achieve the above-mentioned climate goals, energy efficiency in buildings must be significantly improved and integrated renewables installed (BMUB, 2017, pp. 398–400). Political instruments must therefore address both new buildings and especially the building stock (energy savings potential is shown in Figure 4). Accordingly, the German government has put in place an energy efficiency policy package that comprises of a wide range of policy instruments (Bundesregierung, 2017). It is technically possible to achieve low-energy or zero-energy buildings across the whole building stock. To achieve this, it is crucial that the public policies complement and promote each other (BMUB, 2017, pp. 398–400).

The German policy package firstly comprises of the Energy Saving Ordinance that sets minimum energy efficiency requirements. It was latest updated in 2014 and implemented in

[11] With the exeption of the sector „other" that accounts for less than 1% of emissions.

2016. Other public policies include information transparency through free energy advice and mandatory energy certificates; financial incentives, such as tax cuts and subsidies to boost innovation and R&D (BMUB, 2017, pp. 398–400). Figure 5 exemplifies the different policy instruments and their effect on the building market. The policies are discussed individually next.

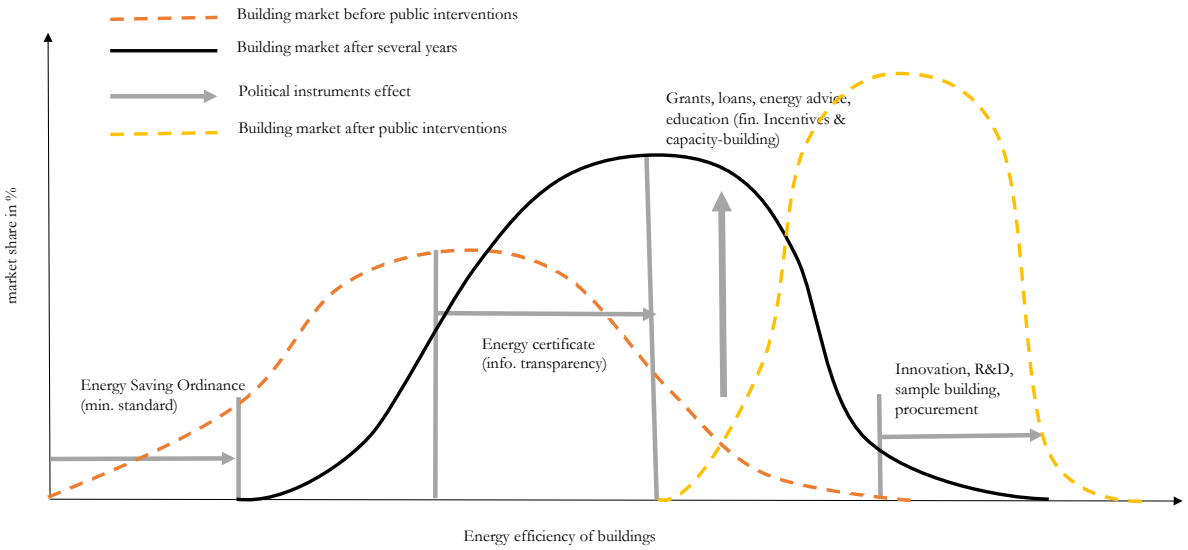


Figure 5 Political instruments effect on and market development of the building sector. Based on: (BMUB, 2017, p. 399). Public policies should complement each other and create a push and pull environment to accelerate the energy transition in the building sector.

Minimum standard

The minimum standard for the construction sector is the Energy Saving Ordinance. It was introduced in 1978 and regularly updated since then. The last update dates from 2014 with effective implementation in 2016 (BDI, 2013). The regulation on energy-saving thermal insulation and energy-saving systems for buildings known as "EnEV" was first introduced in 2009. The primary energy consumption standards are differentiated between newly constructed residential buildings (§ 3 EnEV 2009) and non-residential buildings (§ 4 EnEV 2009) (Schuberth & Tschetschorke, 2013).

The standard comprises of energy efficiency requirements for different parts of the building envelope and allows the remaining energy demand to be covered by renewable energy. The use of renewable heating systems for construction works is in turn regulated by the 2011 Renewable Energy Heat Act (EEWärmeG) (German Institute of Energy-Efficient Architecture, 2018). Public buildings need to consider the Renewable Energy Heat Act when retrofitting buildings. For all other building, the standard only applies to construction projects.

Table 1 shows the difference in consumption from the building stock average in 2013 and the EnEV 2009 standard. EnEV 2014/2016 is approximately 25% lower than EnEV 2009 requirements, yet the complexity of the methodology doesn't allow a proper comparison (Kersten, 2014).

Minimum requirements for energy efficiency push the market towards a more energy efficient building stock. They are a central aspect of the push and pull strategy illustrated in Figure 5. EnEV standards are tightened at regular intervals, removing the most inefficient components and systems from the market. Even though the minimum standard is only applicable to new buildings, it represents a business-as-usual baseline and is used in other policy instruments as a reference (see next sections).

Table 1 Overview of square meter consumption (kWh/m²a) of the building stock in 2014 and the EnEV 2009 values. Data source: (Henger, 2014)

In kWh/m²a		in 2013	E100	E85	E70	E40
Single and double family houses	Per square meter housing area	218	91,1	84,5	57,1	45,2
	Per square meter used area	172,3	72,9	69,6	46,4	37,7
Apartment buildings	Per square meter housing area	173,8	120,5	115,9	75,7	62,7
	Per square meter used area	144,8	93	88,8	59,9	48,5

For electrical efficiency, the minimum standard is set on an EU-level and the minimum standard is the ecodesign Directive 2010/30/EU (European Parliament and Council, 2010). It sets minimum energy efficiency standards that manufacturers need to meet in order to place their products on the European market. Eco-design requirements deviated for each appliance (ibid.)

Information transparency

On an EU level, there are energy efficiency policies in three domains: the energy sector, buildings and energy efficient products (EC, 2018). Energy labelling can be traced back to the 1960s for home appliances, but the EU has expanded labelling to housing, in the form of mandatory energy efficiency certificates accompanying the sale and rental of buildings (Waide & Watson, 2013). Energy efficiency labels perform the very basic function of providing information about the energy consumption and energy performance of products and consequently provide transparency so to correct the classic market failure of lack of information (Waide & Watson, 2013). For buildings, it provides useful information that should enable anticipation of heating consumption and therefore heating costs, yet, it can be argued that it does not really reflect the actual energy consumption of a given building or apartment (German Consumer Center, 2018).

Part of the German government's energy efficiency policy package is free energy advice for construction and retrofit measures that informs about technical and financial opportunities (Bundesregierung, 2017). Energy performance certificates and free energy advice (and best practice examples) pull the market so that the average energy efficiency level of new buildings rises (see Figure 5).

Innovation, research and development (R&D) and capacity-building

Additional education and training measures for skilled workers in the building sector are intended for a stronger market penetration of energy-efficient construction technologies and practices. So to address information deficits, energy certificates, examples of good practice for refurbishments, information and motivation programs as well as individual advice and energy audits should show the homeowners efficiency potential and present cost-effective opportunities for retrofits (BMUB, 2017, pp. 398–400). Similar free energy advice and information is provided to builders, in the form of online databases, hotlines and conferences. The promotion of research and development as well as demonstration projects is intended to advance further innovations for energy-efficient buildings and to provide best-practice examples (BMUB, 2017, pp. 398–400).

The EU's Energy Efficiency Directive (EED) (Directive 2012/27/EU) sets binding measures to help the EU reach its 20% energy efficiency target by 2020. As an exemplary role in the energy retrofit in countries' building stock and to drive innovation and create demand on the

market, Article 5 of the EED states that , starting in 2014, public buildings[12] should be retrofitted to 3% annual rate (EC, n.d.). In Germany, the directive has been transposed with an alternative approach to the implementation. The Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU) have adopted several measures such as information initiatives, implemented by the German Energy Agency (dena), as well as federal support programs funding energy consulting for municipalities, the development of energy efficiency contracting projects and the development of municipal action plans, and retrofitting implemented by the German Federal Office of Economics and Export Control (BAFA) (CA EED, 2016).

Financial incentives

As mentioned in section 2.2.2, there are significantly greater efficiency potentials in the existing building stock than in new buildings. Policy instruments that address financing barriers as well as the tenant landlord dilemma are of importance here, as financial support for implementation support combined with financial incentives such as grants and tax incentives for investors can increase the market penetration of energy-efficient renovations (see Figure 5). Therefore, the German government has committed to further develop, stabilise and expand its GHG building renovation program until 2018, which supports refurbishments of the existing building stock by private households (Bundesregierung, 2017).

Kfw standards go beyond the minimum standard EnEV but use the standard as a baseline. For example, a so-called KfW Efficiency House 100 meets the requirements of the EnEV. A KfW Efficiency House 85 requires 85% of the energy of the reference building, a KfW Efficiency House 55 as low as 55% (KfW, 2018). To achieve the low primary energy demand levels, integrated renewables are required, therefore there is a programme dedicated to renewable energy for heating in buildings: the market incentive program (MAP). Both the KfW standards are related financial support and the MAP programme aim to push for more energy efficient measures (compared to regular construction and renovations) and increase the percentage share of energy efficient buildings (see Figure 5).

Figure 6 summarises all German policy instruments of the building sector in a policy map. The instruments are shown at three different planning stages, and categorised into information, financial incentives and minimum standards. Because this thesis focuses on tracking investments, policies related to financial incentives in the planning and investment phase are the most relevant, namely the KfW and MAP programmes, circled in black.

[12] Measured in total floor area of heated and/or cooled buildings owned and occupied by its central government.

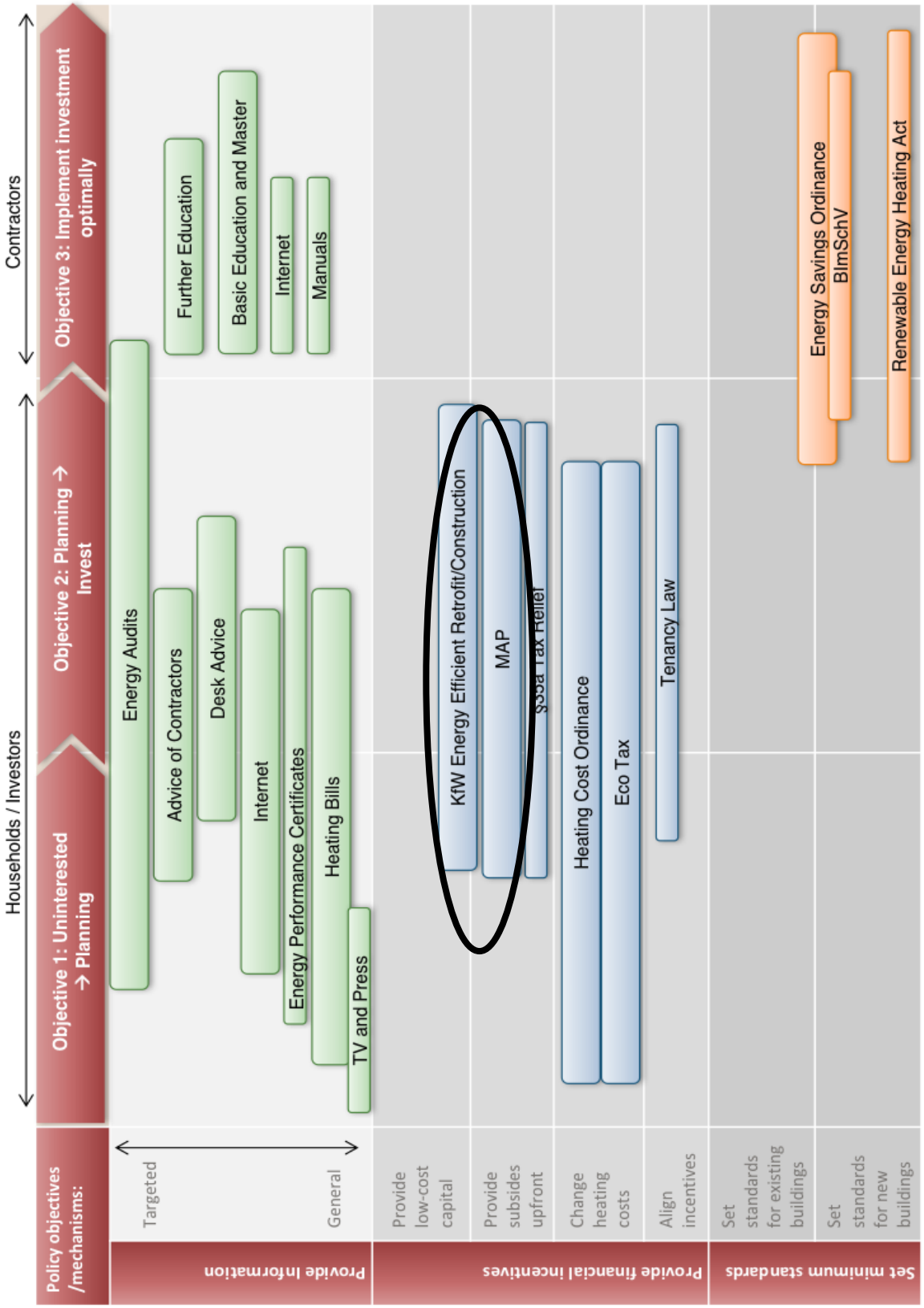


Figure 6 Map of German policies and programmes supporting thermal energy demand reductions as of 2012. Source: (Neuhoff, Novikova, Amecke, & Stelmakh, 2012). The KfW and MAP programmes are policies related to financial incentives in the planning and investment phase, hence these are the most relevant to this research.

2.4 Investment needs and trends

Investment needs

The EC states that energy efficiency measures in the building sector are lacking most funding, as current levels cover only 26% of total investment needs to reach the 2030 EU climate targets (EC, 2017, p. 13). In Germany, several research groups have estimated the investment needs and gaps, mainly relying on macro-economic modelling. To do so, they estimate the total investment of achieving the country's 2050 commitments and deduct investments from the reference scenario from it, based on historic trends and current policies (Novikova, Juergens, Stelmakh, Peterka, & Emmrich, 2018). The scenario targets, time frame and resulting annual investment needs are shown in Table 2.

Table 2 Overview of studies assessing investment needs and gaps in the building sector to reach Germany's climate targets, studies found from Novikova et al., (2018). Investments needs for the German building stock range between EUR 7 and 20 billion annually.

