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Climate finance land-scape of the German building sector

Kopernikus Projects Enavi
Working Package 4 | Task 7 “Technical-systemic analysis with a focus on energy efficiency in buildings”

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KOPERNIKUS PROJEKTE
Die Zukunft unserer Energie

GEFÖRDERT VOM
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Forschungsinitiative Kopernikus

The Federal Ministry of Education and Research (BMBF) has allocated a total of EUR 400 million to fund the Kopernikus program until 2025. The objective of the program is to develop innovative technological and economic solutions that can facilitate the transition to a more sustainable energy system. Over a period of 10 years, more than 230 partners from science, business and civil society will conduct research in four subject areas: "New Network Structures", "Storage of Renewable Energies", "Reorientation of Industrial Processes" and "System Integration". Researchers are adopting a holistic approach to these four subprojects in order to examine specific issues relevant to the individuals and institutions that play key roles in energy generation, transmission, supply, and distribution. The program's 10-year lifespan ensures that the initiative will include a long-term interchange between theory and practice.

System integration: ENavi

As a participant in the "ENavi" subproject, IKEM is partnering with roughly 90 institutions from the fields of science, business, and law to develop a navigation system that promotes the transition to sustainable energy. Because system integration is vital to the success of comprehensive energy reforms, the program partners' integrative approach includes research on heat, gas, and fuel use. IKEM plays a key role in ensuring that the findings from theoretical analyses can be applied in practice. From the outset, field tests are conducted to assess the concrete technical, economic, and legal implications of the energy transition. Test results can then be applied to other regions. Program partners intend to expand the initiative to include research on 50 municipally owned power generation and electricity distribution companies, or *Stadtwerke*.

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Executive Summary

Why is the building sector important?

- Buildings play a special role in Germany's energy transition. They are responsible for up to 30% of Germany's GHG emissions. The sector's primary energy demand is to be reduced by 80% by 2050 compared to 2008. It emissions should be reduced by 67-68% by 2030 compared to 1990. Annual investments needed to reach these targets range between EUR 7 and 20 billion.

- Both residential and non-residential buildings are important for sector decarbonisation. In 2016, the households accounted for 26% of Germany's final energy consumption for electricity and heating their homes. Construction rate is low and new buildings mostly exceed the required energy performance standards. Existing residential buildings constructed in 1948 – 1978 represent the highest energy saving potential. Non-residential buildings account for 13% of the building stock but produce 47% of its GHG emissions.

How much capital was invested in energy transition of the building sector in 2016?

- Climate-specific investments in the German building sector amounted to EUR 31.6 billion in 2016. Almost all investments were directed to residential buildings with EUR 25,6 billion, whereas public buildings and corporate buildings received less investments, EUR 1,4 billion and EUR 3,6 billion respectively[1].

- Investment in thermal energy efficiency increased if compared with 2010. In 2016, investments in thermal efficiency measures were dominant, with EUR 24 billion whereas renewable energy accounted for EUR 6 billion followed by electrical efficiency with EUR 1,5 billion. This might be a positive trend since Germany is on track with its renewable electricity targets but lagging behind with energy efficiency and renewable heat targets.

[1] This might be an underestimate though, since, due to severe data limitations, the study was not able to track climate finance spending from municipal budgets as well as the corporate climate-specific investment beyond the KfW programmes.

- Majority of investment was made into construction sector with close to EUR 21 billion whereas investments for the existing building stock only amounted to almost EUR 10.5 billion. This is disproportionate to the dominant share of floor space of the existing building stock and may signal insufficient retrofit financing. Hence, increasing the retrofit rate remains one of the key challenges and might require additional financing incentives and policy tools to facilitate investment.

Who were the main investors and what made these investments possible?

- Private sector invested EUR 26.7 billion in decarbonisation of the building sector, which is 79% of the total climate-specific investment identified in 2016. Households remain the main investor, but their share has decreased from 85% in 2010 to 51% in 2016. The corporate sector, such as housing companies, invested close to EUR 10.5 billion equivalent to 33% of total investments.

- The KfW and BAFA play a prominent role in providing finance and facilitating information and advice. KfW is the main climate finance provider for at least last five years, accounting for 62% of total investment identified in 2016, or EUR 19.6 billion. In 2016, KfW financed over 60% of all new residential dwellings in Germany.

- Concessional loans remain the main financial instrument for decarbonisation of the residential buildings. Implemented for many years now, they set a best practice case for driving climate investment into buildings. Regional state banks and commercial banks play important role too as intermediaries.

Is the sector on track to reach its targets?

- It is challenging to determine whether the identified investment volume and its structure is sufficient to reach the energy and climate targets of the building sector. Even though the results of this study fall within the investment need ranges estimated by other studies, it would be speculative to conclude whether the sector is on track or not. Additional research and improving data availability would be required.

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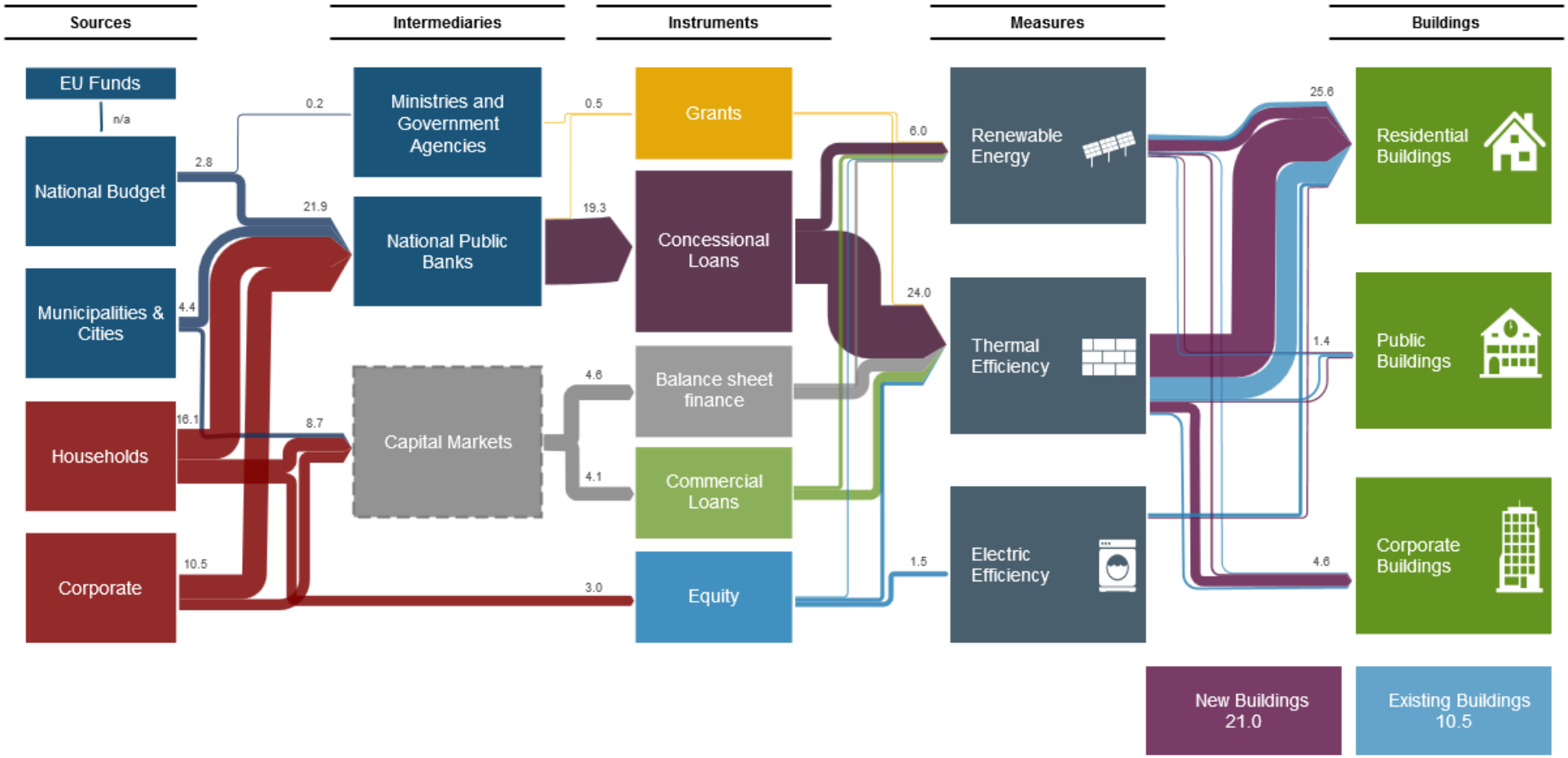
Landscape of Climate finance in the German building sector in 2016, EUR billion.



