TEXTE
23/2021

Final report

Carbon Bubble – Analyses, economic risks, measures and instruments

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Abstract

Carbon Bubble – Analyses, economic risks, measures and instruments

The transition to a low carbon economy poses risks to the financial sector. In 2015, the G20 already questioned whether investments in fossil-fuel-dependent infrastructure could lead to global financial risks – the so called 'carbon bubble'. As G20 president, the German government by means of the German Environment Agency (UBA) has commissioned a consortium of Navigant – A Guidehouse Company, University of Oxford (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, University of Zurich (Finexus) and Germanwatch to analyse and evaluate the risk of a 'carbon bubble' in the German financial system.

The term 'carbon bubble' refers to the idea that companies relying on fossil fuels are incorrectly valued on the stock markets as the true costs associated to climate change and respective policies, are generally not yet taken into account in a company's stock market valuation.

The study (1) assesses the carbon risks in the German economy, (2) conducts a carbon stress test for German financial institutions and (3) recommends regulatory instruments to mitigate carbon risks in financial markets in Germany and beyond. The outcome of this highly relevant project will enable the German government to detect, understand and mitigate the risks and will support German financial institutions in assessing the carbon risk of individual financial portfolios.

Carbon Bubble – Analysen, wirtschaftliche Risiken, Maßnahmen und Instrumente

Die Transformation hin zu einer kohlenstoffarmen Wirtschaft stellt die Finanzbranche vor Herausforderungen. Die G20-Länder warfen daher bereits 2015 die Frage auf, ob und inwieweit Investitionen in Vermögenswerte, die von fossilen Brennstoffen abhängig sind, überbewertet sind und damit zu globalen Finanzmarktrisiken – einer sogenannten „Carbon Bubble" – führen können. Vor diesem Hintergrund hat Deutschland als G20 Vorsitz ein Konsortium bestehend aus Navigant – A Guidehouse Company, der Oxford Universität (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, Universität Zürich (Finexus) und Germanwatch damit beauftragt, die transitorischen Klimarisiken im deutschen Finanzsystem zu analysieren und zu evaluieren.

Hinter dem Begriff „Carbon Bubble" verbirgt sich die Problematik, dass von fossilen Brennstoffen abhängige Firmen, wie zum Beispiel die fossile Energiewirtschaft oder treibhausgasintensive Industrien, am Kapitalmarkt falsch bewertet werden. Da die mit dem Klimawandel verbundenen Kosten und die sich aus der Klimapolitik ergebenden Transformationsprozesse in der Unternehmensbewertung noch nicht berücksichtigt werden, könnte eine erhebliche Überbewertung dieser Firmen am Kapitalmarkt vorliegen.

Die vorliegende Studie (1) bewertet die Kohlenstoffrisiken in der deutschen Wirtschaft, (2) entwickelt einen Carbon Stresstest für deutsche Finanzinstitute und (3) empfiehlt regulatorische Instrumente zur Reduktion von Kohlenstoffrisiken im Finanzmarkt. Das Ergebnis hilft der deutschen Regierung bei der Identifikation, Bewertung und Reduktion des Risikos einer „Carbon Bubble" in Deutschland. Außerdem unterstützt es deutsche Finanzinstitute bei der Bewertung von Kohlenstoffrisiken individueller Finanzportfolios.

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Abbreviations

BF/BOF	Blast Furnace/Basic Oxygen Furnace
2° II	2° Investing Initiative
BaFin	German Federal Financial Supervisory Authority
BaFin MaRisk	BaFin minimum requirements to risk management (for banks)
BAFU	Federal Office for the Environment (Switzerland)
BMU	Federal Minister for the Environment, Nature Conservation, and Nuclear Safety
BRSG	German Federal Data Protection Act
CMU	Capital Market Union
COP	Conference of the Parties
CSR	Corporate Social Responsibility
CVA	Credit Valuation Adjustments
DCF	Discounted Cash Flow
EAD	Exposure at Default
EAF	Electric Arc Furnace
EBA	European Banking Authority
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
EL	Expected Loss
EnergieSTG	Energy Tax Law
ESG Label	Environmental, Social, Governmental Label
ESRB	European Systemic Risk Board
ETP	Energy Technology Perspectives
ETS	Emission Trading Scheme
EU	European Union
EZB	European Central Bank
FSB	Finance Stability Board
GFSG	Green Finance Study Group
GIZ	German Corporation for International Cooperation GmbH
HLEG	High Level Expert Group on Sustainable Finance
IAS	International Accounting Standards
ICGI	Investment Climate and Governance Initiative
IEA	International Energy Agency
IFRS	International Financial Reporting Standards

IORP	Institutions for Occupational Retirement Provision Directive
KAGB	German Capital Investment Code
KWG	Banking Act
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LPAA	Lima Paris Action Agenda
MACC	Marginal Abatement Cost Curve (Grenzvermeidungskostenkurven)
MCR	Minimum Capital Requirement
MFI	Monetary Financial Institutions
MSCI	Morgan Stanley Capital International
NGO	Non-governmental organisation
NSFR	Net Stable Funding Ratio
ORSA	Own Risk and Solvency Assessment
PAM	Performance Assessment Matrix
PD	Probability of Default
PFAV	Pension Funds Supervision Ordinance
PP	Percentage points
RWA	Risk Weighted Assets
SASB	Sustainability Accounting Standards Board
SCR	Solvency Capital Requirement
SIB	Systemically Important Banks
SME	Small and medium enterprise
SRP	Supervisory Review Process
StromSTG	Electricity tax law
TCFD	Task Force on Climate-Related Financial Disclosure
UBA	Federal Environment Agency
UN PRI	UN Principles for Responsible Investment
UNEP FI	United Nations Environmental Program Financing Initiative
VAG	Insurance Supervision Act
VersRücklG	Pension Reserve Act
WP	Work Package
WRI	World Resource Institute
WWF	World Wide Fund for Nature