Study	Target	Time frame	Annual investment needs
(Schlesinger, Lindenberger, & Lutz, 2014)	80% GHG emission reduction by 2050	2012-2050	EUR 6.7 billion EUR *
(Gornig, Hagedorn, & Michelsen, 2013)	20% less primary energy consumption by 2020	2014-2020	EUR 10,25 billion**
(Gerbert et al., 2018)	80% and 95% emission reduction targets in 2050	2018-2050	EUR 13,5 & 20 billion***

* EUR 5.6 billion for households and EUR 1.1 billion for the tertiary sector
** Annual investment needs for 2016
*** EUR 13,5 and 20 billion are investment needs for respectively 80% and 95% GHG reduction targets

Investment trends

Juergens et al., (2012a, 2013) found that in 2010 EUR 10.5 billion was invested into the building sector, of which EUR 5.8 billion into energy efficiency investments in buildings and appliances and the rest into renewable energy integrated into buildings amounted to EUR 5.8 billion. Nearly 70% of these investments came from households (ibid.). Another study used an econometric model and calculated EUR 38 billion related to energy efficiency and integrated renewables in the building sector of which EUR 25 billion went to thermal efficiency[13] in 2017 (Gornig & Michelsen, 2018).

According to OECD, IEA and IRENA (2017), the focus of energy efficiency investments in the building sector in Germany is on retrofits and renovation, which is in line with the policy targets. These investments are supported by public finance in the form of concessional loans and grants, typically given on a regional, rather than on a national or municipal level (Li & Grießhaber, 2013). Yet, Juergens et al. (2012) state that with investment trends being focused on new buildings more than the existing building stock, Germany would not reach its sector specific decarbonisation target. Investment trends are further discussed in the result and discussion sections of this thesis.

[13] The study assumes that 30-40% of the total investments are climate related.

2.5 Literature review summary

The literature review investigated climate finance in an international, European and national context, the German building stock, its energy profile and regulatory framework, and literature on the sector's investment needs and trends. While climate finance may sound self-explanatory, it may cover different expenditures depending on the context. There have been a few attempts to standardise climate finance and overall it covers investments in either climate change mitigation or climate change adaptation. Nevertheless, definitions of climate finance remain heterogeneous and no harmonized global standard exists. Typically, the role of public finance to mobilise private finance is a central aspect of climate finance but the correlation is difficult to assess.

Methods for tracking climate finance are heterogeneous. Currently, research projects are undergoing to harmonise methodologies. The think-tank CPI established a new approach to climate finance by tracking it along its lifecycle providing an overview of finance flows from source to use for a given year. This method is called a Landscape of climate finance and has been replicated in a national context by several studies, such as in this thesis that focuses on the building sector only.

The German building stock is rather old, has a low construction rate and long-lasting buildings of which most were erected between post-war times and before the first national Energy Ordinance in 1978. Consequently, there is a high thermal retrofitting potential but high upfront costs, information deficit, the split-benefit dilemma, limited access to financial services and other barriers constrain such retrofits. To overcome these barriers and reach energy transition targets for the building sector, the German government has put in place a policy package that comprises of free energy advice, a harsher building code, subsidies and more. Despite the relevance of the building sector for the energy transition, it seems that investments are lacking to reach the investment needs. Furthermore, households are by far the largest investor in the sector and integrated renewable energy and energy efficiency measures are key to the sector's decarbonisation.

3 Analytical Framework and Methodology

3.1 Analytical framework

The key approaches to define and track climate finance in the international, European, and national context were reviewed. As section 2.1.3 concluded, several countries found the Landscape method as a convenient tool to present and to analyse finance flows. This section introduces and discusses the concept in detail as it is the core methodological tool of the thesis. First the concept is introduced on a broader level, followed by a more detailed step by step review to finally discuss advantages, limitations and crucial aspects.

3.1.1 The concept of climate finance Landscapes

As section 2.1.3 illustrated, a principal output of many pieces of research tracking climate finance is a "Landscape of climate finance". The landscape approach allows tracking climate finance flows along their lifecycle, starting from the source of money and the relevant intermediaries, through instruments used, followed by channels, and uses and visualises these in the form of a diagram. Figure 7 shows a dummy Landscape of climate finance. This approach of tracking climate finance was introduced by CPI (Buchner et al., 2011) less than a decade ago. Since then it has been increasingly used as a tool of research and analytical groups worldwide.

In 2012, Juergens et al. tracked climate finance flows using the Landscape method in Germany. It provided the first national application of the Landscape method. The purpose was to understand how investments address domestic climate and energy transition commitments, namely the German Energy Concept of 2010. Such country-level landscape showed who invests into climate-related measures, what kind of measures these are, how much money the actors invest, using which intermediaries, and what type of money it is. This information was critical to understand which measures need more investment, whether public finance is successful in leveraging private investment, which financing instruments are the most successful, and which intermediaries help the most in this process.

As explained in the literature review, there is a lack of consensus on one official definition of climate finance, It renders climate finance tracking difficult. In fact, defining climate finance and how to track it is an ongoing discussion. The present thesis defines the Landscape method as a visual representation of finance flows and interactions between sources of finance, the intermediaries which disburse it, financial instruments used, sectors that received finance and the measures that were funded, categorised as such in "columns" (see Figure 7 for a simplified version of such a Landscape). Colour-coded arrows, whose sizes reflect the magnitude of finance, represent the flow of finance across the Landscape. Following, each category of such a Landscape is explained.

3.1.2 Main elements of the Landscape

As said, the main elements of the climate finance landscape are its columns representing the sources of finance, the intermediaries which disburse this finance, financial instruments used, and the uses of climate finance as well as the interactions represented by arrows. This section will explain the meaning of the columns and define elements which can populate them.

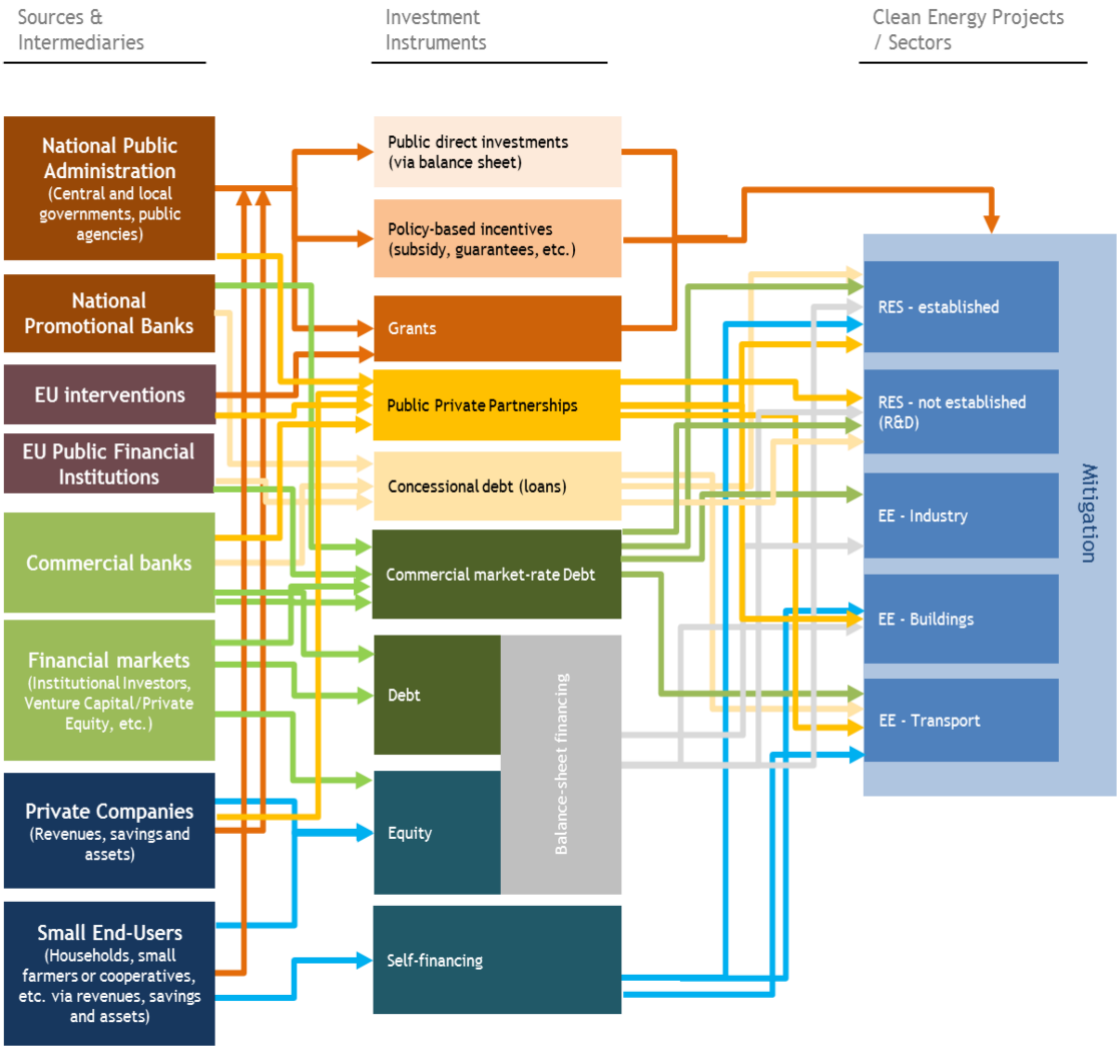


Figure 7: Dummy Landscape of climate/energy finance. Source: Eichler et al. (2017). The authors analysed the Belgium Landscape of climate finance available in 2017. Based on their research along the German and French Landscapes, they reviewed various possible alternatives and gathered them in a dummy diagram with only three columns.

Sources

Sources of finance capture information on where climate investments come from (Juergens et al. 2012). The sources are typically split into private and public sources.

The source of capital is allocated to the entity that invests into a given measures. Therefore, even if a household borrows from the bank that in return sources the capital from capital markets, for the purpose of this research, the source is the borrower, namely the household. The underlying assumption is that borrowed capital is to be repaid within an agreed timeframe, plus the cost of capital; therefore, the capital is allocated to the borrower. The cost of capital would be allocated to the lender, but it is not seen as climate finance, hence it is irrelevant to this research.

Private sources include households, farmers, private companies, and cooperatives. Among these, the most relevant for the buildings sector are households, housing associations, owners and investors into commercial assets such as hotels, commercial office space, supermarkets, and others.

Public sources include finance from EU funds and national public budget. National public sources could be federal budget, regional budget, or local budget. The public finance includes direct investment into public assets and the financial incentives (policy-based investment) to private and public actors to leverage their investment into energy transition measures. For the building sector, the public direct investment includes the investment into energy efficiency and integrated renewable energy of federal, regional, and municipal buildings. The policy-based investment may include for instance grants to households for building retrofit measures.

Intermediaries

Intermediaries are agencies that link climate finance sources to investments, offering different financial instruments and sometimes using specific disbursement channels (Juergens et al., 2012). Intermediaries include EU public financial institutions, EU financial intermediaries, national financial institutions, national financial intermediaries, commercial banks, and financial market actors.

Table 3 Definitions of relevant financial instruments.

Term	Definition	Source
Debt	Lending money to a company, government, or project in the form of a loan or bond.	(Reyes, 2012)
Direct investment	Direct investment provides capital funding in exchange for an equity interest without the purchase of regular shares of a company's stock.	(Investopedia, 2018)
Equity	A stock or any other security representing an ownership interest or partial ownership of a company. The value of the investment is related to the success, rather than the interest payments accrued by debt finance. In this context, equity equals cash, therefore it is households' budget or equity from the tertirary sector, which means this money does not go through a specific instrument.	(Investopedia, 2018; Reyes, 2012)
Grant	Transfers made in goods, cash, or services from a government or other organisation to an eligible recipient for a specified purpose, with no repayment required.	(OECD, 2018b)
Guarantee	A written commitment to cover risks for all or part of a third party's debt, obligation, or loan portfolios in order to provide potential economic and regulatory capital relief.	(European Structural and Investment Funds, 2014)
Loan	The act of giving an agreed sum of money to another party in exchange for future repayment of the principal amount, along with interest or other finance charges, within an agreed period of time.	(European Structural and Investment Funds, 2014)
Commercial market-rate loan	A commercial loan is a debt-based funding arrangement between a business and a financial institution, typically used to fund major capital expenditures and or cover operational costs that the company may otherwise be unable to afford.	(Investopedia, 2018)
Concessional (soft) loan	A loan that is extended on terms substantially more generous than market loans. The concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these. Concessional loans typically have long grace periods.	(IMF, 2003)
Subsidy	A subsidy is a benefit given to an individual, business or institution, usually by the government. It is usually in the form of a cash payment or a tax reduction. The subsidy is typically given to remove some type of burden, and it is often considered to be in the overall interest of the public, given to promote a social good or an economic policy.	(Investopedia, 2018)
Public-private partnerships	A long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance.	(Public-private-partnership in infrastructure Resoyrce Center (PPPIRC), 2018)

EU public financial institutions include the European Structural and Investment Funds, such as the European Regional Development Fund and the Cohesion Fund. The EU financial intermediaries include European Investment Bank (EIB) and the funds and facilities, which it co-manages and co-finances.

The national financial institutions include federal and regional ministries and public agencies as well as local public agencies. The national public financial intermediaries include in Germany is the government-owned national development bank KfW and regional development banks (Länder Förderbanken). Financial market actors typically include institutional investors, such as pension funds, insurance funds, investment funds, and other entities.

Instruments

Financial instruments are tradable assets that could be cash, a contractual right to deliver or receive cash or another type of financial instrument, or evidence of one's ownership of an entity (Investopedia, 2018). These instruments include equity; commercial loans; various subsidies including grants, concessional loans, guarantees, and debt instruments such as loans, finance delivered through public-private partnerships and others. The definitions of these financial instruments is provided in Table 3. Climate finance in Germany's building sector is mainly delivered through concessional loans, grants, equity, and commercial loans (Novikova, Amecke, Stelmakh, Buchner, & Jürgens, 2013).

Sector recipients and measures

In a national context, recipients of climate finance are the sectors, such as energy generation and distribution, industry, buildings, agriculture, and transportation. Within each sector, climate finance is used for certain measures that may include the improvement of energy efficiency in assets, the investment into renewable energy generation, transmission and distribution, the reduction of methane leakage in agriculture, adaptation to climate change, and more. Within each sector, climate finance could be further broken down into segments such as the decarbonisation of the existing building stock and low carbon construction. For transportation, the finance flows could be broken down into aviation, railway, road infrastructure, marine, and other. For the industry sector, finance flows are often broken down by branch.