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.

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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

Term	Definition	Source
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.	
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.	

I. Introduction

Buildings play a special role in Germany's energy transition. Accounting for up to 30% of the country total GHG emissions, this sector has one of the most ambitious targets set by the German Energy Concept and the Climate Action Plan 2050. To decrease energy demand and emissions from buildings, the policy focus lies on increasing energy efficiency and producing the remaining energy through renewable sources. Substantial additional investments are needed to reach climate targets and finance the energy transition.

This report aims to track how much capital was invested in climate and energy transition measures in the German building sector in 2016. Namely, it seeks to answer the following questions:

- How much capital was invested in energy transition of the building sector in 2016?
- Who were the main investors and what made these investments possible?
- What financing instruments were the most common?
- What type of measures and buildings were invested in?

Furthermore, this report aims to compare how the climate finance landscape evolved since 2010 when the study by Juergens et al. (2012) mapped the climate finance flows for the first time for the buildings sector. The report provides a comprehensive snapshot of key stakeholders and investment flows, pointing to potential financings gaps are and which actors could best help leverage more investment volume.

This report is composed of five chapters. Following this introduction, Chapter II introduces the methodology and analytical framework. Chapter III provides background on the building sector in Germany. It explains the structure the German building stock, its emission and energy profile, reviews the sector's climate targets and existing estimates of investment needs to reach them. Chapter IV presents the findings of the research. Chapter V concludes with a summary of the findings, indicates further research opportunities and provides recommendations how to improve climate finance data tracking and reporting.

II. Methodology

1. The concept of climate finance landscape

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. This approach of tracking climate finance was introduced by CPI in 2011 (Buchner, Falconer, Hervé-Mignucci, Trabacchi, & Brinkman, 2011). 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.

Following this approach, this landscape study includes the following elements – sources, intermediaries, instruments, and sector recipients and measures. Definitions of each element are presented below.

a) 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.

Public sources include EU funds, national federal budget, regional budget, or local budgets. The public finance includes direct investment into public assets and the financial incentives (policy-based investment) to leverage investment by private and public actors. 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.

Private sources include households, housing associations, owners and investors into commercial assets such as hotels, commercial office space, supermarkets, and others. The source of capital is allocated to the entity that invests into a given measure. Namely, even if a household takes a loan to finance its investment, borrowed capital is to be repaid within an agreed timeframe. Therefore, for the purpose of this research, the source is allocated to the borrower, namely the household. The cost of capital would be allocated to the lender and is not seen as climate finance, hence not included in this research.

b) 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 and intermediaries, national public financial institutions and intermediaries, commercial banks, and financial market actors.

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 agencies, and local public agencies. The national public financial intermediaries include state owned promotional bank KfW and regional development banks (Länder Förderbanken). Financial market actors include commercial banks, institutional investors, such as pension funds, insurance funds, investment funds, and other entities.

c) Instruments

Climate finance in Germany's building sector is mainly delivered through concessional and commercial loans, grants, equity, public guarantees and other forms of public-private partner-ships (Novikova, Amecke, Stelmakh, Buchner, & Jürgens, 2013). The definitions of these financial instruments are provided in Table 2.

Table 1 Definitions of relevant financial instruments

Term	Definition	Source
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,	(Investopedia, 2018; Reyes, 2012)

Term	Definition	Source
	rather than the interest payments accrued by debt finance. In this context, equity equals cash, therefore it is households' budget or equity from the tertiary sector, which means this money does not go through a specific instrument.	
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 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)
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)

d) Sector recipients and measures

In the buildings sector the investments are split by building segments and measure types. Building segments include residential, public and commercial buildings. Measure types include integrates renewable energy, thermal efficiency measures and electric efficiency.

2. Research boundaries

a) Temporal scope

The report tracks investments that occurred in 2016, not the ones that were planned for that year. As of today, 2016 is the most recent year for which statistics on the building stock, construction or energy statistics, public budgets, annual reports of financial institutions, and monitoring reports of public subsidy programmes are complete.

b) Scope of measures tracked

The research focuses on additional investments beyond the business-as-usual (BAU) baseline and are in line with Germany's energy concept. The specific focus lies on measures related to the

mitigation of GHG emissions associated with the building sector, namely thermal energy efficiency measures, electrical efficiency measures, and measures to increase the share of integrated renewable energy sources in the building sector. BAU finance is differentiated from climate finance as follows:

- In the construction sector, investments that meet the minimum legal standard for construction are considered as the baseline (Bürger et al., 2016). Therefore, additional investments are those that 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 annual retrofit rate is less than 1% whereas the additionality is any retrofit that goes beyond it. Germany's Energy Concept targets a 2% annual retrofit rate (Bundesregierung, 2010). Unfortunately, data on BAU retrofit levels are lacking in the literature, especially in financial terms. Furthermore, investment that reduces the primary energy consumption in existing buildings without reaching the EnEV 2014/2016 requirements are included. This is mainly because the existing building stock has a much higher energy demand than new buildings and it is assumed that energy saving measures receiving public support would not have happened in the BAU case.
- 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.

Table 2 Climate finance definitions and research boundaries.

	Climate-specific investment		Climate-related investment	
	Incremental cost	Total capital investment	Incremental cost	Total capital investment
Tangible	Electric efficiency (purchase of household appliances)	• Renewable energy • Energy efficiency retrofits in existing buildings • Construction of new buildings exceeding EnEV 2014/2016	Measures that deliver co-benefits in terms of emission reduction	
Intangible	R&D, information policies, training, and capacity building			

Covered by the report Not covered by the report

Source: Adopted from Juergens et al., 2012, p. 5

Table 1 further illustrates the boundaries applied in research. There are three layers to defining climate finance measures. First, investments are split into tangible, such as direct investments, and intangible ones, such as R&D or information tools. In this report, only tangible investments are tracked. Second, 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.

Third, depending on the context, an investment can be tracked as total capital investment or as the incremental cost. Incremental cost is the share of the total 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 to reach higher energy efficiency standard. Due to the extensive range of measures and the very limited data available on their technicalities and performance, 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. Due to lack of updated estimates of incremental cost for thermal efficiency measures, this study tracked total thermal efficiency investment and incremental electric efficiency investment.

For the integrated renewable energy and construction of new buildings that exceed the latest Energy Saving Ordinance, EnEV 2014/2016, the total capital investment is included to have the comparable estimates with the results from 2010 (Juergens et al. 2012). What share of such investment is actually incremental is an open methodological question which is beyond this study but is to be tackled by in the follow up research.

c) Sectoral scope

In this study covers all buildings except those that belong to the industrial and agricultural sectors. The report 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[2] 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 manufactur-

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

ing 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. Data collection and analysis

The report follows CPI's approach to track climate finance (Buchner et al., 2011), followed by other publications of national Landscapes (Ampri, et al., 2014; Falconer, 2017; Hainaut, Gouiffes, & Cochran, 2017; Hainaut, Morel, & Cochran, 2015, 2017; Juergens et al., 2012; Novikova et al., 2013; Rademaekers, Debeer, De Kezel, & Van Nuffel, 2016; Rademaekers, Eichler, Perroy, & van der Laan, 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.