Executive summary

The present report summarizes the methodological approach and the main findings of the **Carbon Bubble project - analyses, economic risks, measures and instruments.**

Background

The Paris Agreement of 2015, signed and ratified by more than 170 countries, and its commitment to limit global warming to well below 2°C, poses new major challenges to the world's economies. With the current energy systems' upheaval towards low-carbon systems and in some cases rapidly growing shares of renewable energy, it is difficult to reliably predict the speed at which fossil fuel production and fossil fuel-dependent sectors and infrastructures will transform. New economic risks and opportunities are emerging. The former could create a so-called **carbon bubble** on the market. Against the background of increasingly ambitious targets to reduce greenhouse gas (GHG) emissions, there is a growing discrepancy between the continued extraction and use of fossil fuel resources and the necessary decarbonization of current energy systems and economies. Experts fear that companies and industries that base current assets and future business success on fossil fuels and fossil fuel dependent investments could be drastically overvalued and burdened with so-called **stranded assets** in the future. The ability to adequately assess new climate-related risks and opportunities is therefore an important step to avoid financial losses and to allocate capital appropriately and efficiently through the financial system.

Climate risks (also referred to as climate risks) can generally be divided into **(a) physical risks and (b) transition risk or carbon risks**[1]. Physical risks are associated with the physical effects of climate change, such as extreme weather events or sea-level rise. Transition or carbon risks, on the other hand, embody society's efforts to reduce GHG emissions and include areas such as policy and regulation, technology, the market and economy, as well as reputational factors. An example of political factors is the introduction of a carbon price, which can increase the carbon risk of emission-intensive sectors.

Both physical risks and carbon risks will have increasingly far-reaching effects on companies and their assets. This report **focuses exclusively on transition and carbon risks**, while physical risks are not considered.

The Project Carbon Bubble

Although carbon risks potentially affect the entire investment chain, they are still poorly understood and rarely integrated into the decision-making of the real and financial economy. In 2015, the G20 questioned whether investments in fossil fuel-dependent infrastructure could lead to global financial risks in the form of a carbon bubble. Numerous international studies followed. Subsequently, the Federal Government, supported by the Federal Environment Agency (UBA), commissioned a consortium of Navigant - A Guidehouse Company, Oxford University (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, University of Zurich (Finexus) and Germanwatch, supported by Allianz Climate Solutions, to analyze and evaluate transitory climate risks in the German financial system.

The aim of the study is (1) to assess the carbon risks in the German economy, (2) to develop a carbon stress testing tool for financial institutions and (3) to develop and assess regulatory instruments to

[1] It is important to note that throughout the report, the terms transition risk and carbon risk are used interchangeably, meaning that they refer to the same risks. The reason for this is that the TCFD (2017) distinguishes climate-related risks into physical risks and transition risks, while the UNEP/FI (2012) distinguishes climate-related risks into physical risks and carbon risks. Both definitions, i.e. transition risks and carbon risks, are essentially referring to four risks: policy and legal, technology, market and economic factors as well as reputational risks.

mitigate carbon risks in the financial markets. This will enable the German government to identify and mitigate carbon risks in the German economy at an early stage and to raise the profile of German financial institutions when assessing carbon risks in individual financial portfolios.

While carbon risks are likely to be material across the entire investment chain, they remain poorly understood and are not integrated into financial decision-making. In 2015, the G20 already questioned whether investments in fossil-fuel-dependent infrastructure could lead to global financial risks in the form of a 'carbon bubble'. As G20 president, the German government by means of the German Environment Agency (UBA) therefore commissioned a consortium of Navigant – A Guidehouse Company, University of Oxford (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, University of Zurich (Finexus) and Germanwatch with the support of Allianz Climate Solutions to analyze and evaluate the risk of a 'carbon bubble' in the German financial system.

The objective was (1) to assess the carbon risks in the German economy, (2) to conduct a carbon stress test for German financial institutions and (3) to develop and evaluate regulatory instruments to mitigate carbon risks in financial markets in Germany and beyond. This will enable the German government to detect, understand and mitigate the carbon risks in the German economy and will support German financial institutions in assessing the carbon risks in individual financial portfolios.

The study is structured into three parts that follow the three-fold objective above. The first part analyses and assesses the impact of carbon risks on the German economy. The second part turns to the perspective of German financial institutions analyzing how financial institutions can identify and assess such carbon risks in their portfolios. As part of this, a carbon quick scan tool (i.e. a carbon stress test tool) is developed. The third and last part builds on the findings of the former two parts and assesses regulatory instruments to mitigate carbon risks in financial markets in Germany and beyond.

Part 1: Carbon risks in the German economy

The **analysis of carbon risks and their impact on the German economy is conducted by assessing the risks of financial losses to sectors that are of central relevance for the German economy and are likely to be vulnerable towards carbon risks**.

Sectors were thus selected based on their economic relevance, their exposure to carbon risks and their vulnerability towards rising production costs. Overall, **23 sectors and/or sub-sectors were selected for an in-depth analysis of carbon risks** including sectors such as animal production, basic metals, basic chemicals, coal, cement & lime, construction, electric power generation, food, paper, glass, land transport, machinery, motor vehicles and warehousing.