Table 4 compares the approach to sector recipients and measures in the three national studies in Europe that applied the Landscape concept. The three studies were constructed in a very similar manner. The differences lie in adaptation finance, nuclear infrastructure and intangible assets, such as innovation and capacity-building.

3.1.3 Advantages of the method

The main advantage of climate finance Landscapes is that they provide a comprehensive snapshot of stakeholders, finance flows and their proportions and recipient of climate investments. Based on the playground drawn by the landscape concept, it is possible to assess over- and underspending and provide insights on what should be further investigated. This information has the potential to be directly incorporated in policy-making (Buchner et al., 2011)

The Landscape method clearly reflects the proportion and significance of finance between public and private sources, which in turn exhibits the leverage of public finance on private investments. The extent to which each recipient or sector (depending on the context) and each measure type is financed is clearly demarcated. Investment patterns and the relative importance of instruments in the delivery of climate finance can be evaluated. For instance, the ratio of concessional loans to commercial loans indicates a policy-based transformation, whereas the higher share of commercial loans would signal a market-driven transformation (Novikova, personal communication, April 13rd, 2018).

Finally, comparing such Landscapes for two different timeframes or countries, may help to understand the effectiveness of additional (climate-related) policies that were introduced in between two studies or in to different countries using the same method.

Table 4 Comparison of sector recipients and measures covered by different European climate finance Landscapes. Source: Adapted from Eichler et al. (2017) with updates from this literature review.

European National Landscapes of Climate finance				
Country		Germany	France	Belgium
Year of publication		2012	Annually since 2014	2015
Investments tracked for		2010	Annually since 2011	2013
Measures tracked				
Mitigation		X	X	X
Adaptation		-	-	P
Climate Services		-	-	X
Sectoral scope				
Buildings		X	X	X
Transport		X	X	X
Agricult.	Energy	X	X	X
	Other GHG	X	P	P
Industry		X	X	X
Energy	Fossil	P	X	P
	Nuclear	-	P	-
	Networks	X	P	P
Investment type				
Tangible		X	X	X
Intangible		P	-	P
		X : Tracked	P : Partially tracked	- : Not tracked

3.1.4 Limitations of the method

As any other method, the climate finance landscape approach has several limitations. One of them is that constructing such a Landscape requires a significant amount of input data, which are often difficult and time-consuming to collect or obtain. To add to this, the peculiar way of tracking additional investments that vary from business-as-usual investments is typically not tracked in that way by national statistics, banks or companies. Therefore, it requires the development of a systematic approach to define "additional" investments. As in other research methods but particularly relevant here is the fact that, due to the financial aspect of the topic, many of the relevant stakeholders do not have an incentive to share such information for analysis purposes.

A general limitation of tracking climate finance, that also applies for the landscape methods, is that the results do not permit to assess impact or effectiveness. In other words, it does not supply information on impact on climate mitigation or adaptation such as GHG emissions or energy savings or kWh produced per EUR spent. For example climate finance in renewables had gone down after a peak in 2015, this does not necessarily mean that less renewable energy

was installed, but in this case the decrease was also (and mostly) due to the fall in prices for solar and wind power plants (Climate Transparency, 2017).

The Landscape has major limitations in properly assessing the gaps to reach climate targets, as the translation from GHG emissions or energy savings needs to be translates into financial terms. Assessing investment needs is typically done by building scenarios using macro-economic modelling. Such a method is not necessarily compatible with the Landscape method, as it uses a bottom-down approach and uses other assumptions.

The Landscape only reflects the effect of quantitative contributions. Other public interventions, such as capacity-building, information campaigns or regulatory frameworks also have leverage on climate finance, yet in a more complex and indirect way that is more difficult to quantify. It does not properly reflect the leverage of public spending on private finance. As the UNFCCC Standing Committee on Finance puts it "co-financing [is often seen] as best available evidence of private finance mobilization, and many climate funds use leverage ratios as one of their key results indicators" (UNFCCC, 2016, p. 9). High leverage ratios do not necessarily prove the effectiveness of public finance, when investments are commercially viable (UNFCCC, 2016, p. 9).

An example is the commercialisation of renewable energy, which can be profitable without public incentives. The report further addresses the issues of inconsistent leverage methodology, the lack of empirical basis to define a leverage ratio and the fact that "co-financing data varies across types of public finance instruments and sources of finance, and is often incomplete" (UNFCCC, 2016, p. 77). Therefore, even by tracking public finance and private investments, concluding on public leverage is very limited.

3.1.5 The main steps, additionality and critical issues

The main steps in tracking climate finance with the Landscape method is as follow:

1. Defining and scoping climate finance flows to be tracked;
2. Creating a detailed database containing information on sectors, their segments, and measures for which the finance will be tracked;
3. Researching where and how the finance into these measures may come from, including the analysis of literature, interviews, surveys, and others;
4. Setting the baseline definitions i.e. what is counted as BAU finance and additional finance into energy transitions;
5. Assessing and calculating selected finance flows from the sources through intermediaries and instruments to the final measure;
6. And, designing the climate finance Landscape.

One of the most critical issues in the assessment and calculation of climate finance flows is the additionality principle. The core concept in the additionality principle is the concept of baseline, a prediction of the quantified amount of an input to, or output from, an activity resulting from the expected future behaviour of the actors proposing, and affected by, a proposed activity in the absence of one or more policy interventions, holding all other factors constant. Therefore, additionality is the property of an activity being additional to the baseline, e.g. if policy interventions are deemed to be causing the activity to take place (see Gillenwater, 2012a, 2012b).

To tackle the issue of the additionality aspect of finance in the building sector, Novikova et al. (2013) relied on the definition of incremental costs. Incremental costs refer to investments necessary to cover the difference, or "increment," between the more carbon-intensive baseline option and a less carbon-intensive option (GEF, 2010). Thus, for electrical appliances, the

authors suggested only tracking incremental costs of purchased appliances which were more efficient than the minimum energy efficiency class allowed on the market. For existing buildings, the authors suggested a similar approach. They compared the costs of BAU retrofits with thermal efficiency retrofits costs. They found the incremental share to be around 30% based on several studies and expert interviews. For example Neuhoff et al. (2011) found the incremental ratio to be 37.5%. The following section explains how this thesis deals with the additionality dilemma in tracking climate finance flows.

3.2 Research design and method

The previous chapter discussed the concept of the climate finance Landscape and the approach of analysing it in a particular situation. The present chapter describes how the research concept was applied to the thesis research, its scope and boundaries. It then discusses data collection and categorisation to finally address data analysis and the design of the Landscape. In order to enable a comparison of results with the previous Landscape of climate finance in Germany, the research design and methods follow the ones from Juergens et al. (2012, 2013) and Novikova et al. (2013). In this manner, research question 2 on assessing climate finance trends between 2010 and 2016 can be answered.

3.2.1 Definition of climate finance Landscape for this thesis

In line with its aim and research questions, this thesis applies the climate finance Landscape method in order to track finance flows of Germany's building sector decarbonisation. The research focuses on additional investments beyond the business-as-usual (BAU) baseline and are in line with Germany's energy concept. Consequently, the focus lies on those measures which relate to the mitigation of GHG emissions associated with the building sector. The mitigation measures for the sector include thermal energy efficiency measures, electrical efficiency measures, and measures to increase the share of integrated renewable energy sources in the building sector.

How exactly the thesis deals with differentiating BAU finance from climate finance is reviewed in more detail for each type of measure. In the construction sector, investments that meet the minimum legal standard for construction are the baseline (Bürger et al., 2016). Therefore, additional investments drive the primary energy consumption down more than required by the latest Energy Saving Ordinance, EnEV 2014/2016.

For the existing building stock, the baseline, is less than 1% annual retrofit rate whereas the additionality is any retrofit that goes beyond it. Germany's Energy Concept targets a 2% annual retrofit rate (Bundesregierung, 2010). Unfortunately, literature is lacking on BAU retrofit levels, especially in financial terms.

As visualised in Figure 4 of the literature review, the existing building stock has a much higher energy demand than newly constructed buildings. Investment that drive the primary energy consumption down without reaching the latest Energy Saving Ordinance, EnEV 2014/2016 requirements cannot be excluded. It is assumed that an energy saving measure receiving public subsidies would not have happened in the BAU case. As such, total investment costs are tracked as climate finance. Additionally, the public support schemes specifically target energy saving measures. Except the free rider effect, of investors using public subsidies for other reasons than energy savings, all investments are clearly targeted at reducing the primary energy consumption, in line with the sector climate targets.

For electrical efficiency, the baseline is identified as the last efficiency category available on the market, for instance if class E is banned, then class D is BAU and the incremental cost of buying products class A, B and C compared to class D is considered as additional investment.

3.2.2 Boundaries of the Landscape

Temporal scope

Climate finance Landscapes provide a snapshot of capital flows within a given time period. Those investments are racked that actually occurred in 2016, not the ones that were planned for that year. Thus, the research relies on data published retroactively of these investments. As of today, 2016 is the most recent year for which statistics on the building stock, public budgets, financial institutions annual reports, and monitoring reports of public subsidy programmes are complete. While financial reports already available for 2017, other data sources are published with a two-year delay, such as construction or energy statistics.

Scope of measures tracked

In line with the definition of a Landscape, the research focuses on additional investments beyond the BAU baseline that are in line with Germany's Energy Concept. Table 5 illustrates the boundaries applied to the thesis. There are three layers to defining climate finance measures..

Table 5 Climate finance definition in the German climate finance Landscape. Source: (Juergens et al., 2012, p. 5).

	CLIMATE-SPECIFIC INVESTMENT		CLIMATE-RELATED INVESTMENT	
	Incremental cost	Total capital invetsment	Incremental cost	Total capital invetsment
Tangible	energy efficiency, non-energy related reduction measures	renewable energy	measures that deliver co.benefits in terms of emission reduction e.g. Agri-environmental measures, investment in transport modal shift, etc.	
Intangible	R&D, information policies, training and capacity building			

included in the German Climate Finance diagram

included in discussion

With the exception of renewable energy investment in the industry sector, where incremental investment data was available, and energy efficiency investment in the energy sector, where we could access only total capital investment data

First, there is a distinction between climate-specific investments such as energy efficiency or renewable energy, and climate-related investments such as grid development. Only climate-specific measures are tracked

Second, depending on the context, an investment can be tracked as total capital investment, such as solar power or as solely the incremental cost. Incremental cost is the share of the cost that occurred beyond BAU. For example if the price difference between a new regular heating system and a new highly efficient heating system is EUR 20, then that is the incremental cost, in other words the extra cost to reach higher energy efficiency standards. If the new highly efficient heating system overall cost is EUR 200, (200-20) EUR 180 is not considered as climate finance.

Due to the extensive range of measures receiving investment and the very limited data available on the technicalities and performances of these measures, an accurate assessment of the incremental cost is not achievable. Juergens et al. (2013) relied on literature and expert interviews to assess an average incremental cost of 30% for thermal efficiency retrofits.

To counter the uncertainty of this specific method, two sensitivity analyses are created. The primary study assumes the total investment cost to be climate finance. The first sensitivity analysis applies the same assumptions as Juergens et al. (2013), namely a 30% incremental cost ration for thermal efficiency measures in the existing building stock. The second sensitivity analysis applies the 30% incremental ration to all energy efficiency measures, including thermal and electrical, in new buildings as well as in the building stock. The sensitivity analyses do not replicate the whole Landscape, but only apply the alternative assumptions to certain measures.

Thirdly, investments are split into tangible, such as direct investments, and intangible ones, such as R&D or information tools. In this thesis, only tangible investments are tracked.

Two financial incentive programmes are tracked in this study: the ones provided by the Government (BAFA) and the ones provided by Germany's public bank (KfW), which are circled in black in Figure 6 of the lietarture review.

Sectoral scope

In this study the sectoral scope is the building sector. It covers all buildings except those that belong to the industrial and agricultural sector. The building sector definition is included within the data provided online. Residential buildings are reported on separately, yet non-residential buildings do not have a clear split between industrial, agricultural, commercial or public buildings.

The thesis relies on the same definition of the building sector as the previous German Landscape of climate finance (Juergens et al., 2012). The study in turn relied on the sector definition of official German Energy Balances (AGEB, 2011), which include households and the tertiary sector (excluding agriculture). The tertiary sector is defined as classes[14] WZ2008-F to WZ2008-U defined by the German Statistical office (Destatis, 2007), excluding WZ2008-H (the transportation sector). These include manufacturing firms with fewer than 20 employees, which are not covered under manufacturing industry and construction industry as well as commercial properties and enterprise premises, commercial enterprises, private and public service companies and organisations (including banks, insurance companies, laundries, hospitals, public authorities, and the German postal service). It is assumed that all entities refer to the official building sector definition.

3.2.3 Data Collection, Categorisation and Analysis

The thesis follows CPI's Global Landscape of Climate finance to track climate finance (Buchner et al., 2011). As explained in the literature review, this analytical framework is also used by publications of national Landscapes (Ampri, et al., 2014; Falconer, 2017; Hainaut, Gouiffes, & Cochran, 2017; Hainaut, Morel, & Cochran, 2015b, 2017; Juergens et al., 2012a; Novikova et al., 2013; Rademaekers et al., 2016, 2017). This framework permits to track finance flows along their lifecycle, giving a comprehensive overview of climate finance rather than ordinary investment volume of climate finance.

Building upon Buchner et al. (2011), Juergens et al. (2012) applied this analytical framework to Germany and introduced five sectors in the stead of recipients (industry, energy generation and distribution, transport, agriculture and buildings). The authors clearly split sources from intermediaries and did not quantify disbursement channels due to a lack of data. For this thesis, the collected data on climate finance is categorised by sources, intermediaries, instruments, measures and building type. Measures are typically the last category in the Landscape, but for

[14] The 2008 classification of industry branches has not been revised since then. The classification has five layers: sections, divisions, groups, classes and subclasses.

comparison purposes the exact same structure as Juergens et al. (2012, 2013) is applied. The authors did not break-down climate finance to the level of the building type: residential, pubic or tertiary sector buildings. This is the first study to dive into that level of detail. Collected data on the building type is then added at the end of the Landscape. The finance flows are further split into public and private capital such as households, municipalities, public banks etc.

As a starting point for data collection, references provided by Juergens et al. (2012a, 2012) and Novikova et al (2013) were first reviewed. If not update the reference was available, then it was updated with a more recent publication. Alternatively, data and assumptions from Juergens et al. (2012, 2013) was used.

For simplification purposes, hereafter the publications by Juergens et al. (2012, 2013) and Novikova et al (2013) are referred to as the "2010 Landscape", as they are three publications from the same research project and thus include the same assumptions and results[15].