For this report, the data was collected and categorised by sources, intermediaries, instruments, measures and building type, following the same data sources and structure as Juergens et al. (2012) for comparison purposes. 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. The finance flows are split into public and private capital such as households, municipalities, public banks etc. This is the first study to break-down climate finance to the level of the building type: residential, pubic or tertiary sector buildings.

More on data collection, assumptions, analysis and visualisation in Annex A.

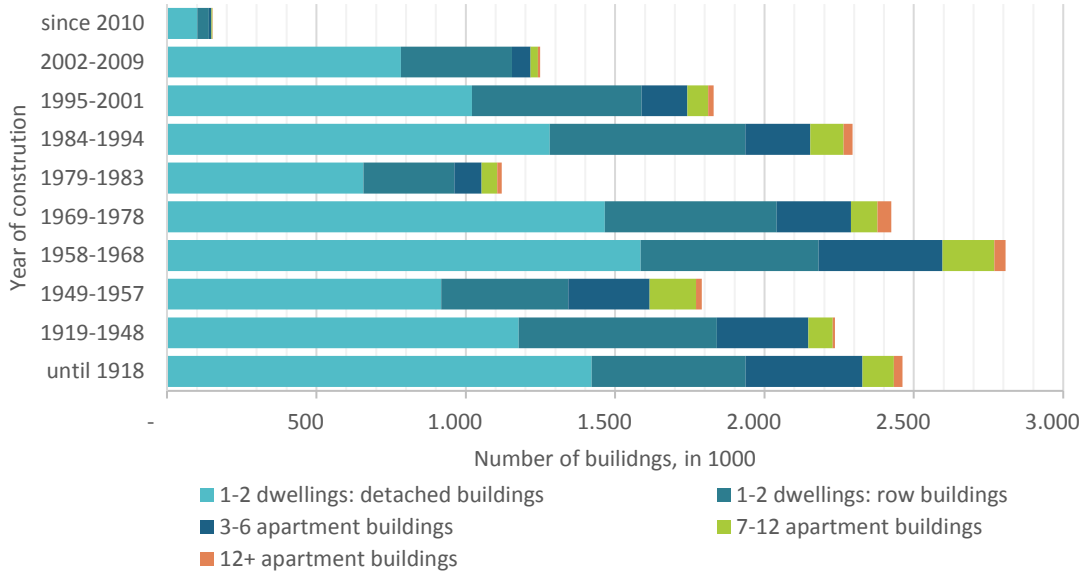
III. The German building sector

1. Structure of the building stock

Germany has a rather old building stock (see Figure 1). Most of the total building stock is constructed before 2010. With the low annual construction rate and long-lasting existing buildings, it is expected that buildings constructed before 2010 will still represent 85% of the total building stock by 2050 (Amecke et al., 2013; OECD/IEA & IRENA, 2017). Most buildings were constructed before the first Thermal Insulation Ordinance (1978). They have very old and inefficient envelopes that are very costly to upgrade. The average retrofit rate is approximately 1% per year, which leads to the risk of stranded assets (Amecke et al., 2013; Bollmann, von Mallinckrodt, & Röttmer, 2018).

The residential sector accounts for 87% of total building stock, consisting mostly 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 1. In 2016, German authorities administered building permits for 23 760 dwellings renovations and 189 836 apartment construction projects (AGEB, 2018).

Figure 1. Structure of the German residential building stock as of 2016.



Data Source: (Bürger et al., 2016).

Despite the relevance of non-residential buildings, less research and literature are available for it. German statistics differentiate between residential or non-residential buildings, but not between the industry, agricultural, tertiary or public sector. 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).

2. Energy and emission profile and targets

The building sector is responsible for up to 30% of Germany's GHG emissions. It bears ambitious energy and emission reduction targets set in the Energy Concept and the Climate Action Plan (Table 1). Aside from the national targets, EU imposes additional targets for the building sector. Namely, 88 – 91 % emission reduction by 2050 as compared to 1990 and annual renovation of 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government to meet at least the minimum energy performance requirements (Directive 2012/27/EU).

Table 3. Energy and emission reduction targets of the German building sector.

National target	Policy
80% primary energy demand reduction by 2050 compared to 2008, of which 20% are to be achieved by 2020	The Energy Concept (2010)
2% rate of building renovation to upgrade energy performance	
67-68% emissions reduction by 2030, below 1990 levels	The Climate Action Plan 2050 (2016)
Climate neutrality of all new buildings by 2020 and of all buildings, including the existing building stock, by 2100	

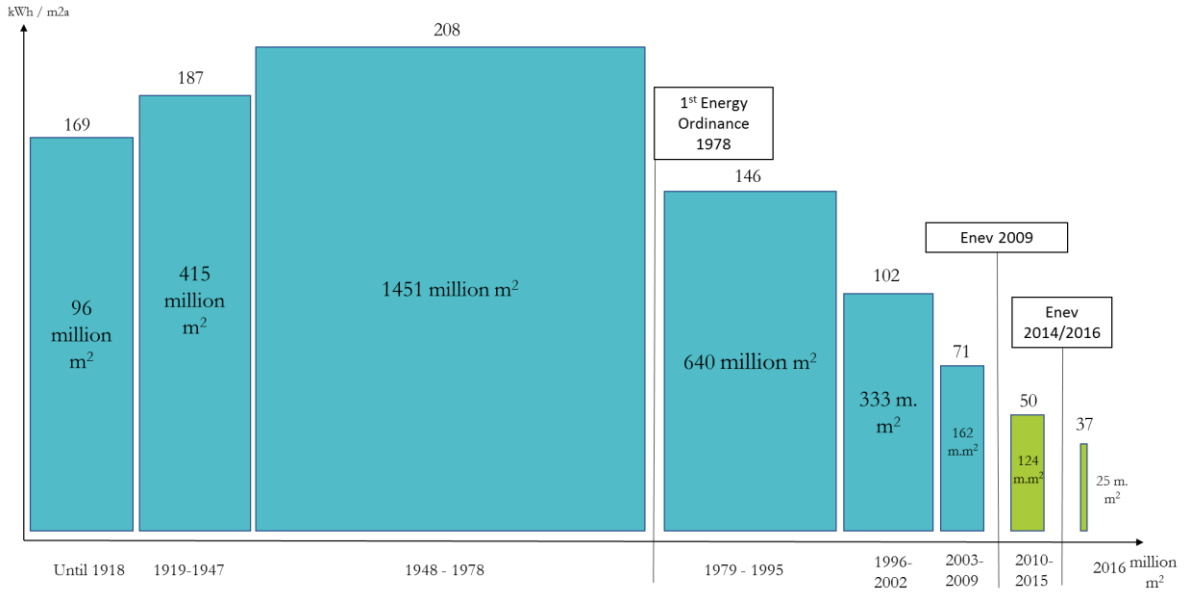
In 2016, the German residential sector accounted for 26% of the final energy consumption, out of which roughly 69% was used to heat buildings (BMWi, 2018). Furthermore, households accounted for 25% of electricity consumption and 42% of district heating in 2015 (AGEB, 2017). Although evolving energy efficiency 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)[3]. As described in the previous section, not all non-residential buildings are relevant to this report, as climate finance flows into buildings from the industrial and agricultural sector were not tracked.

[3] 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.

Building codes had a strong effect on new building energy performance (Figure 2). Energy consumption per square meter drastically dropped each time after the introduction of three major Energy Saving Ordinances, in 1978, 2009 and 2015. Figure 2 also illustrates that residential 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.