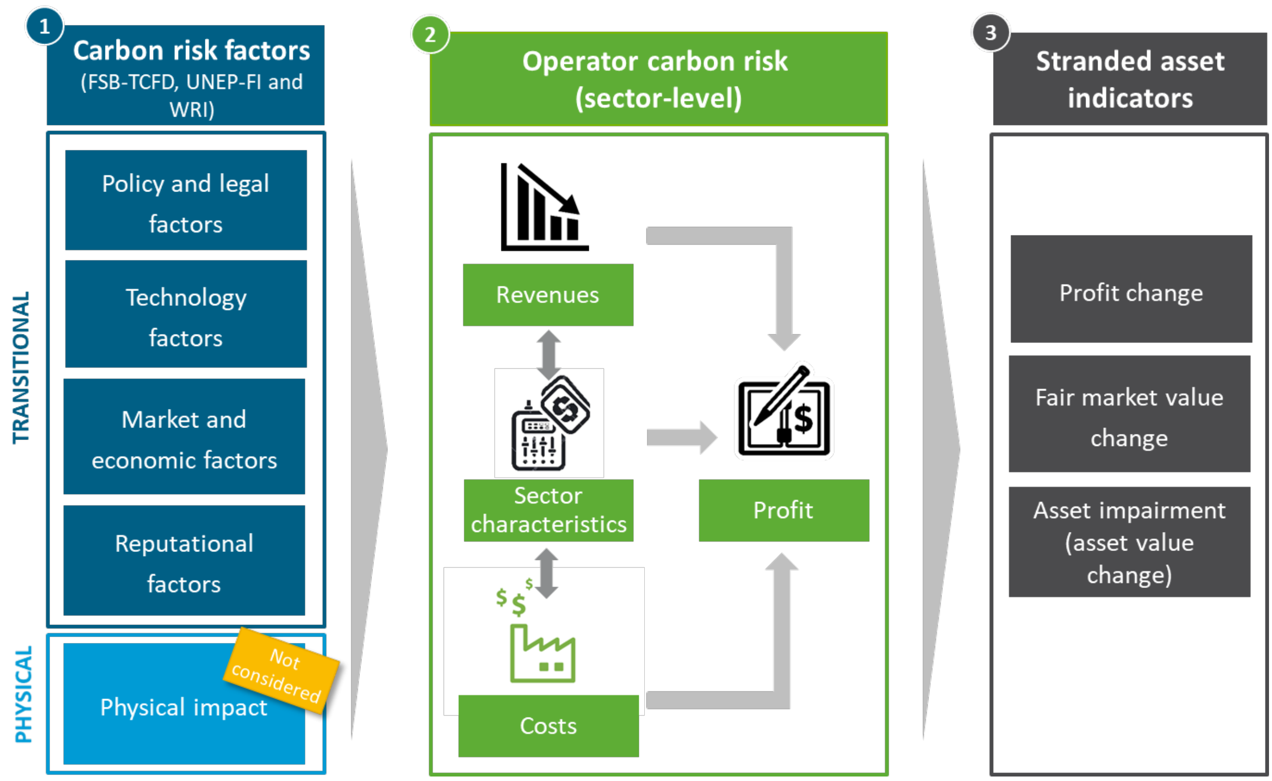
For each **sector**, it was assessed how sensitive the financial performance is to carbon risks **under the IEA** 2 °C and 1.5°C[2] **climate scenarios in 2030, comparing financial performance in 2030 with 2015 by means of a comparative-static analysis**. Examples for such carbon risks under the IEA 2 °C climate scenario were increasing CO2 prices, steep emission caps, reduction in energy consumption and reduction in output. The carbon risks, which also depend on sector characteristics, are derived on sector-level and expressed via so-called stranded asset indicators. The stranded asset indicator "Profit change", for example, estimates the development of profit under the assumption of certain carbon risks. The **financial loss of a sector due to the materialization of carbon risks is used to estimate the sensitivity of a sector towards the low-carbon transition**.

Figure 1-1 illustrates the general methodical framework used to calculate the impacts of carbon risks on the financial performance of sectors. In a first step, carbon risks are derived from the low-carbon

[2] 2 °C Scenario (2DS)

transformation pathways of IEA 2 °C and 1.5 °C climate scenarios. In a second step, the impacts of such carbon risks on the financial performance of sectors, which is from now on also referred to as 'operator carbon risk', are analyzed. In a third step, this impact on the financial performance of sectors is expressed by means of three stranded asset indicators.

Figure 1-1: Methodological approach determining the impact of carbon risks on the financial performance of sectors



Source: Own representation, Navigant – A Guidehouse Company.

The results of our analysis on the impacts of carbon risks on the German economy under the IEA 2 °C climate scenario[3] indicate that the following five German sectors are **exposed to the highest carbon risks and therefore also to a negative profit development (measured by the change in profit margin)** (see Figure 1-2):

- **Coal.** The coal sector is the sector with the most negative profit development between 2015 and 2030. This loss is mainly driven by the decline in revenues by ~68%, which is caused by the significant decline in coal demand under the IEA 2 °C climate scenario as the average coal usage of the economy decreases substantially.
- **Cement & lime.** The cement & lime sector also shows a highly negative profit development between 2015 and 2030. Despite increasing revenues due to higher demand, the sector's profit margin will likely decrease significantly by 2030[4]. The reason for this lies in the significant increase of emission costs and emission abatement costs to comply with the emission cap under the IEA 2 °C climate scenario.
- **Non-RES power.** The non-RES power sector comprises the conventional power plants using coal, gas and petroleum to generate electricity. The profit margin of the sector is expected to decrease by ~13 percentage points resulting from 2015 to 2030. This loss is the result of a

[3] The results of the IEA 1.5 °C climate scenario are not explicitly shown in this summary chapter.

[4] Note that no output price increases are assumed for any sector covered in this study, i.e. real prices are kept constant.

decrease in revenues by 50% due to a reduction in economic output and an increase of emission costs under the IEA 2 °C climate scenario.

- **BF/BOF iron & steel.** The profit margin of the integrated Blast Furnace (BF)/Basic Oxygen Furnace (BOF) route in the iron & steel sector is expected to decrease by ~11 percentage points. The main driver for this is the revenue decrease of ~11% due to less economic output as the BF/BOF iron & steel production route will partially be replaced by the Electric Arc Furnace (EAF) iron & steel production route and an increase of emission costs under the IEA 2 °C climate scenario.
- **Animal Production[5].** Under the IEA 2 °C climate scenario, the profit margin of the animal production sector in Germany is expected to decrease by ~5 percentage points. While the revenue side increases by ~12% due to an increase in economic output, the costs are expected to increase by ~17% with ~10 percentage points stemming from increased economic output and ~7 percentage points from increased emission costs.