Sources

Among finance sources, the thesis focused mostly on Germany's government budget, as this was the main source of finance in the 2010 Landscape. EU funds also contribute to public finance, yet due to time constraints, EU funds could not be explored nor quantified. According to the results of the 2010 Landscape, philanthropy capital was solely directed to R&D, innovation and advocacy measures, thus they are not quantified in this thesis.

For this study, the 2018 national government budget is used, as it provides information on the actually investments from the previous year, namely 2016. The 2010 study (Juergens et al. 2012) provides several budget streams that have been updated for 2016. Additionally, more and new budget streams are added for 2016.

BAFA solely offers grants, therefore the total sum of BAFA grants represents the source of capital from public budgets. It is backtracked from the measures that fall into the defined boundaries of this thesis.

KfW predominantly offers concessional loans, therefore its contribution to climate finance cannot be assessed directly. The role of government guarantees provided to public banks and the grant-equivalent value of concessional loans that compensate for the opportunity cost incurred from concessional interest rate buy-downs is not quantified. What is quantified as public source are transfers from Germany's government budget to KfW programmes (Budget Act, 2018). The quantification of these instruments would either increase or decrease the share of public money in the compilation of climate-specific finance in Germany.

Apart from the national government budget, financial contributions of each investor are backtracked from data provided by intermediaries. Thus, investments that did not flow through any intermediary are not tracked in this research. For instance, a household or a company that installed solar panels from its own source of capital, without public support, is not tracked. To track such investments, surveys would need to be sent out, which is too resource and time intensive for the purpose of this thesis. Investments in electrical efficiency are the exception. Due to the type of appliances tracked, namely refrigerators, washing machines and tumble driers, the total investments into electrical efficiency are allocated to households.

[15] Juergens et al. (2012) is the German Landscape of Climate finance for 2010, Juergens et al. (2013) is the publications that comprises of all the annexes of the Landscape and contains separate Landscapes for each of the five sectors. Novikova et al. (2013) published a separate study solely on the residential sector, yet using the results from the same piece of research as Juergens et al. (2012, 2013).

Leveraged public finance comes from municipalities, cities and public companies that invest in renewable energy and thermal efficiency in residential or public buildings and is also backtracked from the programmes. The source of finance for public buildings belonging to the Federal State were tracked directly from the national government budget.

Intermediaries

The intermediaries of the German building sector were identified based on the 2010 Landscape and internet search. Two databases for public support in the building sector were found: "energiefoerderung.info" and "förderdatenbank.de". Browsing these databases with the key terms (in German) "energy efficiency" and "renewable energy" permitted to find a wide range of public subsidy programmes. Such programmes are provided on the national level by two entities: the Federal Office of Economics and Export Control (BAFA) and the German national government-owned development bank (KfW). On a regional level, each of the sixteen German federal States has a regional development bank (Länder Förderbank).

Commercial banks are also identified as intermediaries. Nevertheless, as mentioned before, only investments that got public support could be identified. The annual reports of the three largest commercial banks in Germany were browsed (Deutsche bank, DZ Bank and Commerzbank), yet no climate finance as defined in this study was found. Backed with the results of the 2010 Landscape that could not assess climate finance contributions form commercial banks, data was not collected. Investments flowing through commercial banks was back-calculated as co-financing. The proportion of climate finance identified as co-debt from market-rate debt is allocated to commercial banks.

Programme	Facts and assumptions	Reference
Solar thermal	The investors split is 98,3% households, 0,5% public entities and 1,2% tertiary sector and 100% to the existing building stock.	(BAFA, 2017a, 2017h; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Biomass	The investors split is 97,2% households, 0,4% public entities and 2,4% tertiary sector and 100% to the existing building stock.	(BAFA, 2017a, 2017b; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Heat pumps	The investors split is 91,9% households, 0,2% public entities and 7,9% tertiary sector and 62% of investments went to construction works and 38% to the existing building stock.	(BAFA, 2017a, 2017i; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Heating optimization /pump replacement *	The investors split is 100% households and 100% of investments went to the existing building stock. Due to a lack of data, it is assumed that the grant volume covered 30% of total investments.	(BAFA, 2017a, 2017d; BMWi, 2016, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Refrigeration and air-conditioning	The investors split is 100% tertiary sector and 50% of investments went to construction works and 50% to the existing building stock.	(BAFA, 2017e, 2017a)
Combined Heat and Power (CHP)	Total investments went to the industry sector, therefore this programme is outside the scope of the building sector.	(BAFA, 2017a, 2017f; Bundesregierung, 2015), BAFA, personal communication, April 12th-May 30th, .2018

Small CHP	It is assumed that the investors split is 97,3% households, 1% public entities and 1,7% tertiary sector and 50% of investments went to construction works and 50% to the existing building stock.	(BAFA, 2017g, 2017a; Bundesregierung, 2012, p. 8)
Cross-section technology	Due to the nature of the measure, all investments were directed to the industry sector.	(BAFA, 2017c, 2017a), BAFA personal communication, April 12th-May 30th, .2018
Renewables	Energy efficiency	

The data from relevant intermediaries was collected and then broken down into instrument type, measure type and building type. The collected data is in the form of specific public support programmes. Therefore, each programme is assessed individually. Table 7 and Table 7 exhibit the collected data presented by programme. Each programme is categorised separately.

Instruments

BAFA provides the percent support of total investment volumes in its annual financial report (BAFA, 2017a) which was also confirmed through personal communication. For KfW, it is assumed that on average 70% of total investment volumes are covered by public support. Due to the significant investment volume of each measure, it is assumed that co-financing requires further debt as it cannot solely be covered by households' and companies' equity. Additionally, market-rate interest rates are presently low[16]. It is assumed that households co-finance with a debt-equity ratio of 80-20%. Indeed, Juergens et al. (2012) found that 80-20% is the typical co-financing structure for small-scale private renewable energy investment and existing buildings energy efficiency investment (Juergens et al., 2013, p. 16). Public and corporate investments are assumed to be co-financed with equity.

Equity is generally referred to as a stock or any other security representing an ownership interest or partial ownership of a company. However, equity has a broader definition. It is the difference between assets and liabilities and can also include retained earnings. In the context of this thesis, equity is defined as capital that does not take another financial form and over which the investor has full ownership. Accordingly, households' budget is regarded as equity.

Disbursement channels

As in the 2010 Landscape, disbursement channels are not quantified, due to a lack of data. However, disbursement channels are part of the discussion (see Figure 9).

Measures and recipients of climate finance (building type)

In line with the 2010 Landscape, the building sector measures were split into three major categories: (1) integrated renewable energy, 2) thermal efficiency and 3) electrical efficiency. The 2010 Landscape did not track the type of building that received climate finance. Thermal efficiency was split into construction and retrofit. Here, all measures are split into either construction or the existing building stock and subcategorised as residential, public or commercial buildings. This results in six building type categories.

For the categorisation of the building type, the programme description and measures lists are used for KfW. Additionally, especially when the data is not self-explanatory, KfW reviewed the

[16] For example, the average interested rate for a 5-10 year housing loan in Germany had an effective (incl. transaction costs) interest rate of 1,6% p.a. (Deutsche Bundesbank, n.d., p. 3)

building categorisation through email contact. Based on BAFA's programme description, it is assumed that all investments went to residential existing buildings (BMWi, 2016, pp. 3–4)

Measures in construction (new buildings)

Landscape stated that only incremental costs of energy efficiency measures were accounted for, yet, in the building construction sector, the total investment costs were tracked as climate finance. This is most likely due to a lack of information. The total investment in construction equals to the amount of relevant concessional loans and grants from KfW received by various actors plus calculated co-financing. As in the 2010 Landscape, total investment volumes are tracked.

The development bank KfW has in fact established its own energy consumption standard for buildings that are more energy efficient than the minimum requirements. For example a "KfW efficiency houses 55", means that that building's primary energy consumption is only 55% of the reference house from the building code EnEV 2016 (KfW, 2018). This way, KfW covers the additional cost of implementing thermal efficiency or integrated renewable installations that bring the dwelling's primary energy consumption down even lower than the minimum standard (EnEV 2014/2016). In construction, the least efficient dwelling that could get support from KfW is still 30% below the national minimum requirement (KfW efficiency house 70). Due to resource and time constraints and for comparative purposes with the 2010 Landscape, KfW's methodology of assessing climate finance is applied.

Measures in the existing building stock

The total investment into the thermal efficiency retrofits and the installation of renewable energy systems in the existing building stock equals to the amount of relevant concessional loans and grants from KfW received by various actors plus calculated co-financing (see Table 7). Volumes of loans and grants are taken directly from KfW's annual report (KfW, 2016).

Only buildings that received public subsidies from KfW or BAFA could be tracked. No statistics are available on retrofit investments overall, therefore the share of the tracked investments compared to BAU or overall investments cannot be assessed.

KfW's methodology is used. Even for measures in the existing building stock, the development bank uses its efficiency house scale. A building that is retrofitted to save energy but does not achieve the Energy Saving Ordinance EnEV for new buildings can be counted as climate finance. For example, a subsidised measure could be "KfW efficiency house 115", meaning that the given building is retrofitted to have a primary energy demand 15% higher than EnEV.

KfW's efficiency houses both include energy efficiency measures as well as integrated renewables. Based on the monitoring report of the programmes "energy efficient construction and retrofitting", ratios are established for each efficiency house standard by each programme, as shown in Table 8.

The present research faces the incremental cost issue in a different approach. It assumes the total investments costs of energy efficiency measure complying with KfW and BAFA requirements to count as climate finance. To then assess the sensitivity of this assumptions, it creates two sensitivity analyses, as explained in section 3.2.4.

Electrical efficiency in office equipment, appliances, and lights

To calculate the additional finance into electrical efficiency of all appliances and equipment, it was calculated as a sum of individual estimates for each appliance. First, we defined the BAU class from the minimum standard. We then calculated the difference in price from one class to

the other. The extra cost from one energy efficiency class to the next was then added for all classes above the business as usual one. The next assumptions and limitations were applied:

Only three major domestic appliances are covered, due to data availability: refrigerators, washing machines, and tumble dryers. The estimate represents a lower bound as it does not include appliances and equipment other than those listed. Sales numbers and structure by energy efficiency classes are tracked for the year 2015 from the latest available publication (Michel, Attali, & Bush, 2016).

For washing machines, energy efficiency class A was banned from EU markets since 2013, therefore class A+ was assumed as BAU and sales of more energy efficient classes than A+ was tracked as climate finance (Michel, Kreitz, Attali, & Bush, 2017). Prices by energy efficiency classes for washing machines were assumed as in 2015 (Michel et al., 2016). EcoTopTen prices for March 2018 show a 10% increase in price for energy efficiency class A+++ from 2015 to March 2018 (EcoTopTen, 2018b), yet prices for other energy efficiency classes are not given, therefore we used 2015 price data.

For refrigerators, energy efficiency class A was banned from EU markets since 2014, therefore class A+ as assumed as BAU and sales of more energy efficient classes than A+ was tracked as climate finance (Michel et al., 2017). Prices by energy efficiency classes for refrigerators were assumed as the average value of the EcoTopTen list for Germany for June 2017 (EcoTopTen, 2018a). The average price for A+++ was backed up with another study (TU Freiberg, 2017) that deviates by only 14€ (less than 2%). The prices for energy efficiency class A++ as not available, therefore we calculated the average price between energy efficiency class A+++ and A+.

For tumble driers, energy efficiency class C was banned from EU markets since 2015, therefore class B was assumed as BAU. Yet class C has been proven to be more energy efficient than class B insome cases, therefore we include class B into the BAU and sales of more energy efficient classes than B was tracked as climate finance (Michel et al., 2017). Prices by energy efficiency classes for classes A+++ and A++ for tumble driers were assumed as the average value of the EcoTopten list for Germany for March 2018 (EcoTopTen, 2018c). The average price for energy efficiency class A+ was the average price for EU sales in 2015 (Michel et al., 2016).

Moreover, the construction and existing building stock split was assumed to be 30 to 70% as no literature on the topic could be found nor does it seem to be tracked. Here, surveying household behaviour would enable a more accurate split.

3.2.4 Sensitivity analysis

Two sensitivity analysis are conducted. The diverging assumptions are explained here and the results are given in the results and analysis section. These sensitivity analyses are not visually represented as a Landscape as the primary study is. They are meant as a support to the methodological discussion and give insight as to the sensitivity degree of such a study. The reason behind this sensitivity analysis, is that from talking to various experts in the field and reading through the methodologies and results of various publication, it seems that the main concept of the Landscape is applied in very different manners. After talking to the authors of the annually published French landscapes, it became clear that methods to assess climate finance in the building sector largely deviate. They take the 2005 building code as a baseline and assume all new buildings after that to be considered as climate finance. How the incremental ratio for these buildings is calculated is not disclosed in detail in the annual reports and was not discussed in personal communication.

To counter the uncertainty of this specific method, two sensitivity analyses are created. The primary study assumes the total investment cost to be climate finance. The first sensitivity

analysis applies the same assumptions as Juergens et al. (2013), namely a 30% incremental cost ration for thermal efficiency measures in the existing building stock. The second sensitivity analysis applies the 30% incremental ration to all energy efficiency measures, including thermal and electrical, in new buildings as well as in the building stock. The sensitivity analyses do not replicate the whole Landscape, but only apply the alternative assumptions to certain measures.

Table 6 Data categorisation and analysis of programmes from the the Federal Office of Economics and Export Control (BAFA)

Programme	Facts and assumptions	Reference
Solar thermal	The investors split is 98,3% households, 0,5% public entities and 1,2% tertiary sector and 100% to the existing building stock.	(BAFA, 2017a, 2017h; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Biomass	The investors split is 97,2% households, 0,4% public entities and 2,4% tertiary sector and 100% to the existing building stock.	(BAFA, 2017a, 2017b; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Heat pumps	The investors split is 91,9% households, 0,2% public entities and 7,9% tertiary sector and 62% of investments went to construction works and 38% to the existing building stock.	(BAFA, 2017a, 2017i; Bundesregierung, 2012, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Heating optimization /pump replacement *	The investors split is 100% households and 100% of investments went to the existing building stock. Due to a lack of data, it is assumed that the grant volume covered 30% of total investments.	(BAFA, 2017a, 2017d; BMWi, 2016, p. 8), BAFA, personal communication, April 12th-May 30th, .2018
Refrigeration and air-conditioning	The investors split is 100% tertiary sector and 50% of investments went to construction works and 50% to the existing building stock.	(BAFA, 2017e, 2017a)
Combined Heat and Power (CHP)	Total investments went to the industry sector, therefore this programme is outside the scope of the building sector.	(BAFA, 2017a, 2017f; Bundesregierung, 2015), BAFA, personal communication, April 12th-May 30th, .2018
Small CHP	It is assumed that the investors split is 97,3% households, 1% public entities and 1,7% tertiary sector and 50% of investments went to construction works and 50% to the existing building stock.	(BAFA, 2017g, 2017a; Bundesregierung, 2012, p. 8)
Cross-section technology	Due to the nature of the measure, all investments were directed to the industry sector.	(BAFA, 2017c, 2017a), BAFA personal communication, April 12th-May 30th, .2018
Renewables		Energy efficiency

3.2.5 Summary by public subsidy programme

The approach to constructing the Landscape of climate finance for the German building sector was to review publicly available sources of data. In a second step, assumptions were formulated based on previous publications and additional literature, which are referenced within the tables.