Figure 2. Energy consumption of the residential building stock by time classes.

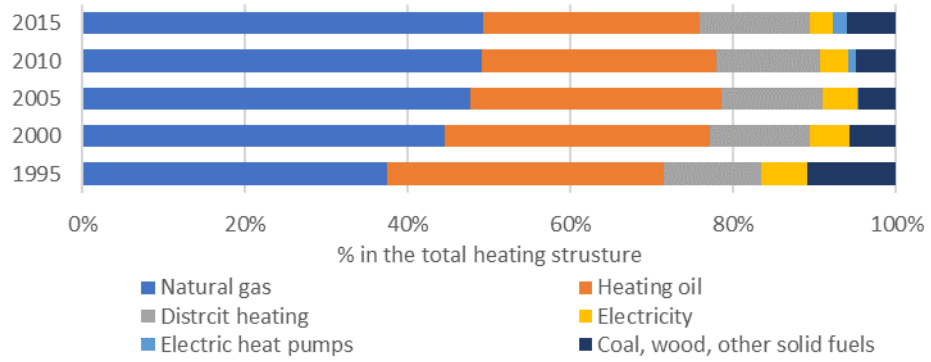


Data source: (BMWi, 2014; Destatis, 2018; Kersten, 2014; Loga, Diefenbach, Stein, & Born, 2012). The magnitude of the building stock in illustrated in million square meters on the x-axis and the average energy consumption of the given section in annual kilowatt-hour per square meter (kWh/m²a). Buildings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

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[4] 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).

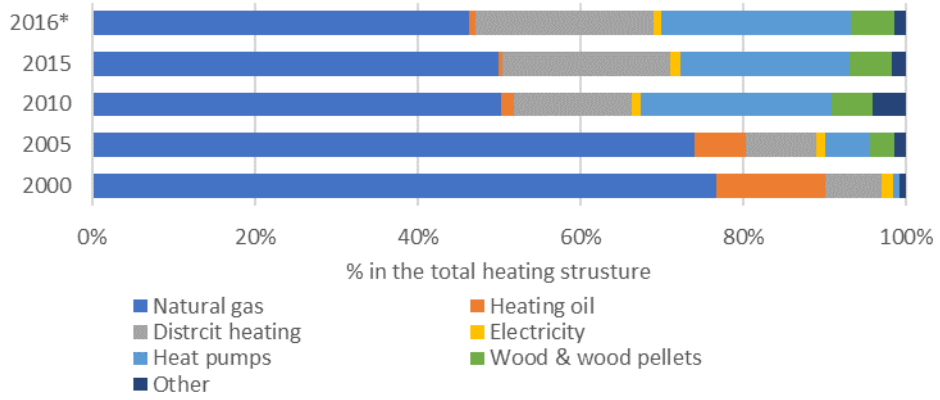
Figure 3. Heating systems by fuel source in existing residential buildings.

[4] 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).



Data source: (AGEB, 2018).

Figure 4. Heating systems by fuel source in new residential buildings.



Data source: (AGEB, 2018). * Data until September 2016.

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[5] 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.

3. Investment needs

Several research groups have estimated the investment gaps and needs to achieve Germany's climate targets, including decarbonisation of the building sector, using 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 4.

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

Table 4. Estimates of investment needs in the building sector to reach Germany's climate targets.

Target	Annual investment need	Time frame	Reference
80% GHG emission reduction by 2050	EUR 6.7 billion EUR	2012-2050	(Schlesinger, Lindenberger, & Lutz, 2014)
20% less primary energy consumption by 2020	EUR 10.25 billion*	2014-2020	(Gornig, Hagedorn, & Michelsen, 2013)
80% and 95% emission reduction targets in 2050	EUR 13.5 and 20 billion	2018-2050	(Gerbert et al., 2018)

* Annual investment need for 2016

Source: Novikova et al., (2018)

Investment need estimates for the German building stock range between EUR 7 and 20 billion annually. Assessment by Schlesinger et al. (2015) suggests that to achieve 80% reduction target requires annual incremental investment of EUR 5.6 billion for households and EUR 1.1 billion for the tertiary sector over 2012-2050. Gerbert et al., (2018) provides higher estimates – EUR 13.5 and EUR 20 billion of additional investment are needed to reach 80% and 95% GHG reduction targets respectively.

4. Investment barriers

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

a) High upfront costs and uncertain energy prices

Private households with low or middle income may not be able to afford high investments in energy retrofits. 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). Furthermore, energy price uncertainty and energy subsidies affect the cost-effectiveness and payback period calculation of energy efficiency investments (BMWi, 2014, pp. 12 & 13)(Ürge-Vorsatz et al., 2012, pp. 698–703).

b) Split-incentive

The split-incentive case is strong in Germany because around 55% of households live in rented dwellings in 2014.[6] Tenants lack an incentive to invest in energy efficiency measures when utility bills are included in the rent and they are most likely to move out before the investment pays back (Forni & Zajaros, 2014). The landlords also have little incentives to pursue energy efficiency retrofits as they do not benefit from the energy savings and it is uncertain whether they

[6] DESTATIS

are able to recoup the cost through higher rent (BMWi, 2014, pp. 12 & 13). As a result, rented homes are less well insulated and have lower energy efficiency appliances (Papineau, 2015).

c) Information and training deficit

Building owners often have little experience in management and proper cost-benefit analysis of larger investment projects such as energy renovation, which makes them more risk averse to energy efficiency retrofits (BMWi, 2014, pp. 12 & 13). Although heating and insulation the insulation technologies and products continue to evolve, the high degree of innovation leads to the lack of qualified planners, architects or technical workers (ibid.).

d) 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 efficiency measures (BMWi, 2014, pp. 12–13; Ürge-Vorsatz et al., 2012, pp. 698–703). From a behavioural economic point of view, households 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).

IV. Climate finance in the building sector

1. Total climate finance investment

Based on the methodology of this report, it is estimated that at least EUR 31.6 billion was invested for Germany's building sector decarbonisation in 2016. Of this, EUR 26.7 billion was private. These investments largely occurred due to public support of EUR 2.8 billion, which is only a fraction that could be quantified.

Of the total amount, investments supporting thermal efficiency measures were largely dominant, with EUR 24 billion whereas renewable energy accounted for EUR 6 billion followed by electrical efficiency with EUR 1,5 billion. Tracked investments mostly supported measures in the construction sector with close to EUR 21 billion, whereas investments for the existing building stock only amounted to almost EUR 10.5 billion.