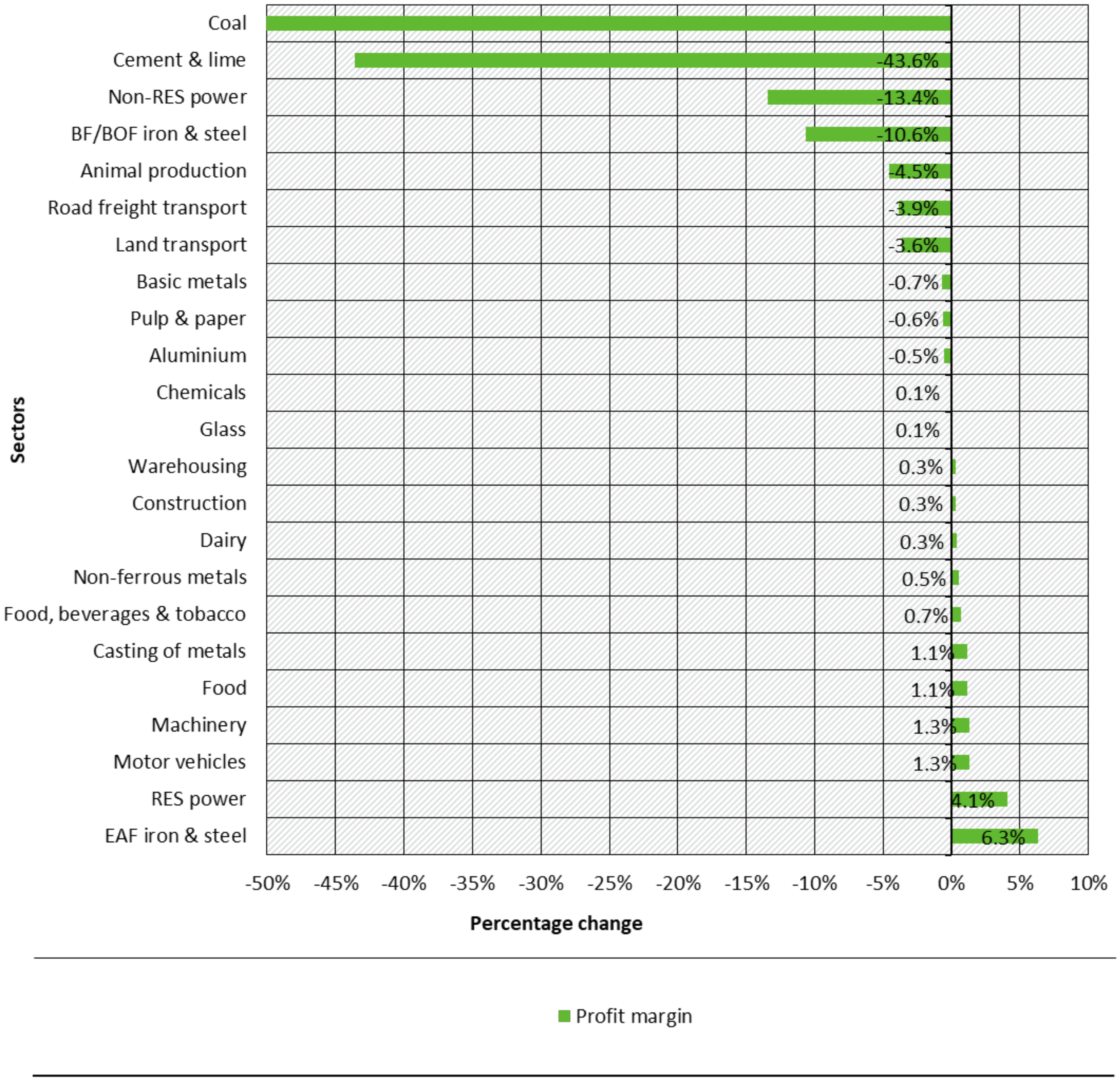
At the same time, there are many sectors with now or very low negative/positive developments in profit under the IEA 2 °C climate scenario. These sectors are basic metals, pulp & paper, aluminium, chemicals, glass, warehousing, construction, dairy, non-ferrous metals, food, beverages & tobacco and casting of metals.

There are two sectors with an extraordinary increase in the profit margin until 2030. These two sectors are EAF iron & steel and RES power. This positive development is caused by the positive impact on production levels driven by economic change.

The overall findings of the impact of carbon risks on the German economy in this report were **largely consistent with the findings of the Moody's Heat Map**, which qualitatively assessed inter alia the credit impact of carbon risks globally for 86 sectors.

[5] It is important to note that we assume a carbon price for the animal production sector even though the sector is currently not covered under the EU emission trading scheme. This is done as otherwise no financial impact on the animal production sector could have been estimated.

Figure 1-2: Change in profit margin in percentage points under the IEA 2°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