Finally, the collected data then categorised and analysed was sent to KfW, BAFA and regional development banks for review. BAFA and KfW partially reviewed the assumptions and confirmed or corrected them. On the other hand regional development banks could not do so,

as they do not track climate finance at all or not fitting the needs of this study. Despite personal communication, some assumptions remain unconfirmed. Table 6 and Table 7 and summarise the collected data and its analysis. References are also provided by programme. It is assumed that for all programmes, the KfW's subsidies cover an average of 70% of total investment costs.

Table 7 exhibits data categorisation and analysis for the development bank KfW. Out of 15 identified programmes that are climate related, three are disregarded because they do not support measures in residential or tertiary sector buildings. Because of a lack of data, several sources of information are applied to the programmes, so to split investments as they are needed for the Landscape. Each programme has a programme description that discloses some information, as well as the annual report of KfW that discloses which measures were funded per programme. Email contact with KfW representatives is also used to assess the numbers. For the investor split, a press release from 2012 is used, as KfW has so far not answered.

Column A describes the measures that were selected from the program and identified as 1) fitting the building sector definition as defined in this thesis and 2) measures that fall into one of the three measure categories tracked, 3) tangible investments as defined in methodology.

Column B presents the investor split assumed for each programme. The breakdown by investors does not provide many insights for research question 2, the investments trends, as it is based on the same assumptions as back then. Column C is the breakdown by building type, which is mostly self-explanatory from the program title and programme description.

Column D discloses the share of investments that took place within Germany. Finally, column E provides the references to the choices made in the previous columns. The personal communication with KfW corrected certain assumptions directly inside the excel table that was shared with them and sent own calculations (only prepared for internal purposes). The communication mainly took shape in sending excel tables back and forth. In fact, it is expected that KfW may provide more information soon, but it exceeds the timeframe of this thesis.

Table 7 Data categorisation and analysis for KfW programmes. The reference to different breakdowns is provided in column E. The analysed data was sent to KfW for review. Some assumptions could be confirmed, yet most remained unconfirmed (KfW, personal communication, April 26th – May 18th 2018).

Program	Breakdown by measure	Breakdown by actor	Breakdown by building type	Location	References
	A	B	C	D	E
IKU - Investment Credit Municipal Companies	Applicable measures are: Efficient energy generation / distribution. - storage and energy saving. The measures have a total of 230 millions. According to the disclosed measures of the programme, we assume all measures to be energy efficiency measures. Here, there is no double-counting with BAFA.	This programme is available to public entities and only to private companies or actors with at least 50% public stakes or with a PPP agreement. As it is difficult to assess the split between corporate and public ownership of investors, we assume that all investments come from the public sector.	The sector boundaries are based on the disclosed programme measures. All programme measures are in the public sector.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: 148 Programme description
Energy-efficient renovation - individual measures	Applicable measures are: renewable heat generation, thermal retrofit in building envelope, district heating, heating optimization / pump replacement, efficient air conditioning. The measures have a total of 1 397 millions. According to the disclosed measures of the programme, we assume that renewables have a value of 11 millions and energy efficiency measures of 1 386 millions.	The investor split is as follow: households (78%), corporations (21%), public institutions (1%).	This programme solely covers residential buildings.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012)
Energy-efficient retrofit - EFH	Applicable measures are: Retrofitting to KfW efficiency house standards. The measures have a total of 2 049 millions. According to the disclosed measures of the programme, it is assumed that renewables have a value of 205 millions and energy efficiency measures of 1 844 millions.	The investor split is as follow: households (78%), corporations (21%), public institutions (1%).	This programme solely covers residential buildings.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012)
Energy-efficient construction	Applicable measures are: KfW efficiency house construction, initial purchase of KfW efficiency house. The measures have a total of 11 238 millions. We assume that renewables account for 10% and energy efficiency measures for 90%.	The investor split is as follow: households (70%), corporations (29%), public institutions (1%).	This programme solely covers residential buildings.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012)
Energy-efficient retrofit. add. loan	Applicable measures are: biomass and solar thermal installations. The measures have a total of 19 millions. According to the disclosed measures of the programme, we assume that renewables have a value of 19 millions and energy efficiency measures of 0 million. The loans can support measures that receive grants from BAFA.	The investor split is as follow: households (78%), corporations (21%), public institutions (1%).	This programme solely covers residential buildings.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012)
IKU - Energy urban retrofit – district supply	Applicable measures are: construction of plants from sewage / biogas, replacement / conversion of inefficient engines / pumps, cooling and heat supply in the district: decentralised storage, cooling and heat supply in the district: CHP, optimisation of measuring and control technology, district heat supply: new / expansion / modernisation of the heating network, district heat supply: use of industrial waste heat, district heat supply: conventional CHP and district heat supply: biogas CHP. The measures have a total of 135 million. According to the disclosed measures of the programme, renewables have a value of 15 million and energy efficiency measures of 120 million.	This programme is available to public entities and only to private companies or actors with at least 50% public stakes or with a PPP agreement. As it is difficult to assess the split between corporate and public ownership of investors, we assume that all investments come from the public sector.	This programme solely covers non-residential public building and small-scale district energy production.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: 202 Programme description
IKU - Energy-efficient retrofitting	Applicable measures are: thermal retrofit in building envelope, KfW efficiency house construction, KfW efficiency house renovation, lighting optimisation. The measures have a total of 118 million. According to the disclosed measures of the programme, and the underlying assumptions, we assume that renewables have a value of 9 millions and energy efficiency measures of 109 millions. Here, there is no double-counting with BAFA.	This programme is available to public entities and only to private companies or actors with at least 50% public stakes or with a PPP agreement. As it is difficult to assess the split between corporate and public ownership of investors, we assume that all investments come from the public sector.	This programme solely covers non-residential public buildings such as schools, administrative buildings or sports halls.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: 220/219 Programme description

Program	Breakdown by measure	Breakdown by actor	Breakdown by building type	Location	References
	A	B	C	D	E
Environ IKU - energy efficient constr.	Applicable measures are: KfW efficiency house construction. The measures have a total of 436 millions. According to the disclosed measures of the programme, and the underlying assumptions, renewables have a value of 87 millions and energy efficiency measures of 349 millions.	This programme is available to public entities and only to private companies or actors with at least 50% public stakes or with a PPP agreement. As it is difficult to assess the split between corporate and public ownership of investors, we assume that all investments come from the public sector.	This programme solely covers non-residential public buildings such as schools, administrative buildings or sports halls.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: 220/219 Programme description
Environ.	According to the programme description, we assume there is no eligible measures for the building sector as defined in this study.	-		-	Programme value and supported measures: (KfW, 2016)
Renewable Energy Program "Standard"	Applicable measures are: small-scale renewable electricity generation. The measures have a total of 239 millions	The investor split is as follow: households (70%), corporations (25%), public institutions (5%). As only small-scale renewables are picked from the list of measures, the ratios are higher for households in an otherwise corporate investment dominated programme..	We assume that the selected measures are applicable to the building sector in following building types: residential (75%), public (0%), corporate (25%).	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012)
Renewable Energy Program "Premium"	Applicable measures are: biomass heating installations, energy efficient heat storage, large heating pumps and solar collector system. The measures have a total of 34 millions.	The investor split is as follow: households (70%), corporations (25%), public institutions (5%). As only small-scale renewables are picked from the list of measures, the ratios are higher for households in an otherwise corporate investment dominated programme..	We assume that the selected measures are applicable to the building sector in following building types: residential (75%), public (0%), corporate (25%).	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by actor: (Bundesregierung, 2012) Debt-equity ratio: Juergens et al 2013
Energy efficiency program – constr. and	Applicable measures are: heating optimization / pump replacement, thermal retrofit in building envelope, KfW efficiency house construction, KfW efficiency house renovation, renewable heat generation, heat storage, heat recovery / waste heat. The measures have a total of 3 005 millions.	This programme is only applicable to the corporate sector. Industrial measures are not taken into account, from the left measures, it is assumed that 70% come from the tertiary sector (and 30% industry sector).	We assume the following share: 70% commercial and 30% industrial buildings.	All investments to take place in Germany..	Programme value and supported measures: (KfW, 2016)
Energy & environ. loans	Supported measure are not disclosed in KfW's report, therefore we are not able to track this programme in the Landscape.	The programme includes the industry and agriculture sector. The programme is applicable for large commercial enterprises with a group turnover of EUR 500 mil. to 4 bn.			Programme value and supported measures: (KfW, 2016)
Energy-Efficient retro. - investment grant	Applicable measures are: renewable heat generation, thermal retrofit in building envelope, heating optimization / pump replacement, district heating, fuel cell system , air conditioning, KfW efficiency house renovation. The measures have a total of 246 millions. According to the disclosed measures of the programme and email contact with KfW, renewables have a value of 15,1 millions and energy efficiency measures of 230,9 millions.	This programme is only available to households.	This programme solely covers residential buildings.	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Conditions: 430 Zuschuss Merkblatt Breakdown by actor: 430 Zuschuss Merkblatt Email contact with KfW
Energy retrofi	The measures are climate-relevant but not climate-specific, therefore we do not track these investments.				Programme value and supported measures: (KfW, 2016)

The measures disclosed in KfW's report help to make a split between renewable energy and energy efficiency measures and the type of building. The exception is when a building is constructed or retrofitted to one of KfW's standards. In this case, the measure simply lists the building energy consumption standard, such as "KfW effieicency house 70". As a rule, it can be said that the lower the primary energy consumption of a house, the higher the proportion of renewables are in the house, as without renewables the low energy consumption levels is harder to reach (Diefenbach et al., 2018). Table 8 shows the renewable energy to energy efficiency ratios assumed.

Table 8 Share of renewable energy and energy efficiency measures in KfW efficiency houses for each public subsidy programme, in %.

Programme code														
Primary energy demand standard	152		153		219		220		276		277		430	
	RE	EE	RE	EE	RE	EE	RE	EE	RE	EE	RE	EE	RE	EE
KfW energy efficient house 115	10	90	20	80	10	90	20	80	-	-	10	90	10	90
KfW energy efficient house 100	10	90	20	80	10	90	20	80	-	-	10	90	10	90
KfW energy efficient house 85	10	90	20	80	10	90	20	80	-	-	10	90	10	90
KfW energy efficient house 70	10	90	20	80	10	90	20	80	20	80	10	90	10	90
KfW energy efficient house 55	10	90	20	80	10	90	20	80	20	80	-	-	10	90
KfW energy efficient house 40	10	90	20	80	10	90	20	80	-	-	-	-	10	90
KfW energy efficient house 40 plus	10	90	20	80	10	90	20	80	-	-	-	-	10	90
KfW energy efficient house listed build.	10	90	20	80	10	90	20	80	-	-	10	90	10	90
RE: Renewable energy						EE: Energy efficiency								

3.3 Data coding and visualisation

Once the collected data was categorised, one master file was created, compiling all the necessary information for the construction of the Landscape. In line with the analytical framework and creating the format of a Landscape, the coding matrix was established, as shown in Table 9.

Not all the collected data was detailed enough that it could be categorised that way. This is the reason why in the end, only the collected data from the intermediaries KfW and BAFA is processed in the Landscape. Another significant source of data was provided by regional development bank. The data is presented separately in the results section. Other sources of data on climate finance were found through the research as explained before, yet most investment volumes were then reported as a plane investment volume with no other information. As too many assumptions would need to be developed to process such one-sided data, it was disregarded.

Research question 2 aims to assess the development of the landscape of climate finance in the German building sector between 2010 and 2016. Therefore, this thesis organised the data in a similar fashion as Juergens et al. (2012) did. The recipient of climate finance typically comes before the financed measures. It was chosen to inverse the order of these two categories so to allow a better comparison with the 2012 study, which did not have the recipient "column" in the building sector Landscape.

The final step to the Landscape is the visualisation of the investment flows. The collected data now categorised and coded, the next step is to establish the connection from one part of the matrix to the next, thus tracking climate finance along its lifecycle. As a modelling tool, the web software Sankeyflowshow developed by THORTEC Software GmbH was sued. While there is a broad choice of recently developed software, the choice was made on due to functionality, ease of use, and cost criteria. Finally, the connecting lines are colour-coded so to emphasise the finance flows.

Table 9 Coding matrix applied to the collected data.

Sources	A	Intermediaries	B	Instruments	C	Measures	D	Recipients	E
EU-budget	01	Governments and agencies	01	Grants	01	Integrated renewable energy	01	Residential buildings - Construction	01
National government budget	02	National public banks (kfw)	02	Concessional loans	02	Thermal efficiency	02	Residential buildings - Existing buildings	02
Regional state budget	03	Regional public banks	03	Market-rate debt	03	Electrical efficiency	03	Public buildings - Construction	03
Municipalities, cities	04	Commercial banks	04	Equity	04			Public buildings - Building stock	04
Households	05	Institutional investors	05	Risk management	05			Tertiary sector buildings - Construction	05
Commerce	06							Tertiary sector buildings - Existing buildings	06

4 Results and analysis

4.1 The 2016 Landscape of Climate finance

Research question 1:

How much capital is invested in climate and energy transition measures in the German building sector in 2016?

1. using which capital type, financing models and instruments;
1. by which investors, through which intermediaries and facilitators,
2. for which measures,
3. in which type of building?

The results are presented in five sections following the structure of research question 1.

4.2 Total investments

Based on the methodology of this thesis, it is estimated that EUR 29,9 billion was invested in 2016 for Germany's building sector decarbonisation. Of this, EUR 27,8 billion was private and EUR 1,7 billion was public. These investments largely occurred due to public support, of which only a fraction could be quantified.