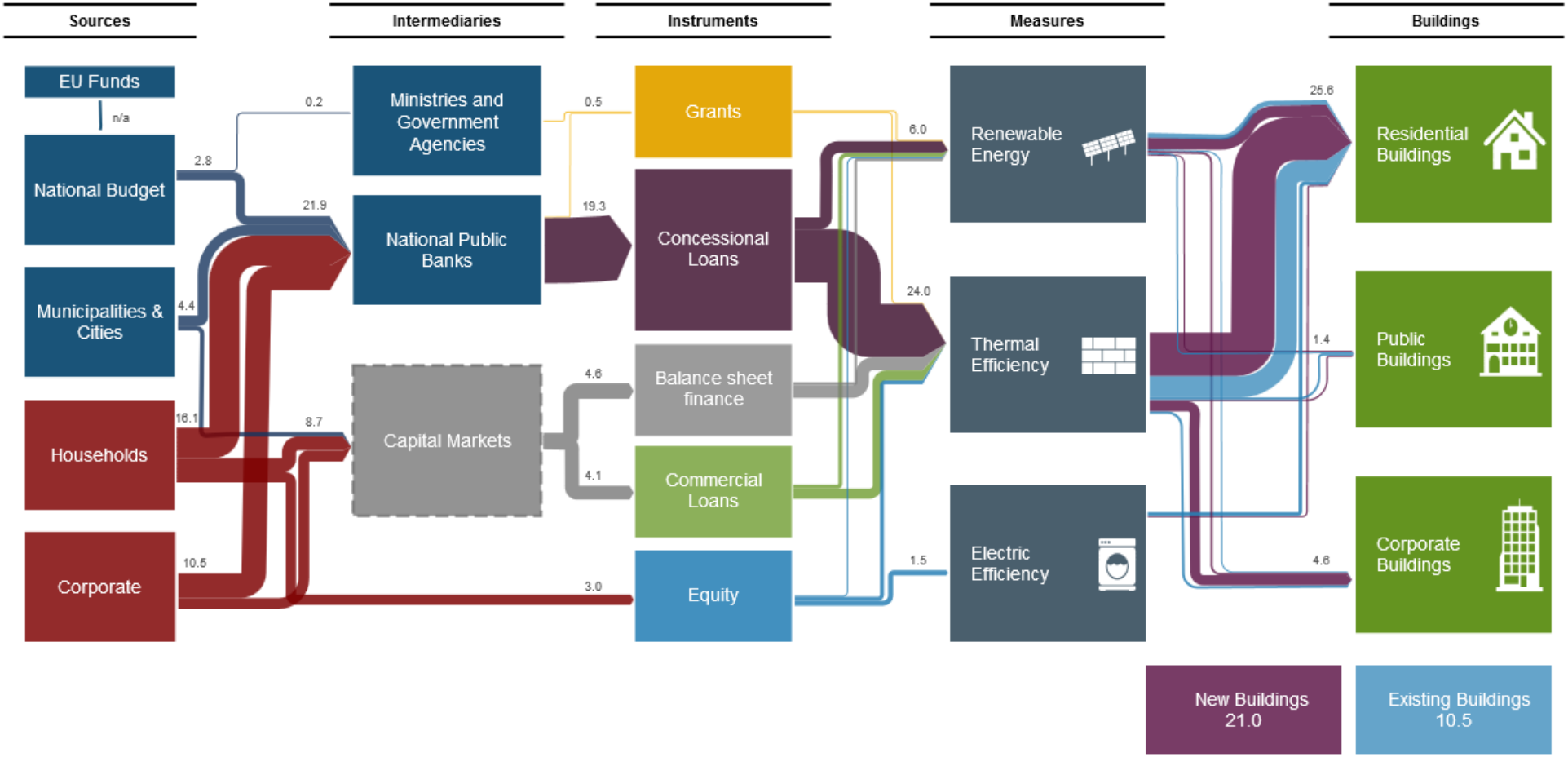
Almost all investments were directed to residential buildings with EUR 25,6 billion, whereas public buildings and buildings from the tertiary sector received far less investments, EUR 1,4 billion and EUR 4.6 billion respectively. Table 5 summarises the results.

Table 5 Source of climate finance in the German building sector in 2016, billion EUR

Building sector	Renewable energy		Thermal efficiency		Electric efficiency		Total
	New buildings	Existing buildings	New buildings	Existing buildings	New buildings	Existing buildings	
Residential	3.4	1.5	12.9	6.3	0.5	1.1	**25.6**
Public	0.1	0.1	0.5	0.7	-	-	**1.4**
Corporate	0.7	0.2	2.9	0.7	-	-	**4.6**
Total	**4.2**	**1.8**	**16.3**	**7.7**	0.5	1.1	**31.6**

The landscape of climate finance in the German building sector for 2016 is shown in Figure 5. It visualises the climate finance flows from sources through intermediaries and instruments to measures and building types.

Figure 5. Landscape of climate finance in the German building sector in 2016, EUR billion.



Source: Author's illustration, adopted from Juergens et al (2012).

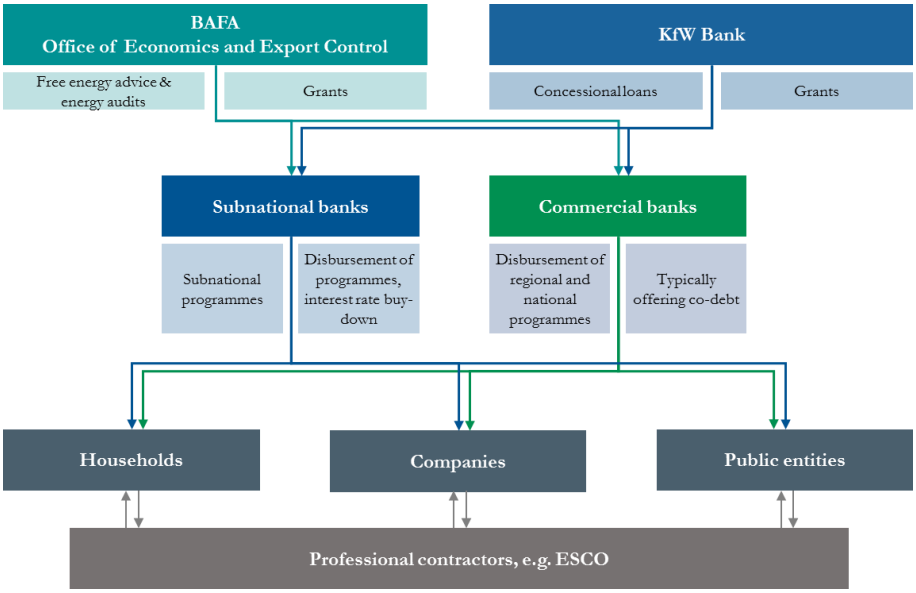
2. Funding sources and intermediaries

a) Public finance

In 2016, public finance for renewable energy and energy efficiency was EUR 2,8 billion. Of this amount, EUR 2,6 billion was disbursed from the German federal budget and EUR 0,2 billion grants from the Office of Economics and Export Control (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 31 billion.

The main public stakeholders in climate finance in the building sector are Office of Economics and Export Control (BAFA) and state owned promotional bank KfW, although commercial banks and regional banks are important for capital disbursement and co-financing (Figure 6). The KfW and BAFA play a prominent role in providing finance and facilitating information and advice, especially to households. BAFA offers grants as a percent support of total investment volume and free energy advice and audit for renewable energy and thermal efficiency measures (BAFA, 2017).

Figure 6. Key stakeholders for climate finance in the building sector.



Source: Author's illustration.

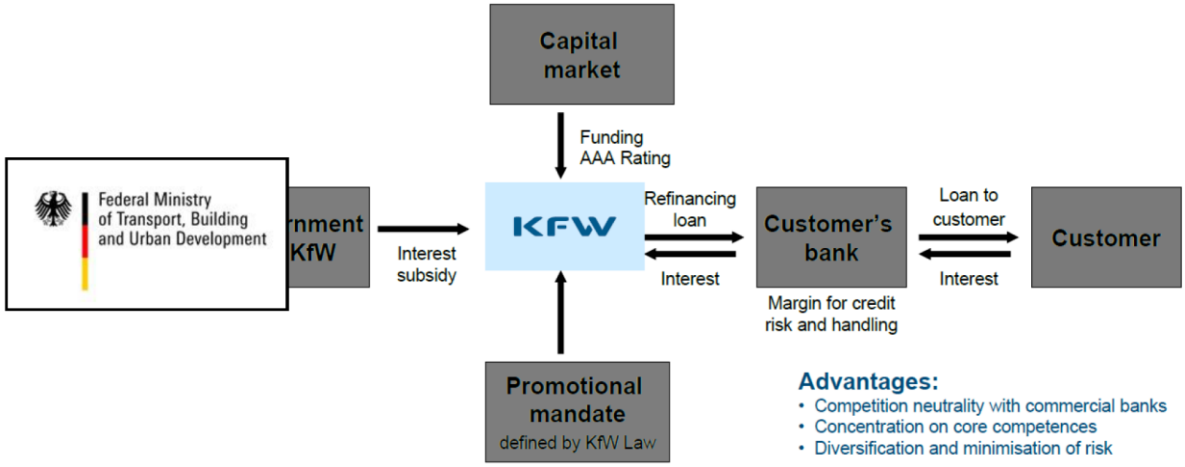
In 2016, KfW provided over EUR 19.3 billion of concessional loans and at least EUR 258 million[7] of grants to households, companies and public entities for renewables and thermal efficiency investments in buildings. This is an increase if compared to EUR 13.2 billion of concessional loans and EUR 147 billion of grants in 2010 (Juergens et al. 2012). The bank by far remains the

[7] The total funding of KfW programmes is actually higher, the study include only direct investment into energy efficiency and renewable energy in buildings

main climate finance provider in the building sector in at least last five years. In 2016, KfW financed over 60% of all new residential dwellings in Germany.