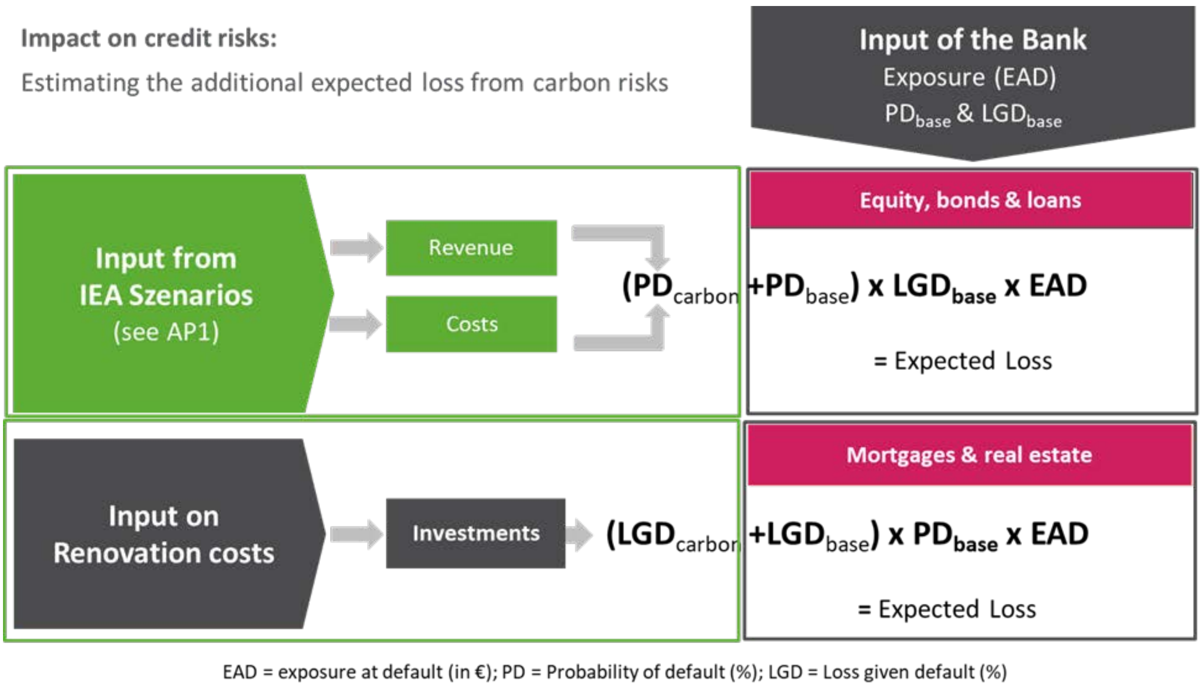
Part 2: Carbon risks in the German financial sector

The identified carbon risks in the real economy in part 1 will potentially trigger risks for the financial sector. For this reason, part 2 of the study analyses the financial relevance of carbon risks in financial markets and develops a carbon quick scan tool for financial institutions. The major objective of the carbon quick scan tool is to identify and assess the possible exposition of German financial institutions towards climate-related financial risks and to support financial institutions with the implementation of the TCFD recommendations.

Firstly, based on an in-depth literature review and the current state of the discussion among policymakers and practitioners, it was assessed how sector-specific carbon risks translate into carbon risks at the level of a financial asset and a portfolio, and how this influences the valuation and the default risk of different financial assets. We found that so far, **existing methods and tools either focus on specific geographies, specific asset classes, specific sectors or specific types of climate-related risks**. We therefore decided to **develop the so-called carbon quick scan tool**, which offers a more comprehensive **approach to assess the climate change impact on financial assets** taking into account different economic sectors, different asset classes and different geographies. The tool encompasses different climate policy scenarios and provides a scenario-based portfolio stress-test model, short "carbon quick scan", in which climate policy scenarios are linked to potential financial impacts for investors. The tool builds on the work of the Task Force on Climate-related Financial Disclosure (TCFD) and is in line with the proposal by UNEP FI and 16 banks to implement the TCFD recommendations. It applies the recommendations to the German context by focusing on the most relevant economic sectors in Germany. In the tool, the following asset classes were included: equity, corporate bonds/loans, sovereign bonds and mortgages. The carbon quick scan tool utilizes the expected loss method to estimate the additional expected loss due to transition risks (see Figure 1-3).

For equity, loans and corporate and sovereign bonds, we determine an additional probability of default (PD), which increases with an increase in transition risk drivers: e.g. increase in costs (CO2 price) and a decline in revenue. For mortgages, an addition loss given default (LDG) rate, which increases with increasing energetic renovation costs, is assumed.

Figure 1-3: Methodical approach to measure carbon risks in the financial sector



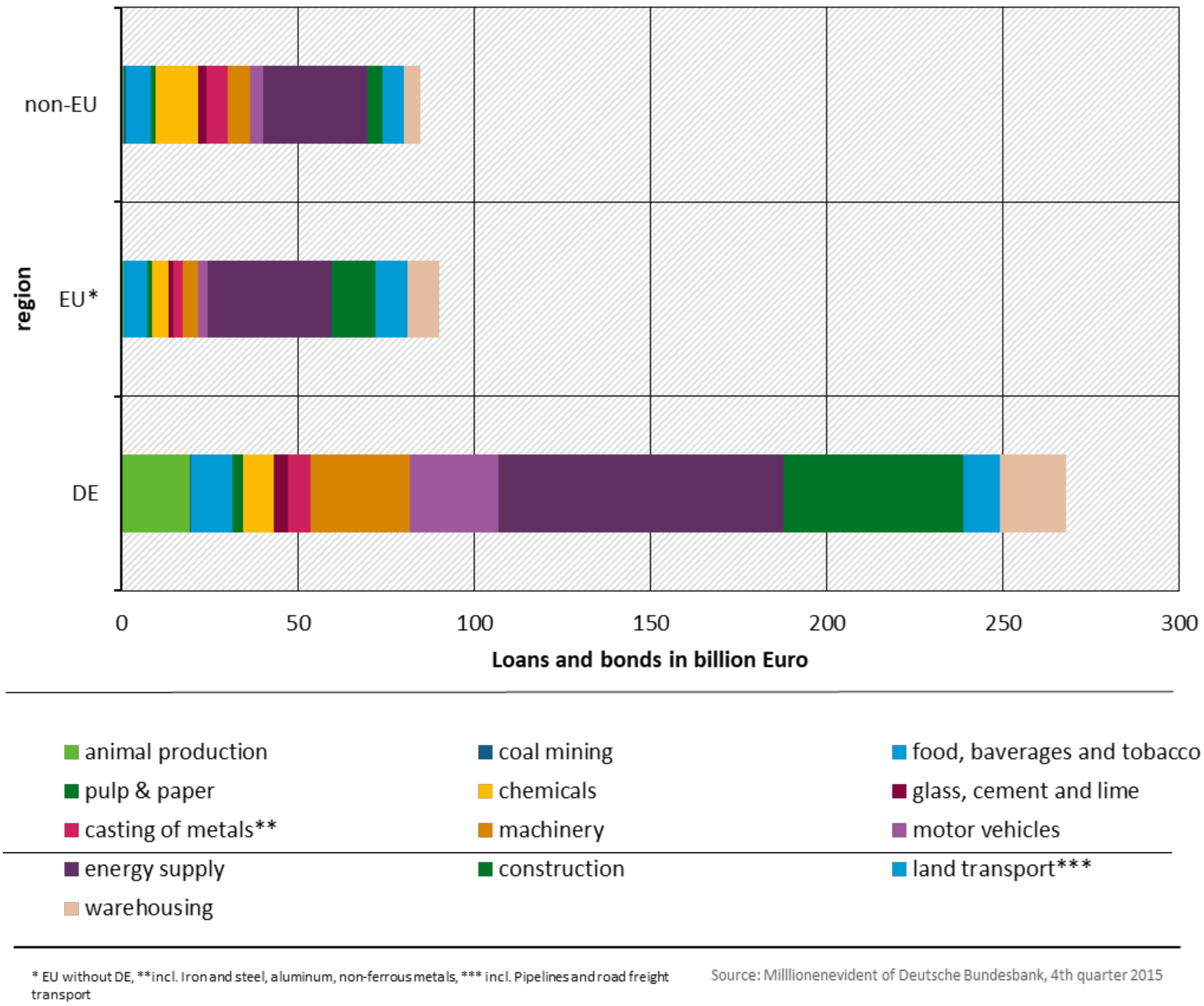
Source: Own representation, Global Climate Forum.