Of the total amount, investments supporting thermal efficiency measures were largely dominant, with EUR 22,9 billion whereas renewable energy accounted for EUR 5,6 billion followed by electrical efficiency with EUR 1,5 billion. Tracked investments mostly supported measures in the construction sector with close to EUR 20 billion, whereas investments for the existing building stock only amounted to almost EUR 10 billion.

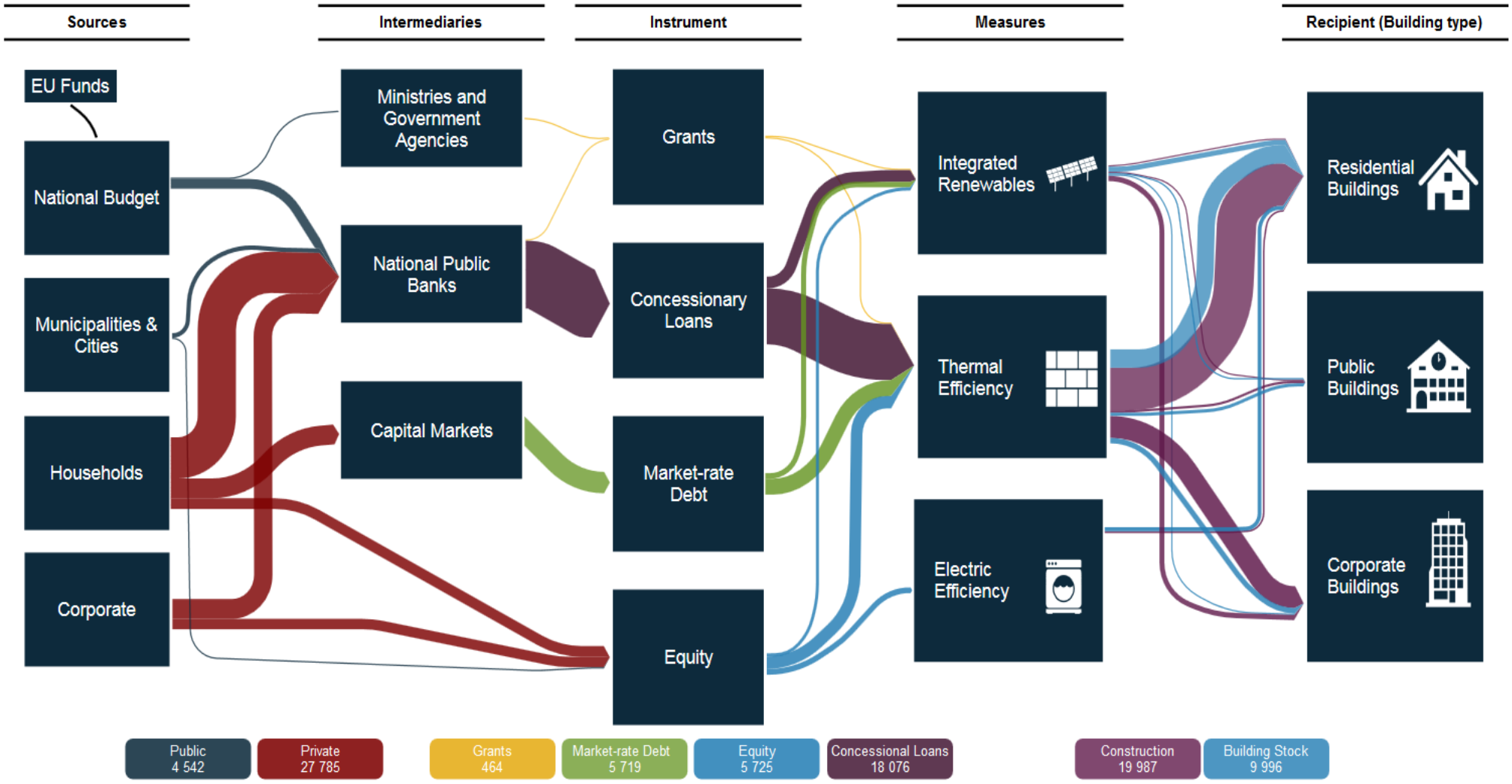
Almost all investments were directed to residential buildings with EUR 25,2 billion, whereas public buildings and buildings from the tertiary sector received far less investments, EUR 1,5 billion and EUR 3,2 billion respectively. Table 10 summarises the results.

Table 10 Source of climate finance in the German building sector in 2016, million EUR

	Climate-specific investment			
Source	Energy Efficiency		Renewable Energy	
	Construction	Building stock	Construction	Building stock
Public	0,5	0,8	0,1	0,06
Private	18,7	7,5	1,5	1,6
private: households	*11,8*	*5,9*	*0,1*	*1,4*
private: corporations	*5,8*	*1,5*	*1,4*	*0,2*
Total	**18,3**	**8,3**	**1,7**	**1,7**

The Landscape of climate finance in the German building sector for 2016 is shown in Figure 8. It visualises the climate finance flows from source through intermediaries, then instruments to then show which measures were financed and in which type of building.

Figure 8 Landscape of Climate finance in the German building sector in 2016. Source: Author. As explained before, public finance is organised in programmes. Therefore, the results are prepared following these programmes. The results are prepared in an Excel format, before being visualised as a Sankey diagram.



4.2.1 Capital type, financing models and instruments

In 2016, concessional loans were the most widely used financing instrument, whereas grants played a minimal role. Considering that subsidies have a maximum limit of support, that does not cover total investment costs, co-financing is provided by either or both commercial debt and equity.

Furthermore, public subsidies are disbursed by commercial banks and regional development banks, which facilitates the combination of public and private financial instruments. Grants were mostly given out by the German Office for Economy and exports (BAFA), which focuses on the market uptake of innovative renewable heating systems and innovative energy efficiency retrofits of heating systems. In contrast, KfW almost only used concessional loans and focused on energy efficiency measures.

Subsidies from BAFA and KfW are mutually excludable (personal communication with BAFA, April 12th-May 30th, 2018), except for one KfW programme that allows the accumulation of BAFA grant and KfW concessional loan. The programme has a very low investment volume, thus the results would be minimally affected.

The role of government guarantees that allow the buy-down between commercial and concessional loan interest rates could not be quantified. The method would be to calculate the grant-equivalent of such concessional loan, but then occurs the risk of tracking the cost of capital instead of climate finance. Explicit contributions from Germany's government budget that specify concessional loans for renewable energy and thermal efficiency in the building sector as defined in this thesis were tracked from their source to the instruments but disregarded from that point on.

Table 11 Budget lines from the Federal government budget allocated to KfW programmes in 2016. Data source: (Budget Act, 2018)

Budget allocated to:	Budget line	Value in EUR billion	Description
KfW building retrofits	0903 6092	1 297	Promotion of measures for the thermal building renovation
KfW concessional loans	661 07 -411	537	Promotion of measures for energy-efficient building renovation, "CO² building retrofitting program"
KfW grants	661 21 -411	4	Grants in the frame of KfW's nearly-zero energy house programs (including the modernisation of heating systems and energy-efficient houses)
KfW concessional loans	661 22 -411	559	Promotion of measures for the Energy-Efficient Renovation of buildings, "CO² building retrofitting program"
KfW grants	891 01 -411	166	Grants to private owners to promote measures of thermal building retrofitting "" CO² building retrofitting program
Total		**2 563**	

4.2.2 Investors, intermediaries and facilitators

Public subsidies accounted for 2,8 billion, of which EUR 2,6 billion could be identified in Germany's Budget Act 2018 and EUR 0,2 billion grants from the government agency BAFA. The contribution of EU funds for the building sector was not quantified due to a lack of data. Altogether, these budget streams boosted public, corporate and household investments of EUR 29,5 billion, out of which households alone invested nearly EUR 19 billion.

The development bank KfW is by far the main intermediary of climate finance in the building sector, followed by commercial banks. KfW was not able to disclose the ratios of investors that

solicited its concessional grants in 2016 (KfW, personal communication, April 26th – May 18th 2018). On the contrary, the government agency BAFA disclosed such information for almost all its programmes. Therefore, for residential programmes, where not only households have access to KfW subsidies but also public and private housing companies, publicly available information dating from 2012 was used to split the investors' shares. The programmes for the public sector are assumed to be fully covered by public investors and the tertiary sector is assumed to fully financed by corporate investments. Overall, it certainly can be stated that households are the main investor of climate finance in the building sector.

Similarly, to the development bank KfW, subnational public banks could not disclose information on the investor split. In fact, even though all regional banks in Germany were investigated and contacted, none could provide data on the level of detail needed for the Landscape method. Nevertheless, EUR 9 billion in subsidies, mainly concessional loans, could be identified and these subsidy programmes are summarised in Table 12. While regional banks play an important role in housing and public infrastructure subsidies, they very rarely track climate or energy transition related investments and BAU or social housing investments separately.

Regional public banks along commercial banks disburse national and regional subsidies[17], yet it appears that regional banks play a more important role in overcoming the barrier of limited access to finance in two ways. First, they further buy-down loan interest rates using regional public funds, and second, they grants concessional loans to entities and to volumes that would not necessarily be granted a loan from a commercial bank, despite national subsidies.

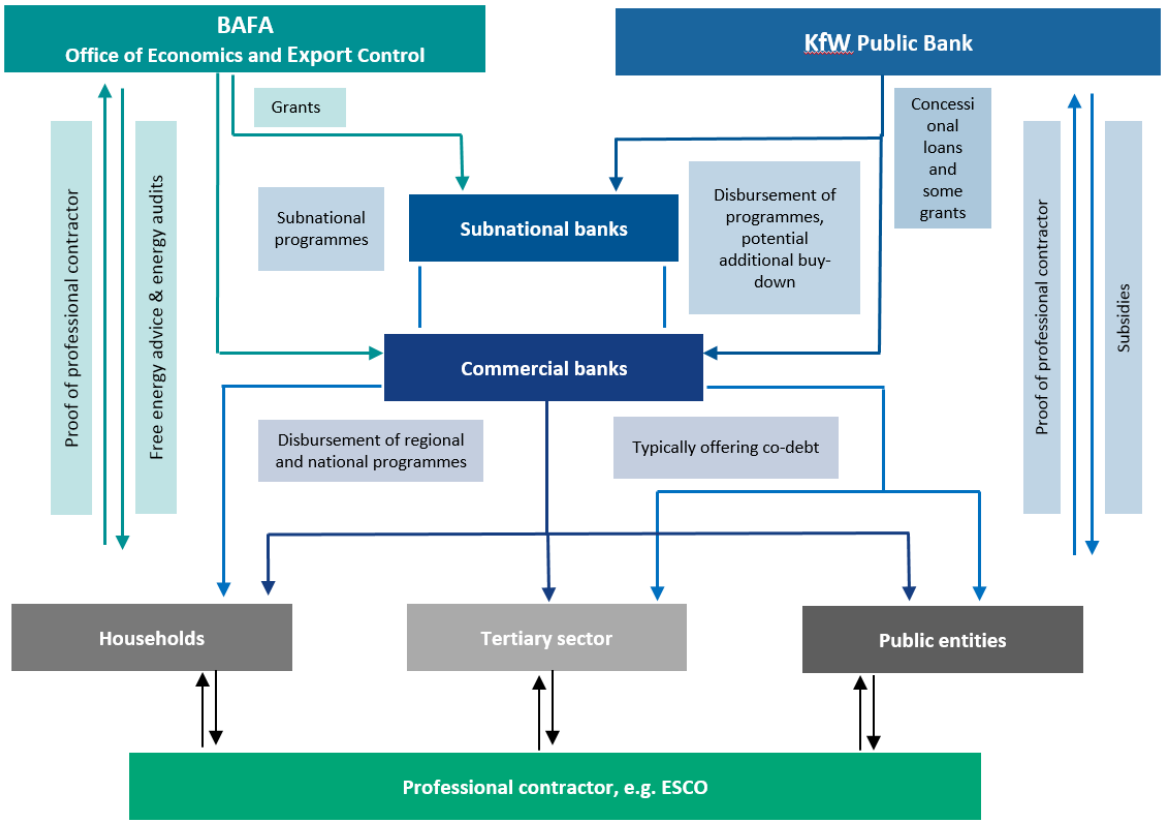
[17] Due to time contraints and untransaparent data, regional subsidies could not be tracked.

Table 12 Overview of entire or partial climate-specific support programmes in the building sector on a regional level, in EUR million. Source: Author.

Federal state	Public Bank	Housing			Public infrastructure			Instru-ments	Reference
		Subsidy	Landscape relevant	Total investment volume	Public infrastructure	Landscape relevant	Total investment volume		
Baden-Wurttemberg	L-Bank	2 709	464	3 638	none found	none found	none found	CL	(LBank, 2017) and personal contact
Bavaria	Bayern-Labo	263	unknown	unknown	97	97	200	CL & G	(BayernLabo, 2017)
	LFA	49	49	93	354	unknown	2 631	CL	(LfA, 2017) and personal contact
Berlin	IBB	533	at least 86,4	at least 169	none found	none found	none found	CL	(IBB, 2017) and personal contact
Brandenburg	ILB	44	at least 7,6	unknown	none found	none found	none found	uncertain	(ILB, 2017) and personal contact
Bremen	BAB	13	13	at most 17	none found	none found	none found	CL	(BAB, 2018) and personal contact
Hamburg	IFB Hamburg	703	39	unknown	none found	none found	none found	CL & G	(IFB Hamburg, 2017) and personal contact
Hesse	WiBank	1 584	at least 11	unknown	none found	none found	none found	uncertain	(WiBank, 2017)
Mecklenburg Western Pomerania	LFI MV	3	unknown	unknown	none found	none found	none found	uncertain	(Lfi M-V, 2017)
Lower Saxony	N Bank	17	at least 3	unknown	none found	none found	none found	uncertain	(NBank, 2017)
North Rhine Westphalia	NRW.BANK	2 118	at least 28	unknown	3 605	unknown	unknown	uncertain	(NRW.BANK, 2017) and personal contact
Rhineland Palatinate	ISB	none found	none found	none found	none found	none found	none found	uncertain	(ISB, 2017)
Saarland	SIKB	125	unknown	unknown	none found	none found	none found	uncertain	(SiKB, 2017)
Saxony-Anhalt	IBS	159	unknown	unknown	none found	none found	none found	CL & G	(IB Sachsen Anhalt, 2017)
Schleswig-Holstein	IB SH	No quantitative data			No quantitative data			N/A	(IB.SH, 2017)
Saxony	SAB	325	unknown	unknown	507	unknown	unknown	CL & G	(SAB, 2017)
Thuringia	TAB	365	unknown	unknown	Included in housing	unknown	unknown	CL	(TAB, 2017)
Total		9 010	at least 238	unknown	5 071	at least 97	unknown		
	CL	Concessional loan		G	Grant				

Figure 9 presents an institutional map that visualises the subsidy system for the building sector. The two national entities BAFA and KfW mainly facilitate information, advice and financial access, especially to households. The institutional map shows the importance of regional banks, even though contribution could not be quantified in the Landscape. For each measure receiving public support, the recipient, typically a household, needs to provide proof that a professional entity was contracted thus leading to capacity-building of the market.