KfW does not have its own branch network and works with the subnational or regional, commercial and savings banks and insurance companies to distribute the loans. Grant applications are processed by KfW directly. The details of support programmes are agreed with the Federal Ministry of Building, transport and Urban Development. Figure 7 illustrates details of how KfW programmes are implemented.

Figure 7. Process and business model of KfW programmes.



Source: KfW Good Practice Factsheet

The budget support from the government helps KfW to offer debt relief and loans at subsidised (concessional) rates to the beneficiaries. The largest share of budget support covers debt relief. In 2016, EUR 2.6 billion were disbursed to support KfW programmes in buildings sector. Table 6 summarises the federal budget allocations for implementation of KfW programmes.

Table 6 Budget allocations from the Federal budget to KfW programmes in 2016.

Budget allocated to:	Budget line	Amount (EUR million)	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, "CO^2 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, "CO^2 building retrofitting program"

Budget allocated to:	Budget line	Amount (EUR million)	Description
KfW grants	891 01 -411	166	Grants to private owners to promote measures of thermal building retrofitting "" CO^2 building retrofitting program
Total		**2,563**	

Data source: (Budget Act, 2018)

Regional banks play important role in implementing and co-financing the BAFA and KfW programmes, as well as implementing subnational programmes on social housing and public infrastructure, often further reducing the cost of capital. With KfW programmes, regional banks often add additional elements depending on the regional context. Supported investment volumes and measures on the regional level are mostly provided in very little detail. Regional banks rarely track climate or energy transition related investments separately. Even though their contribution could not be fully quantified in this report, Table 7 summarises available data on climate-specific finance and programmes offered by the regional banks in 2016.

Table 7 Climate finance relevant programmes in the building sector on a regional level, in EUR million.

Federal state	Public Bank	Financing instruments	Housing			Public infrastructure		
			Amount	Climate finance relevant	Total Investment volume	Public infrastructure	Climate finance relevant	Total investment volume
Baden-Wurttemberg	L-Bank	CL	2,709	464	3,638	n/a	n/a	n/a
Bavaria	Bayern-Labo	CL & G	263	n/a	n/a	97	97	200
	LFA	CL	49	49	93	354	n/a	2,631
Berlin	IBB	CL	533	at least 86.4	at least 169	n/a	n/a	n/a
Brandenburg	ILB	n/a	44	at least 7.6	n/a	n/a	n/a	n/a
Bremen	BAB	CL	13	13	at most 17	n/a	n/a	n/a
Hamburg	IFB Hamburg	CL & G	703	39	n/a	n/a	n/a	n/a
Hesse	WiBank	n/a	1,584	at least 11	n/a	n/a	n/a	n/a
Mecklenburg Western Pomerania	LFI MV	n/a	3	n/a	n/a	n/a	n/a	n/a
Lower Saxony	N Bank	n/a	17	at least 3	n/a	n/a	n/a	n/a
North Rhine Westphalia	NRW. BANK	n/a	2,118	at least 28	n/a	3,605	n/a	n/a
Rhineland Palatinate	ISB	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Saarland	SIKB	n/a	125	n/a	n/a	n/a	n/a	n/a
Saxony-Anhalt	IBS	CL & G	159	n/a	n/a	n/a	n/a	n/a
Schleswig-Holstein	IB SH	n/a		n/a			n/a	
Saxony	SAB	CL & G	325	n/a	n/a	507	n/a	n/a
Thuringia	TAB	CL	365	n/a	n/a	Included in housing	n/a	n/a
Total			**9,010**	**at least 238**	**n/a**	**5,071**	**at least 97**	**n/a**

CL - Concessional loan
G - Grant
n/a – information not available in public domain

Source: (LBank, 2017), (BayernLabo, 2017), (LfA, 2017), (IBB, 2017), (ILB, 2017), (BAB, 2018), (IFB Hamburg, 2017), (WiBank, 2017), (Lfi M-V, 2017), (NBank, 2017), (NRW.BANK, 2017), (ISB, 2017), (SiKB, 2017), (IB Sachsen Anhalt, 2017), (IB.SH, 2017), (SAB, 2017), (TAB, 2017) and personal contacts.

Facilitated by the KfW and BAFA programmes, public entities invested EUR 4.4 billion in energy improvements of public buildings such as schools, hospitals and administrative buildings. Investment by public entities financed directly from their budget was not tracked due to data constraints. Public buildings accounted for only 4% of the total investment. Keeping in mind that the public sector is to play an exemplary role and that climate targets for public buildings are tighter than other sectors, current investments might be insufficient.

b) Private finance

Private sector invested EUR 26.7 billion in decarbonisation of the building sector, which is 85% of the total climate-specific investment in the building sector identified in 2016. The energy transition in the building sector is still mainly financed by households, with over 51% (EUR 16.2

billion), quite a bit lower than the results by of Juergens et. Al. for 2010, which calculated that households contributed 85% of climate finance in the building sector. Companies invested EUR 10.5 billion (34%) in 2016. Apart from electrical efficiency measures, thermal energy efficiency and renewable energy investment by private actors were facilitated by KfW and BAFA programmes.

Similar to the regional banks, commercial banks disburse and co-finance the KfW and BAFA programmes. They also offer financial products for corporate balance sheet finance. Even though commercial banks are important finance providers and intermediaries across all sectors, including buildings, they do not track and publish their climate related finance flows in sufficient detail. Therefore, this study was able to track only the climate finance linked to KfW programmes. Commercial banks co-financed EUR 4.1 billion in loans of households for decarbonisation of building sector in 2016. They also supported investment by public entities and private companies but the exact share is difficult to estimate since these investments are carried on their balance sheets.

3. Financing models and instruments

Renewable energy and energy efficiency investment in buildings is driven by KfW concessional loans, similar to findings from 2010 by Juergens at al. In 2016, concessional loans totalled to EUR 19.3 billion, accounting for 61% of total investment – an increase as compared to 55% in 2010 (Juergens at al., 2012).

Table 8 Funding amount and share by instrument in 2016.

Concessional loans	Grants	Balance sheet finance	Commercial loans	Equity
EUR 19.3 billion	EUR 0.47 billion	EUR 4.6 billion	EUR 4.1 billion	EUR 3.0 million
61%	2%	15%	13%	10%

Grants totalled to EUR 476 million, or 2% of total investment. Normally, grants cover only a small share of total investment and are co-financed with equity or loans obtained from commercial or public banks. EUR 218 million of grants were 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. KfW provided at least EUR 258 million of grants for thermal efficiency measures. BAFA grants and KfW programmes are mutually excludable[8], except for one KfW programme that allows the accumulation of BAFA

[8] Personal communication with BAFA, April 12th-May 30th, 2018

grant and KfW concessional loan. Both grants and concessional loans are disbursed by commercial banks and regional development banks, facilitating blending public and private finance.