We also evaluated the **asset allocation of different financial institutions in Germany and their exposure to carbon risks.** It was identified that banks are mostly exposed to debt (loans and bonds) and that investment and pension funds are mostly exposed to equity investments.

For loans and bonds of German financial institutions, we found an exposure of 443 billion Euro considering loans and bonds to those sectors covered in part 1 of the study (see Figure 1-4). Half of these 443 billion Euro are issued within Germany. The **most important economic sector**, measured in debt invested, is **electricity production, which also faces high carbon risks. The volume of debt invested into the coal sector, which exhibits very high carbon risks, in contrast, is low. Further relevant sectors in terms of debt volume invested are the machinery, construction, motor vehicle and chemical industry, which however exhibit a comparably low carbon risk**.

Overall, five top sectors in terms of high carbon risk and/or high credit exposure in the German financial market are identified. These are shown in Figure 1-5.

Figure 1-4: Loans and bonds of German banks and insurance companies in emission-intensive sectors in Germany, the EU and non-EU countries (in billion euros)



Source: Own representation, Global Climate Forum, based on “Millionenevidenz” of Deutsche Bundesbank (2015).

Figure 1-5: Top 5 sectors with high carbon risk and high credit exposure

Sector	Transition risk (German economy)	Credit-exposure (German banks)
Coal	High	Low
Non-Res Power	High	High
BF/BOF Iron & Steel	High	Moderate
Cement & Lime	High	Moderate
Transport, Animal Production	Moderate	Moderate

Low Moderate High

Source: Own representation, Global Climate Forum.

A large proportion of the assets held by financial institutions are invested into investment funds and/or issued by other financial institutions through the interbank market, as discussed in Battiston et al (2017). This means that it is important for financial institutions to gain greater insight into the climate-related exposure of their business partners. In this study, however, second round or systemic effects will not be considered further.

Part 3: Integration of carbon risks in the financial markets

Building upon the findings in part 1 and part 2, we conducted a comprehensive analysis of regulatory instruments that are most appropriate for implementation into the German financial market. The analysis aims to support governments and regulators in identifying financial markets risks that are induced by carbon risks at an early stage as well as in developing measures to reduce these carbon risks.

An in-depth literature review in combination with a multi-stage selection process allowed us to identify 21 instruments with high potential in terms of relevance to the German financial context. These instruments were then assessed based on several attributes that focused on an instrument's strengths regarding:

- Supporting Carbon Risk Management in Financial Institutions
- Implementation Feasibility
- Impact on Climate Change

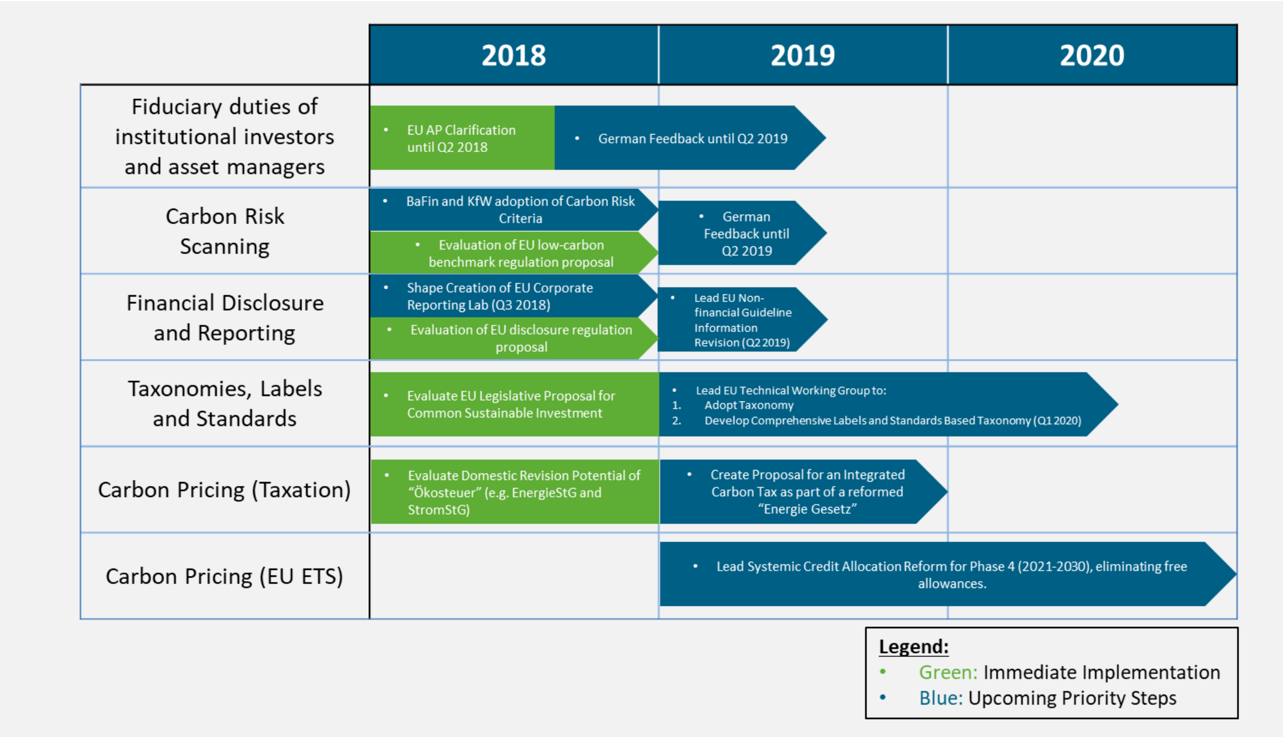
Based on feedback from regulators as well as industry stakeholders, six priority instruments were identified. We conducted an in-depth analysis on this set of instruments, which highlighted opportunities for tailored solutions relevant to the unique specificities in the German financial sector. The analysis informed a recommended roadmap towards implementation of these tools in the German context (see Figure 1-6). The priority instruments and core recommendations are as follows:

- **Fiduciary duties of institutional investors and asset managers**:
  Germany should extend or specify the fiduciary obligations in order to include concrete effects of an investment on climate change/climate protection and an appropriate consideration of carbon risks. The national fiduciary duties can be adjusted by incorporating elements from the BaFin MaRisk, the German Corporate Governance Index and the EU Action Plan. A strict interpretation and more ambitious implementation of non-financial reporting at EU level 2014/95/EU (CSR-RUG) would create additional transparency. The legal liability regulations in

the event of a breach of the consideration of climate risks in the fiduciary duties should be extended.

- **Carbon Risk Scanning**:
  Germany should join initiatives to investigate and actively promote climate-related scenario analyses and stress tests, in particular via the European Central Bank (ECB) (including the European Systemic Risk Board (ESRB)) and the European Banking Authority (EBA). This requirement is in line with the recommendations of the EU High Level Expert Group on Sustainable Finance (HLEG). Another possibility is to strengthen coordination with the German regulatory authority BaFin and KfW in order to create a joint stress testing framework in Germany.
- **Financial Disclosure and Reporting**:
  Germany should initiate an international working group and work towards concrete results to promote convergence and wider adoption of disclosure within an obligatory international supervisory framework. This should be based on the recommendations of the TCFD, the Financial Stability Board (FSB), the EU Action Plan (EU-AP, Action 9) or the French Energy Turnaround Act (Art. 173). This should ensure uniformity of the different approaches and better comparability. The TCFD recommendations and the proposals of the EU Disclosure Regulation (EC, 2018/0179 (COD)) should serve as the main templates.
- **Taxonomies, Labels and Standards**:
  Germany should promote the development of a common taxonomy at EU level (EU-AP Action 1 & 2) in cooperation with industry leaders on ESG assessments such as the UN Principles of Responsible Investment (PRI). The key here is to develop a dynamic, forward-looking approach by anchoring Paris-compatible transformation paths that will enable the development of ESG-compatible business models and products within the paths agreed with the climate targets. The development of EU taxonomy templates should be accompanied and commented by Germany together with the private sector such as Deutsche Börse and ESG analysts.
- **Carbon Pricing (Carbon Taxation):**
  Germany should bundle the German "eco-tax(es)" in a common framework, adapt it to the climate targets and expand it in order to have a leverage effect on the financial sector and thus achieve the same results as a pure carbon tax.
- **EU Emission Trading Scheme:**
  Germany should use its political influence to spur European decision-makers and partners on the revision of the EU ETS system and should work continuously at European level to raise the ambition level of the EU ETS in Phase 4 (2021-2030).

Figure 1-6: Recommended instrument implementation timeline to integrate carbon risks into financial markets



Source: Own representation, Oxford University.

Zusammenfassung

Die vorliegende Zusammenfassung fasst den methodischen Ansatz und die Ergebnisse des Projekts **Carbon Bubble – Analysen, wirtschaftliche Risiken, Maßnahmen und Instrumente** im Kontext der aktuellen Diskussion zum Thema Kohlenstoffrisiken zusammen.

Hintergrund

Das Pariser Übereinkommen von 2015, welches von mehr als 170 Ländern unterzeichnet und ratifiziert wurde, und seine Verpflichtung, die Erderwärmung auf deutlich unter 2 °C zu begrenzen, stellt die Volkswirtschaften der Welt vor neue große Herausforderungen. Da sich die heutigen Energiesysteme mit teilweise stark wachsenden Anteilen an erneuerbaren Energien im Umbruch befinden, ist die Geschwindigkeit der Transformation fossiler Brennstofferzeugung und der von fossilen Brennstoffen abhängiger Sektoren und Infrastrukturen nur schwer abzuschätzen. Neue wirtschaftliche Risiken und Chancen entstehen. Erstere könnten eine sogenannte **Carbon Bubble** (Kohlenstoffblase) am Markt entstehen lassen. Vor dem Hintergrund immer ehrgeizigerer Ziele zur Reduzierung des Ausstoßes von Treibhausgas (THG)-Emissionen besteht eine wachsende Diskrepanz zwischen der weiteren Förderung und Nutzung fossiler Brennstoffressourcen und der notwendigen Dekarbonisierung der gegenwärtigen Energiesysteme und Volkswirtschaften. Experten befürchten, dass Unternehmen und Branchen, die aktuelle Vermögenswerte und künftige Geschäftserfolge auf fossile Brennstoffe sowie auf von fossilen Brennstoffen abhängige Investitionen stützen, drastisch überbewertet und mit sogenannten **Stranded Assets** belastet sein könnten. Die Möglichkeit, neue klimabedingte Risiken und Chancen adäquat einschätzen zu können, ist daher ein wichtiger Schritt, um finanzielle Verluste zu vermeiden und Kapital angemessen und effizient über das Finanzsystem zu allokieren.