Figure 9 Map of institutional actors for climate finance in the building sector. Source: Author.



4.2.3 Financed measures

All measures supported by KfW or BAFA subsidies are disclosed on a rather detailed level. Personal communication with both institutions permitted to resolve uncertainties over the type of measures and whether it occurred in the residential, public or tertiary sector for construction projects or in the existing building stock. On a subnational level, measures are not disclosed with enough detail to be tracked as in the landscape approach.

Overall, investments mainly went to thermal efficiency with EUR 22,8 billion, followed by integrated renewables with EUR 5,6 billion and electrical efficiency with EUR 1,5 billion. The measure that received most investments was the construction of residential "KfW efficiency houses 55", which means that a building's primary energy consumption is only 55% of the reference house from the building code EnEV 2016 (KfW, 2018). Following in terms of investments levels came the construction of residential "KfW efficiency houses 70", "KfW efficiency houses 40" and "KfW efficiency houses 40 plus" and the construction of buildings in the tertiary sector with the "KfW efficiency houses 55" and "KfW efficiency houses 70" standards. The monitoring report of KfW's "efficiency house" programmes surveyed recipients of subsidies about the type of measures financed and the actual consequent change in energy demand. The report found that the higher the building standard (thus the lower the primary energy demand), the more renewable energy measures are invested in, yet overall energy efficiency measures are always dominant (Diefenbach et al., 2018).

4.2.4 Financed building types

This thesis is the first to track climate finance flows down to the building types. Residential buildings received 84% of total investments with EUR 25,2 billion, followed by 11% buildings in the tertiary sector with EUR 3,2 billion and finally 5% public buildings with EUR 1,5 billion.

In the residential sector, KfW supported 68% of buildings constructed in 2016, which shows the extent and outreach of concessional loans. Because German building statistics do further breakdown sectors within non-residential buildings, the outreach in the tertiary and public sector cannot be assessed. Although based on the number of measures and the investment levels it can safely be assumed that it is much less. For instance, there are 12 000 municipalities, yet KfW merely supported 371 measures in the public sector. In contrast to the large investment flows of EUR 20 billion in the construction sector, the existing building stock received far less investments with only EUR 10 billion.

Comparing the national statistics of the building sector (Destatis, 2018) and KfW's annual report (KfW, 2016), it appears that KfW supported 68% of new residential dwellings in 2016. It is possible that a share of newly constructed buildings that did not receive public support also surpassed the Energy Saving Ordinance (minimum energy demand standard), which would count as climate finance. Nevertheless, these concessional loans are available at all German banks, hence it is unlikely that households and companies would opt for market-rate debt instead of concessional loans. To assess climate finance contribution from the remaining 32% of newly constructed dwellings, commercial banks would need to track such investments, which is it not the case[18].

4.2.5 Sensitivity analysis

	Climate-specific investment				
Source	Energy Efficiency		Renewable Energy		Total
In EUR billion	Construction	Building stock	Construction	Building stock	
Primary study	18,3	8,3	1,7	1,7	30
Sensitivity Analysis 1	18,3	3,3	1,7	1,7	25
Sensitivity Analysis 2	5,7	2,5	1,7	1,7	11,5

Figure 10 Comparison of total investments in the primary study and two sensitivity analyses using the incremental cost calculation on different measures. Source: Author.

Sensitivity analysis 1

In the first sensitivity analysis, the assumptions and methodologies under CPI German Landscape of climate finance are replicated. The difference to the primary study is that only 30% of total investments into thermal efficiency measures is accounted for. This results in less than EUR 5 billion difference in overall investments. Because only thermal efficiency in the building stock is accounted as incremental cost and all measures in the construction sector are accounted as total investment costs, investments in new buildings are proportionally more dominant.

Sensitivity analysis 2

The second sensitivity analysis applied the method of calculating the incremental cost of thermal energy efficiency retrofit to all energy efficiency measures, including electrical appliances and thermal efficiency measures in the construction sector.

[18] The authors of the 2010 Landscape had contacted a wide range of banks and only very few responded. Of these none could share such information. In this research, annual financial reports of the three largest German commercial banks were reviewed, and none disclosed climate finance separately.

The results change drastically, and are more than halved. The total budget streams are considered, whereas as most of the output is cut by 70%. Thus, public leverage from national budget for concessional loans gets a higher share. The construction to building stock ratio is barely affected (64-36% incremental cost versus 67-33% in primary study) as the same methods are applies to all measures. On the other hand, renewable energy, of which total investment costs are accounted for gain a higher proportion of total climate finance.

4.3 Climate finance Trends 2010-2016

Research question 2:
How has the climate finance Landscape evolved in the German building sector since 2010?

The main stakeholders in climate finance in the building sector are KfW and BAFA, although commercial banks and regional banks are important for capital disbursement and co-financing. The energy transition in the building sector is still mainly financed by households, with a 63% share, quite a bit lower than the results of the 2010 Landscape, which calculated that households contributed to climate finance in the building sector with a 85% share.

Three studies were identified in the literature review. These gave a range between EUR 6,7 and EUR 20 billion of annual incremental investments needed in the German building sector to achieve the sector's energy transition targets. These studies used macro-economic modelling, which typically underestimates investment needs. In this thesis, a bottom-up methodology is used, which typically overestimates investments. Between the primary study and both sensitivity analyses, an investment range of EUR 13 to EUR 30 billion is given. There is clearly an overlap of investment needs and tracked investments. It remains difficult to assess whether climate finance was sufficient. The wide range of estimates mainly demonstrates the difference in methodologies and the consequent heterogeneous results. Investment trends in residential, public and commercial buildings are further addressed separately.

4.3.1 Residential buildings

In the residential sector, large investment volumes were directed at thermal efficiency, which is crucial to achieve German climate targets. Climate-specific investments in new residential buildings are likely to be on track towards the respective strategy target. 68% of all dwellings constructed in 2016 were funded through KfW concessional loans (Destatis, 2018; KfW, 2016) instead of 50%[19] in 2010 (Juergens et al., 2012a). Furthermore in 2010, investments of renewable energy dominated over investments into energy efficiency whereas in 2016, renewable energy only represents 19% of total investments. Therefore, investments have been redirected towards energy efficiency measures. Furthermore, in 2010 the authors applied an incremental share of thermal efficiency in retrofits of 30%, whereas in this study we assume that 100% of measures supported count as climate finance.

As Figure 4 showed in the literature review, buildings erected between 1948 and 1978 make up for the biggest share in floor area and have the highest primary energy demand. As shown in Table 13, half of buildings from the existing building stock that got support for thermal retrofitting and integrated renewables were constructed in the 1949-1978 timeframe. investments in existing residential buildings were likely insufficient.

[19] Measured in terms of constructed floor space

Table 13 Construction year of buildings that received public support from KfW's retrofitting programme in 2016. Source: Diefenbach et al., (2018, p. 45)

In %	1 and 2 dwellings	3 and more dwellings
Until 1948	19	35
1949-1968	28	34
1969-1978	18	17
1979 and after	35	14
Total 1949-1978	46%	51%

Concessional loans are the main financial instrument used to finance the energy transition in the residential building sector. Compared to grants, concessional loans are a more cost-effective way to use public support than grants, as the total investment cost is born by the investors themselves. Additionally, the fact that government support is available for specific measures, that also require a professional (and listed) contractor to perform the measure, helps to overcome typical barriers of building decarbonisation such as: access to finance, information deficit, and risk of aversion due to unfamiliar technologies. Yet, free riders, using concessional loans just because they exist but who would have built or retrofitted beyond BAU are also calculated here. The free rider effect discords the baseline. considered was the minimum standard, yet, maybe some buildings would be constructed beyond the minimum standard even without public support.

As for electrical retrofitting, which in this study are household appliances, the results show an overstatement of climate finance due to the outdated energy efficiency labels. The methodology is the same as in the 2010 Landscape, but in 2016 the market was already saturated with products classed highly efficient (see Figure 11). In 2019, a new labelling system is due to be implemented (Regulation (EU) 2017/1369, European Parliament and the Council, 2017), which will rescale energy efficiency labels as shown in Figure 11 (right side). The figure illustrates how the rescaled energy efficiency classes will be rescaled. No product on the market will meet the standards for classes A and B at the time of implementation.

4.3.2 Public buildings

The 2012 study barely accounted for public buildings, whereas in 2016 several KfW programmes solely focused on public infrastructure (schools, hospitals administrative buildings). These investments amounted to EUR 1,3 billion, which is very little in comparison to investments in the residential sector. Keeping in mind that the public sector is supposed to play an exemplary role and that climate targets for public buildings are tighter than other sectors, it seems that investments are insufficient.

According to the European Commission (EC), there is no proper renovation monitoring nor is there data to assess whether the annual retrofit rate of 3% is being achieved (EC, n.d.).. As explained in the literature review, Article 5 of the EU's Energy Efficiency Directive (EED)[20] is to boost energy refurbishment in the central government sector, this way showcasing deep renovation of public buildings and inspiring the sub-national government level (CA EED, 2016).

[20] (Directive 2012/27/EU)

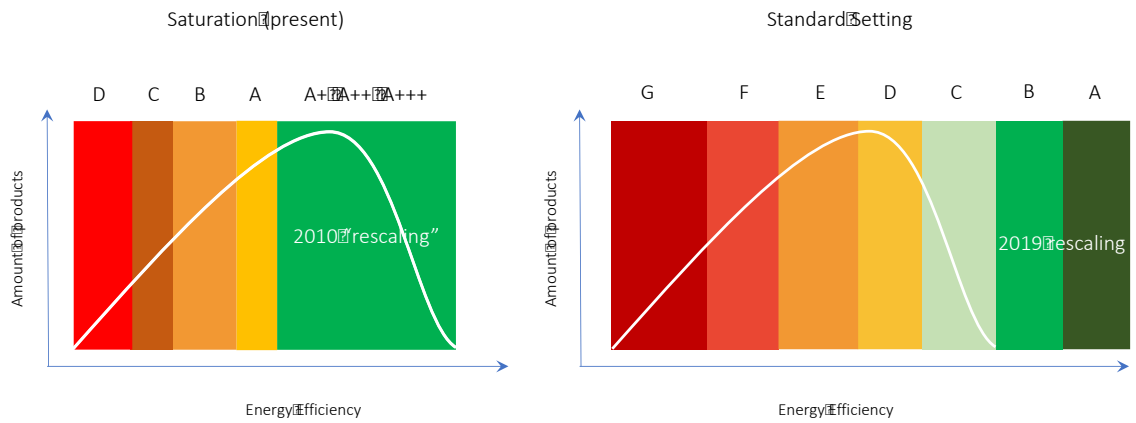


Figure 11 Visualisation of the current household appliances market by energy efficiency label according to Directive 2010/30/EU (left) and the upcoming rescaling starting 2019 Regulation (EU) 2017/1369. Source: Author.

4.3.3 Buildings of the tertiary sector

The level of investments form the 2012 study are unclear, but the corporate sector played a minimal role in the Landscape. In 2016, the corporate sector (industry, tertiary and agriculture) benefits from KfW support in a separate programme.

This type of research might not be the most appropriate to track investments in the industry sector. On the other hand, the authors of the annually published French Landscape of climate finance have also recorded low investments levels from the corporate sector using a different methodology.

Calculating tax incentives and their effect on climate-specific investments is more speculative and requires a more complex methodology. Here again, the French authors used ministry surveys asking companies why they chose to invest in certain measures. From this research, equivalent annual reports could not be found.

4.4 Summary of results

The results of this thesis show that overall climate finance in the building sector has increased. There has been a shift from subsidising mainly renewable energy to energy efficiency measures. This is in line with the climate targets. Despite the existing building stock bearing the highest share of floor space and primary energy consumption, it is underfinanced while the construction sector is over financed. The majority of buildings constructed in 2016 outperformed the minimum primary energy demand standard by at least 30%. The market for highly efficient electric appliances is currently saturated which leads to an overestimation of climate finance for such measures.

While the residential sector is well funded and has abundant policy mechanisms, public buildings and commercial buildings barely receive any climate finance. For commercial buildings two potential reasons are identified: 1) tax incentives and other non-tracked financial instruments have a higher impact on climate investments, and 2) low energy and carbon prices deprioritise energy saving measures. Financial subsidies for public buildings have merged since 2010, yet investments in these programmes are very low. The sensitivity analysis shows how the divergence of results in total investments terms when adjusting the definition and calculation of climate finance.

5 Discussion

Is climate finance sufficient in the building sector? The results of this study are mixed and are difficult to place in the broader context of the German energy transition. Results do not indicate whether investments are sufficient to meet Germany's climate targets because only a share of the actual climate-specific investment in the sector could be measured, due to data availability constraints.

According to the lead author of that study (Ingmar Juergens, personal communication, April 22nd, 2018), the main challenge of the 2012 study was to find the budget lines and reports that contain information on climate finance. This research tracked these and data availability did not improve. The main data availability constraints were faced in the present research too. The main limitation is that publicly available information is not detailed enough to be used to track climate finance. For the German building sector, expert interviews with the climate finance stakeholders and experts in the field of building decarbonisation are required. Juergens et al. (2012, 2013) did not disclose the conducted interviews. Thus, the replication of the study was very limited.

Data availability is a recurring issue in all Landscape studies, yet, in France, the think-tank I4CE has tracked climate finance annually in all sectors since 2015 (tracking investments since 2011). In 2015, the French Government drafted a law (2015-992) relating to the energy transition for green growth (French National Assembly and the Senate, 2015). Specifically relevant to this study is Article 173, stating that the government sets a national carbon dioxide budget for given timeframes, and specific institutions (financial institutions, public banks, insurances and pensions funds) need to then disclose actions to achieve the budget. These institutions are to disclose information on how they take into account policy criteria relating to the respect of social, environmental and quality objectives in investment decisions, the governance of such actions and on how they work to contribute to the national energy and ecological transition. Reporting on the nature of criteria and the way in which they are applied is set through a standard form fixed by decree. Therefore, France has established a standard for reporting energy-transition related measures that contribute to GHG reduction (I4CE, personal communication, May 28th, 2018).