Balance sheet finance represented 15% of total investment, or EUR 4.6 billion. It was used for co-financing loans from KfW programmes and BAFA grants by companies and public entities. It can include a combination of debt and equity carried on their balance sheets.

Commercial loans to households amounted EUR 4.1 billion, or 13% of total investment in 2016. As mentioned before, due to data availability and reporting constraints, only the loans associated with KfW or BAFA support programmes were quantified. Therefore, the total volume of commercial loans and other market-rate debt instruments might be higher.

Equity represented EUR 3 billion, or 10% of the total investment. Similar to commercial loans, this study accounts only the equity investment which was as co-financing of the concessional loans for thermal efficiency and renewable energy, as well as purchases of energy efficient appliances (electric efficiency). So, again, the total equity investment in decarbonisation of buildings could have been higher in 2016.

4. Financed building types and measures

Climate finance was disbursed across new and existing residential, public and corporate tertiary buildings into renewable energy, thermal and electric efficiency measures. Residential buildings received 81% of total investments with EUR 25,6 billion, followed by buildings in the tertiary sector with EUR 4.6 billion (15%) and finally, public buildings with EUR 1.4 billion (Figure 7). Most of finance (67%) was provided for construction of new buildings.

The investments mainly went to thermal efficiency with EUR 24 billion, followed by integrated renewables with EUR 6 billion and electrical efficiency with EUR 1.5 billion. The investment volumes should be compared to the result by Juergens et. al (2012) with caution, since this report calculates total capital investment in renewable energy and thermal efficiency, while all electric efficiency accounts for incremental cost only.

a) Residential buildings

Residential buildings received 81% of total investments (EUR 25.6 billion). Large investment volumes, EUR 24 billion, were directed at thermal efficiency, which is crucial to achieve German climate and energy targets. Climate-specific investments in new residential buildings are likely to be on track towards the respective strategy target. In 2016, renewable energy represented

19%, or EUR 6 billion, of total investments, while in 2010 it dominated over energy efficiency investments with a 81% share.

Comparing the national statistics of the building sector (Destatis, 2018) and KfW annual report (KfW, 2016), it appears that KfW supported over 60% of new residential dwellings in 2016. The share and volume of KfW in new residential construction increased as compared to 50%[9] (EUR 13.2 billion) in 2010 (Juergens et al., 2012). This shows the extent and outreach of concessional loans.

The measure that received most investments was the construction of residential "KfW efficiency houses 55". It means that a building's primary energy consumption is only 55% of the reference house from the Energy Saving Ordinance 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". The monitoring report of the KfW "efficiency house" programmes 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). For each measure receiving KfW support, the recipient, typically a household, needs to provide proof that a professional entity was contracted thus leading to capacity-building of the market.

This study was not able to estimate what share of the remaining 32% of the new residential construction that did not receive KfW support has surpassed the EnEV 2016. Doing so requires tracking climate investment data by commercial banks or other finance providers in sufficient detail, which is currently not the case. As KfW concessional loans are available at all German banks at cost below the market rates, it is unlikely that significant share of households and companies would opt for market-rate debt instruments.

Table 9 shows that half of the existing buildings that got support for thermal retrofit and integrated renewables were constructed in the 1949-1978 timeframe. As Figure 2 showed, buildings erected between 1948 and 1978 make up for the biggest share in floor area and have the highest primary energy demand.

Table 9 Construction year of buildings supported by KfW energy effieciny retrofit programmes in 2016

Construction year	1 and 2 dwellings	3 and more dwellings
Until 1948	19%	35%
1949-1978:	46%	51%

[9] Measured in terms of constructed floor space

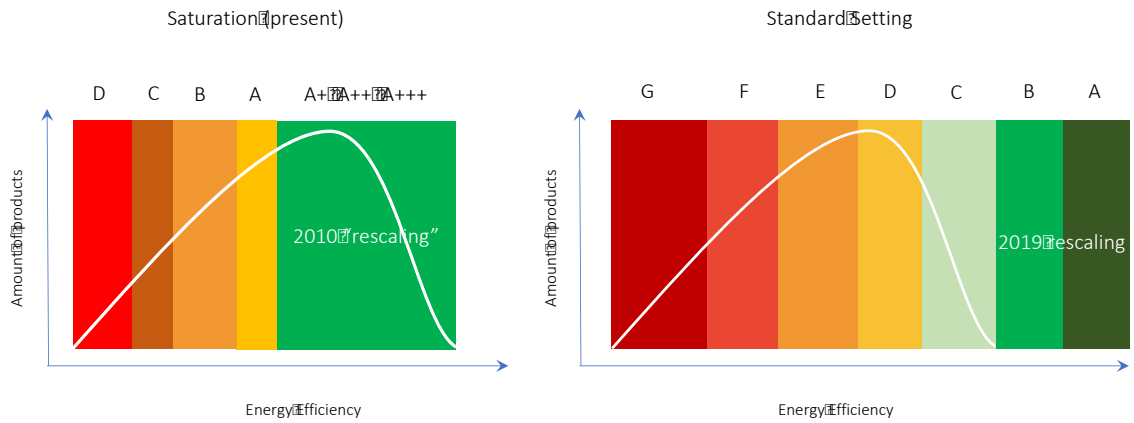
1949-1968	28%	34%
1969-1978	18%	17%
1979 and after	35%	14%

Source: Diefenbach et al., (2018, p. 45)

Concessional loans are the main financial instrument used to finance the energy transition in the residential building sector. In 2016, they account for EUR 19.3 billion, or 61% of total investment in buildings. If compared to grants, concessional loans are a more cost-effective way to use public support and provide access to finance. Additionally, because they are provided upon contracting a professional (and listed) contractor to perform the measure, they help to overcome such barriers as information deficit and aversion to unfamiliar technologies. Yet, free riders that would have implemented the energy saving investments with or without concessional loans, are also included in the estimates.

In 2016, EUR 1.5 billion was invested in purchases of energy efficient household appliances. Figure 8 illustrates the household appliances market by energy efficiency label. According the labelling under the Directive 2010/30/EU, the market is already saturated with products classed highly efficient (A+ and higher). Since the last labelling standards are as old as 2010, a new labelling system is due to be implemented in 2019 (Regulation (EU) 2017/1369, European Parliament and the Council, 2017). It will rescale energy efficiency labels as shown in Figure 8 (right side) and therefore change the marker structure towards a larger share of relatively inefficient appliances.

Figure 8 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.

b) Public buildings

In 2016, EUR 1.4 billion, or only 4% of total investment was invested in decarbonisation of public buildings which is significantly less than investment in the residential sector. It also seems insufficient to meet the national 2% target or the EU 3% target for annual retrofit rate. Currently, there is no proper monitoring or data to assess whether the annual retrofit rate of 3% is being achieved (EC, n.d.).

Several KfW programmes solely focused on public infrastructure (schools, hospitals administrative buildings) but the bank seems to play a lesser role than in the residential sector. In 2016, KfW programmes provided over EUR 3 billion for the public building sector, supporting 371 measures, while there are 12 000 munipalities in total. Municipal budgets and public private partnerships may serve as important funding sources, but these investments were not tracked due to data constraints. In contrast to the large investment flows of EUR 21 billion in the construction sector, the existing building stock received far less investments with only EUR 10 billion.

c) Buildings of the tertiary sector

In 2016, the corporate sector (industry, tertiary and agriculture) benefited from a dedicated KfW programme. Total investment volume associated with the programme amounted EUR 4.6 billion, or 15% of the total investment in the building sector. This might be an underestimate though since, due to severe data limitations, it is not possible to track climate-specific investment in this sector, aside from reported KfW support volumes. Companies normally do not differentiate or report climate-specific investment separately from a usual business cycle investment carried on their balance sheets. Additional methodological approaches are required to come up with more accurate estimates, which are beyond the scope if this study.

V. Conclusions

Findings summary

The study estimated that at least EUR 31.6 billion was invested for Germany's building sector decarbonisation in 2016. The key stakeholders and structure of investment flows remains similar to findings from 2010 by Juergens et al. (2012). Households are the main investors, accounting for over 51% of total investment, or EUR 16.2 billion. BAFA and KfW programmes played a major role in driving private investments.

KfW is the main climate finance provider in the building sector in at least last five years. In 2016, KfW financed over 60% of all new residential dwellings in Germany. KfW concessional loans remain the main financial instrument used to finance the energy transition in the residential building sector. Implemented for many years now, they set a best practice case for driving climate investments into buildings. Regional state banks and commercial banks play important role too as intermediaries.

There seems to be a shift in investment from renewable energy to energy efficiency if compared with 2010. In 2016, investments in thermal efficiency measures were largely dominant, with EUR 24 billion whereas renewable energy accounted for EUR 6 billion followed by electrical efficiency with EUR 1.5 billion. Furthermore, in 2016, majority of investment was made into construction sector with close to EUR 21 billion. This is disproportionate to the dominant share of floor space of the existing building stock and may signal insufficient retrofit financing. Increasing the retrofit rate remains one of the key challenges and might require additional financing incentives and policy tools to facilitate investment.

Almost all investments were directed to residential buildings with EUR 25.6 billion, whereas public buildings and corporate buildings received far less investments, EUR 1.4 billion and EUR 4.6 billion respectively. This might be an underestimate though, since, due to severe data limitations, the study was not able to track climate finance spending from municipal budgets as well as the corporate climate-specific investment beyond the KfW programmes.

It is challenging to determine whether the identified total capital investment volume and its structure is sufficient to reach the energy and climate targets of the building sector. It would be speculative to conclude whether the German building sector is on track or not. Additional research would be required, some of which is suggested in the section below.

Further research

Building upon this report, several opportunities for further research can be gauged depending on the data availability:

- Incremental cost of climate-specific investment in new and existing buildings. Reviewing the assumptions of the Juergens et al (2012) to what extent the share of incremental cost has changed over the past five years would add to the accuracy of the estimates.
- Extended assessment of climate-specific investments for public and corporate buildings. Tracking of investment in public buildings through local budget allocations, green procurement or public private partnerships would provide more accurate picture. Similarly, improving methodology to track climate-specific investment in commercial buildings through corporate finance would add a great value.
- Tracking climate finance in other sectors. A climate finance landscape across all sectors of economy would help to see whether Germany is on track in reaching its climate commitments and where the investment gaps are.
- Assessment of effectiveness and additionality of investment made. A follow up research would be to assess the cost effectiveness of investments made and the additionality of those investments leveraged by public support schemes.
- Investigating the policy framework on disclosing climate finance. Germany has an extensive policy package for its energy transition but none for climate finance reporting. Exploring options and recommendations for policy framework on climate finance reporting in Germany, based on existing case studies in EU states, would provide a solid background for a policy discussion.

Data challenges and recommendations

Data availability remains a major issue and has vastly limited this research. Since the latest study in 2012 (Juergens et al. 2012), no data improvement in the German building sector has been recorded. Tracking challenges are faced for both the public and private finance flows. The main limitation is that publicly available information is not detailed enough to track climate finance from its source to the final beneficiaries and measures. Multiple sector expert interviews and assumptions are required to fill up the data gaps.

To improve data availability and enable tracking climate finance flows not only in the building sector but also other sectors, following steps could be taken.

Define a common definition of climate finance

Definitions of climate finance and tracking methodologies remain heterogeneous. Their streamlining would enable comparability of results as well as mutual learning. Tracking and reporting practices greatly vary among the EU Member States and within the countries. Aligning the taxonomy for sustainable finance by the expert group of the European Commission and the tracking approach to the EU budget's 20% climate action target can significantly contribute to a common definition of climate finance.

Align reporting with climate and energy targets

Data collection and reporting should correspond to national climate and energy transition commitments. In France, for example, the Article 173 of the "Law on Energy Transition for Green Growth" provides a reporting framework for annual assessment of the financial contributions from the public and private sector towards its climate and energy transition targets.

Ensure systematic data collection and reporting

Annual reporting on climate-specific public and private finance at the EU, national and sectoral levels would increase the transparency, improve the accuracy of climate finance mapping and enable the assessment of investment gaps.

Financial intermediaries and companies should disclose more on their climate-specific investment as they represent the largest data gap. Making reporting climate-specific investment mandatory can improve data availability. For example, in France, the above mentioned Article 173 obliges companies to provide "information on the way they take account of the social and environmental consequences of their activity - including the effects of climate change resulting from their activity… - and of their social commitments in favour of sustainable development, the circular economy, the fight against food waste, and the fight against discrimination and promoting diversity" (French National Assembly and the Senate, 2015).

On the EU level, the Directive 2014/95/EU demands large companies[10] to report on their social and environmental actions along their annual financial reports (European Parliament and Council, 2014). Even though the Directive is about non-financial reporting, it gives an incentive for companies to separate their climate relevant activities. Germany transposed the Directive in

[10] 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)

2017, which might improve data availability in the future, namely, for the commercial tertiary sector (German Bundestag, 2017).

Improve transparency of official statistics and annual surveys

Improved transparency and depth of official sectoral statistics on climate-specific investments would significantly improve understanding of where investment takes place, in what amount and where the financing gaps are. Some of the potential improvements in official statistics could be:

- Publishing climate-specific investment by measure (e.g. renewable energy, thermal and electric efficiency) and investor type (e.g. utilities, industry, agriculture, tertiary, or households) across all sectors, including buildings.
- Publishing achieved energy performance standards and their average costs per square meter together with data on building and renovation permits for new and existing residential and non-residential buildings.
- Surveys on households' motivations and investment volumes in renewables and energy efficiency.
- Publishing climate-specific investment in public and commercial tertiary buildings.
- Publishing climate-specific allocations across all public budget lines by the national and state level ministries, public agencies and regional banks.

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Annexes

Annex A. Methodology - Data collection and analysis

(1) Sources

Among finance sources, the report 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 report.

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 report.

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 report. 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.

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 back-tracked from the programmes. The source of finance for public buildings belonging to the Federal State were tracked directly from the national government budget.

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 report were tracked from their source to the instruments but disregarded from that point on.

(2) 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.

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.

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

and Table 11 exhibit the collected data presented by programme. Each programme is categorised separately.

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.

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.

(3) Instruments

BAFA provides the percent support of total investment volumes in its annual financial report (BAFA, 2017) 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[11]. 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 report, 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.

(4) 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.

(5) 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

[11] 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)

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 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)

This study accounts for total capital investment of energy efficiency and renewable energy measure in new construction. 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 11). 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 12.

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.

b) 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 10 and Table 11 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 11 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 report 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 report.

Table 10 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

Table 11 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).

	Breakdown by measure	Breakdown by actor	Breakdown by building type	Location	References
Pro-gram	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 –	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 retrofit-	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	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	This programme solely covers non-residential public buildings such	All investments to take place in Germany.	Programme value and supported measures: (KfW, 2016) Breakdown by ac-

	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.	to assess the split between corporate and public ownership of investors, we assume that all investments come from the public sector.	as schools, administrative buildings or sports halls.		tor: 220/219 Programme description
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. program	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)
Energy Program Renewable "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)
Energy Program Renewable "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 pro-gram – 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. - invest-ment 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 efficiency 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 12 shows the renewable energy to energy efficiency ratios assumed.

Table 12 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							

c) 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 13.

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 report 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 13 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