On the European level, the directive on non-financial reporting (Directive 2014/95/EU) that demands reporting on social and environmental actions taken by companies of a certain size along their annual financial reports so to increase business transparency and accountability on social and environmental issues (European Parliament and Council, 2014). Germany transposed the directive in April 2017, meaning after the timeframe that was investigated in this study (German Bundestag, 2017). Therefore, data availability may have improved since then.

For the building sector, the new law may improve tracking of climate-specific investments in the tertiary sector, as this directive affects large entities[21]. Yet, public and residential buildings, it is unsure as to this law has an effect, as the main actors are KfW, BAFA and subnational entities. Furthermore, Germany has no equivalent to France's "article 173", resulting in less transparency over climate-related investments, especially for publicly linked actors that are mainly targeted by the French law. Also, the directive is non-financial reporting, so in essence it does not improve quantitative climate finance tracking, yet it gives an incentive for companies and financial institutions to separate BAU activities from climate and/or environmental related activities.

Concluding we see that despite the significance of tracking climate finance, there is still a knowledge gap in tracking methods and results. CPI stipulates that "there has been progress in

[21] Company scope: Over 500 employees, Net turnover over EUR 40 million; *or* Balance sheet total over EUR 20 million, Public Interest Entity: Credit institutions, Insurance undertakings, Capital market oriented companies in the legal form of a limited liability company or cooperative (German Bundestag, 2017)

tracking climate finance, but there is still work to be done" (CPI, 2017) and OECD argues that an overall financial architecture is needed to efficiently and effectively track and match climate finance to the climate goals, nationally and internationally (OECD, 2018a).

6 Conclusion

6.1 Summary

The current unsustainable pattern of energy production and use, and its release of greenhouse gas (GHG) emissions due to fuel combustion, has an impact on the environment, in particular on the global climate. In 2010, Germany formalised its energy transition plan in the Energy Concept. Financing this transition requires substantial investment. Several studies find that the building sector bears the highest investment gap.

For Governments to boost the energy transformation, in the buildings sector and other sectors, with proper policy instruments, such as tax or subsidies, it is important to understand the finance flows. Yet the last comprehensive study on climate finance flows dates from 2012. This shows a lack of knowledge on how the structure of climate finance has evolved since.

The aim of the thesis is to track how much capital is invested in climate and energy transition measures in the German building sector in 2016 and to assess climate finance trends between 2010 and 2016. Doing so may seem straightforward, yet these are very complex questions. To identify and measure finance directed at climate mitigation requires overcoming many methodological and conceptual challenges. The think tank Climate Policy Initiative (CPI) introduced a new approach to climate finance by tracking it along its lifecycle providing an overview of finance flows from their source to their use. This method is called the Climate finance Landscape approach. It provides a comprehensive snapshot of stakeholders, recipients of climate investments, finance flows and their proportions. This thesis applies the method to the building sector in Germany.

One of the most critical issues in the assessment and calculation of climate finance flows is the additionality principle. In order to differentiate business-as-usual investments from climate investments, this thesis takes a threefold approach establishing distinct baselines for the construction sector, existing building stock and efficiency of electric appliances.

The results of this thesis show that overall climate finance in the building sector has increased. There has been a shift from subsidising mainly renewable energy to energy efficiency measures. This is in line with the climate targets. Despite the existing building stock bearing the highest share of floor space and primary energy consumption, it is underfinanced while the construction sector is over financed. The majority of buildings constructed in 2016 outperformed the minimum primary energy demand standard by at least 30%. The market for highly efficient electric appliances is currently saturated which leads to an overestimation of climate finance for such measures.

While the residential sector is well funded and has abundant policy mechanisms, public buildings and commercial buildings barely receive any climate finance. For commercial buildings two potential reasons are identified: 1) tax incentives and other non-tracked financial instruments have a higher impact on climate investments, and 2) low energy and carbon prices deprioritise energy saving measures. Financial subsidies for public buildings have merged since 2010, yet investments in these programmes are very low.

Data availability is still a major issue that vastly limits this type of research. Since 2012, no data availability improvement has been recorded. There seems to be a lack of incentive to track climate investment separately. The lack of harmonised tracking methods and the lack of relevant publicly available data for the German building sector greatly limit the results of this research.

6.2 Recommendations

To improve data availability and enable the government to track national climate finance flows, following steps could be taken.

Ensure systematic collection and reporting

Annual reporting about climate-specific public finance (and private co-financing) at EU and national level would increase the transparency of climate finance, improve the accuracy of climate finance mapping and enable the assessment of investment gaps.

Reporting should be aligned with climate policy targets

Data collection and reporting should follow national climate and energy transition commitments. In France, article 174 of the energy transition law requires an annual assessment of the country's financial contribution from the public and private sector towards its climate and energy transition commitments.

Common definitions of climate finance

The heterogeneous definitions of climate finance and the methods on how to track climate finance does not currently enable proper investment volume assessments. Streamlining methods to calculate private co-financing would be important to facilitate comparability of results as well as mutual learning. Reporting practices greatly vary among EU Member States and within the countries. The expert group of the European Commission on a taxonomy for sustainable finance as well as a (necessary) review of the climate tracking approach applied to the EU budget's 20% climate action target should take this into consideration. Both approaches have the potential to significantly contribute to a common definition to be used across public and private finance instruments, funds, programmes, etc.

Improved transparency of official statistics and annual surveys

To better assess climate investments, an improved transparency of official statistics about climate-specific investments is needed. The Federal Statistical Office (Destatis) could make a distinction in its official industry survey between climate-specific investments that are from public or private sources. It could also survey households to track and understand better drivers of renewable or energy efficiency investments. Tracking climate-specific investment by households and the commercial sector representative survey carried out by the responsible ministry or periodic evaluations of the energy consumption of households and the commercial sector might be expanded to include also energy-cost-related information.

Institutions that should track climate finance in the German building sector

National (and state level) ministries should systematically track climate-specific and climate-related finance across all public budget lines. The German Federal Network Agency (BNetzA) could track the investor type (e.g energy utility, industry, agriculture, or household) of all new renewable energy installations, that are connected to the grid[22]. This is particularly relevant, as they do not get much financial support anymore, which does not necessarily mean that investment have slowed.

Destatis tracks building permits, for new and existing buildings and for residential and non-residential buildings as well as average cost in euro per square meter. They could further track

[22] Connecting renewable energy installation to the national grid is required by law.

the energy performance standards of implemented measures and disclose more detailed information on average costs.

The newly created entity for climate finance in the Federal Ministry of Economic Cooperation and Development (BMZ) could ensure a closer cooperation among public and private climate finance stakeholders and contribute to harmonise reporting standards.

6.3 Further research

This thesis created a comprehensive landscape of climate finance in the German building sector. Building upon it, several opportunities for further research can be gauged.

Tracking investments for buildings in the tertiary and public sector

While the residential sector is widely covered in this thesis, it seems that an adapted methodology would enable better tracking of climate finance in public and tertiary buildings. The results show that climate investments in these sector is very limited. It cannot be assessed whether investments are indeed that low or if it is mainly due to the methodology. For example, tax incentives and green procurement laws could be more relevant to these sectors.

Tracking climate finance in other sectors

This research focused on the building sector only, due to time and resource constraints. Naturally, it would be beneficial to track climate finance in other sectors and compare results to the 2012 publication (Juergens et al. 2012).

Investigating the policy framework on tracking / disclosing climate finance

It appears that on an EU level and in France the policy framework surrounding climate finance and the tracking of it is dynamic. Germany has an extensive policy package for its energy transition but none for climate finance reporting. Evidently policies play a dominant role in boosting the energy transition and its funding. Hence researching and comparing such policy frameworks among Member States could enable relevant policy recommendations. The impact of such policies could be researched using empirical data and corporate level surveying methods.

Financial impact

The Landscape method enables to track climate finance volumes. An interesting subsequent research would be to assess the impact per euro spent. This would enable policy recommendations on the most effective financial instruments or in other words which instruments can leverage the most private investments.

Extended Landscape of the building sector

Finally, with additional time and resources, a more extensive research building onto this thesis could bring the debate of climate finance tracking forward. Revising the methodology, in particular how to apply the additionality concept to climate investments, performing expert interviews and conducting surveys would enable more accurate results.

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8 Appendices

Annex A. Climate finance definitions from different organisations. Based on UNFCCC (2016) with updates from IFDC (2017).

Institution	Climate finance	Mitigation	Eligibility	Adaptation	Eligibility	References
OECD DAC	Originally the Rio markers were intended to track environmental considerations in development projects rather than providing a quantification of finance. They are based on definitions and eligibility criteria and distinguish between activities targeting climate change objectives as either "principal" or "significant".	The activity contributes to the objective of stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system by promoting efforts to reduce or limit GHG emissions or to enhance GHG sequestration.	The activity contributes to (a) the mitigation of climate change by limiting anthropogenic emissions of GHGs, including gases regulated by the Montreal Protocol; or (b) the protection and/ or enhancement of GHG sinks and reservoirs; or (c) the integration of climate change concerns with the recipient countries' development objectives through institution building, capacity development, strengthening the regulatory and policy framework, or research; or (d) developing countries' efforts to meet their obligations under the Convention	The activity intends to reduce the vulnerability of human or natural systems to the current and expected impacts of climate change, by maintaining or increasing resilience, through increased ability to adapt to, or absorb, climate change stresses, shocks and variability and/or by helping reduce exposure to them, such as information and knowledge generation, capacity development, planning and the implementation of climate change adaptation actions.	(a) The adaptation objective is explicitly indicated in the activity documentation; and (b) the activity contains specific measures targeting the adaptation definition. Vulnerability assessments of climate variability and change are wanted. To justify for a principal score, three steps are needed: • Clear context of risks, vulnerabilities and impacts related to climate variability and climate change, using a clear and robust evidence base, such as use of material from existing analyses and reports, or original, bespoke climate vulnerability assessment analysis carried out as part of the preparation of a project; • Clear intent to address the identified risks, vulnerabilities and impacts in project documentation; • Clear and direct link between identified risks, vulnerabilities and impacts and the specific project activities.	http://www.oecd.org/dac/stats/46782000.pdf, http://www.oecd.org/dac/stats/45303527.pdf, http://www.oecd.org/dac/environmentdevelopment/Climaterelated% 20development%20 finance_ENG_June2015_July2015.pdf, http://www.oecd.org/dac/stats/DCD-DAC(2016)3-ADD2-FINAL%20 -ENG.pdf
MDBs	Total climate finance is equal to the sum of mitigation, adaptation and dual benefit finance from the MDB own resources as well as external resources.	The activity is based on MDB joint typology, will henceforth draw on the closely aligned MDB IDFC common principles. Some MDBs consider additional activities not covered by the joint approach for their own reporting purposes. Drawing on the OECD DAC Rio markers defi nition, an activity will be classifi ed as related to climate change mitigation if it promotes "eff orts to reduce or limit GHG emissions or enhance GHG sequestration"	Based on a positive list of activities; includes brownfi eld renewable energy, brownfi eld energy effi ciency investments and transport modal shift projects.	The tracking methodology uses a conservative and granular approach to reflect the specific focus of adaptation activities, and reduce the scope for over-reporting. The approach drills down into the 'subproject' or 'project element' level as appropriate, and aims to ensure that project activities address specific climate vulnerabilities identified as being relevant to the project. Activities that may contribute to resilience cannot always be tracked in quantitative terms, or may not have associated costs. It is not intended to capture the value of the entire investment of a project that may increase resilience.	• Setting out the climate vulnerability context of the project • Making an explicit statement of intent to address climate vulnerability as part of the project • Articulating a clear and direct link between the climate vulnerability context and the specifi c project activities	http://www.worldbank.org/content/dam/Worldbank/document/Climate/mdb-climate-finance-2014-joint-report-061615.pdf
IDFC	According to the IDFC methodology, "green fi nance" comprises "climate fi nance" and fi nance for "other environmental objectives", with "climate fi nance" being composed of "green energy and mitigation of greenhouse gases" and "adaptation to climate change"	Uses the definitions and eligibility criteria guidelines provided (defined in annexes B and C of the Green Finance Mapping Report 2015), taking the MDB IDFC common principles for climate mitigation finance tracking into account. The activity promotes "efforts to reduce or limit greenhouse gas (GHG) emissions or enhance GHG sequestration".	Based on a positive list of project categories/activities.	Adaptation finance tracking relates to tracking the finance for activities that address current and expected effects of climate change, where such effects are material for the context of those activities. It may relate to activities consisting of stand-alone projects, multiple projects under larger programs, or project components, sub-components or elements, including those financed through financial intermediaries.	Adaptation finance tracking process consists of: Clear context of risks, vulnerabilities and impacts related to climate variability and climate change; Clear intent to address the identified risks, vulnerabilities and impacts in project documentation; Clear and direct link between identified risks, vulnerabilities and impacts, and the financed activities. Adaptation activities are disaggregated from non-adaptation activities as far as reasonably possible. Climate finance is underreported rather than over-reported (principle of conservativeness).	https://www.idfc.org/Downloads/Publications/01_green_finance_mappings/IDFC_Green_Finance_Mapping_Report_2017_12_11.pdf
CPI	Aligned with the recommended operational defi nition of the UNFCCC SCF. Capital fl ows directed towards low-carbon and climate-resilient development interventions with direct or indirect GHG mitigation or adaptation benefi ts	Resources directed to activities contributing to reducing or avoiding GHG emissions, including gases regulated by the Montreal Protocol; or maintaining or enhancing GHG sinks and reservoirs. It excludes: • Private R&D in technology and investment in manufacturing; • Fossil-fuel based lower carbon and energy-efficient generation.	Positive list, drawing on OECD DAC, MDB and IDFC approaches	Resources directed to activities aimed at reducing the vulnerability of human or natural systems to the impacts of climate change and climaterelated risks, by maintaining or increasing adaptive capacity and resilience.	Positive list, drawing on OECD DAC, MDB and IDFC approaches.	http://climatepolicyinitiative.org/wp-content/uploads/2015/11/A-Closer-Look-at-the-Landscape-2015-Methodology.pdf
IPCC	There is no agreed definition of climate finance. The term 'climate finance' is applied both to the financial resources devoted to addressing climate change globally and to financial flows to developing countries to assist them in addressing climate change.	A human intervention to reduce the sources or enhance the sinks of GHGs. The Fifth Assessment Report of the IPCC in 2014 also assesses human interventions to reduce the sources of other substances that may contribute directly or indirectly to limiting climate change.	N/A	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.	N/A	http://www.ipcc.ch/report/ar5/wg3/