Klimarisiken lassen sich im Allgemeinen in **(a) physische Risiken und (b) Transitions- bzw. Kohlenstoffrisiken**[6] unterteilen. Physische Risiken sind mit den physischen Auswirkungen des Klimawandels, beispielsweise in Form von Extremwettereignissen oder dem Meeresspiegelanstieg, verbunden. Kohlenstoffrisiken dagegen verkörpern das Bemühen der Gesellschaft, THG-Emissionen auf nahezu Null zu reduzieren, und umfassen etwa Bereiche wie Politik und Recht, Technologie, Markt und Wirtschaft sowie Reputation. Ein Beispiel für politische Faktoren ist die Einführung eines CO_2-Preises, welche das Kohlenstoffrisiko eines emissionsintensiven Sektors erhöhen kann.

Physische Risiken und Kohlenstoffrisiken werden sich zukünftig immer weitreichender auf Unternehmen und deren Vermögenswerte auswirken. Der vorliegende Bericht konzentriert sich ausschließlich auf **Transitions- bzw. Kohlenstoffrisiken**, während physische Risiken nicht berücksichtigt werden.

Das Projekt Carbon Bubble

Obwohl Kohlenstoffrisiken potentiell die gesamte Investitionskette betreffen, sind diese nach wie vor schlecht verstanden und selten in die Entscheidungsfindung der Real- und Finanzwirtschaft integriert. 2015 stellten die G20 in Frage, ob Investitionen in von fossilen Brennstoffen abhängige Infrastruktur zu globalen Finanzrisiken in Form einer Kohlenstoffblase führen könnten. Es folgten zahlreiche internationale Studien. Daraufhin beauftragte die Bundesregierung mit Unterstützung des Umweltbundesamtes (UBA) ein **Konsortium aus Navigant - A Guidehouse Company, Oxford Universität (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, Universität Zürich (Finexus) und Germanwatch mit Unterstützung von Allianz Climate Solutions**, die transitorischen Klimarisiken im deutschen Finanzsystem zu analysieren und zu evaluieren.

Ziel der Untersuchung ist es (1) die Kohlenstoffrisiken in der deutschen Wirtschaft zu bewerten, (2) ein Carbon-Stresstest-Tool für Finanzinstitute zu entwickeln und (3) regulatorische Instrumente zur Eindämmung von Kohlenstoffrisiken an den Finanzmärkten zu entwickeln und zu bewerten. Damit kann die Bundesregierung Kohlenstoffrisiken in der deutschen Wirtschaft frühzeitig erkennen und abmildern sowie die Aufmerksamkeit deutscher Finanzinstitute bei der Bewertung von Kohlenstoffrisiken in einzelnen Finanzportfolios erhöhen.

Die Studie besteht aus drei Teilen, die den drei oben genannten Zielen folgen. Der erste Teil analysiert und bewertet die Auswirkungen von Kohlenstoffrisiken auf die deutsche Wirtschaft auf Basis verschiedener Szenarien der Internationalen Energieagentur IEA. Im zweiten Teil wird eine Methode zur Identifizierung und Bewertung von Kohlenstoffrisiken im Finanzsektor entwickelt und vorgestellt. Im Rahmen des Projekts wurde ein **Klimarisikoscanner** entwickelt. Im dritten Teil werden **regulatorische Instrumente** zur Eindämmung von Kohlenstoffrisiken an den Finanzmärkten vorgestellt und bewertet. Daraus werden abschließend Handlungsempfehlungen abgeleitet.

Teil 1: Kohlenstoffrisiken in der deutschen Wirtschaft

Die Analyse von Kohlenstoffrisiken und deren Auswirkungen auf die deutsche Wirtschaft wird in Form einer Bewertung der finanziellen Risiken für diejenigen Sektoren durchgeführt, die für die deutsche Wirtschaft von zentraler Bedeutung sind und die für Kohlenstoffrisiken anfällig sein dürften.

Die Sektoren wurden auf Basis ihrer wirtschaftlichen Relevanz, ihrer Kohlenstoffintensität in der Produktion und ihrer Anfälligkeit gegenüber steigenden Produktionskosten ausgewählt. Insgesamt **wurden 23 Sektoren und Teilsektoren für eine vertiefte Analyse ihrer Kohlenstoffrisiken**

[6] Es ist wichtig zu beachten, dass die Begriffe Transitionsrisiko und Kohlenstoffrisiko im Rahmen des Projekts synonym verwendet werden, was bedeutet, dass sie sich auf dieselben Risiken beziehen. Der Grund dafür ist, dass die TCFD (2017) klimabedingte Risiken nach physischen Risiken und Transitionsrisiken unterscheidet, während das UNEP/FI (2012) klimabedingte Risiken in physische Risiken und Kohlenstoffrisiken unterteilt.

ausgewählt, darunter Branchen wie Tierhaltung, Metallerzeugung und -bearbeitung, Herstellung von chemischen Erzeugnissen, Kohlebergbau, Herstellung von Zement, Kalk und gebranntem Gips, Baugewerbe, Elektrizitätsversorgung, Herstellung von Nahrungsmitteln, Herstellung von Papier und Pappe, Herstellung von Glas- und Glaswaren, Landverkehr, Maschinenbau, Herstellung von Kraftwagen und Kraftwagenteilen und Lagerwesen.

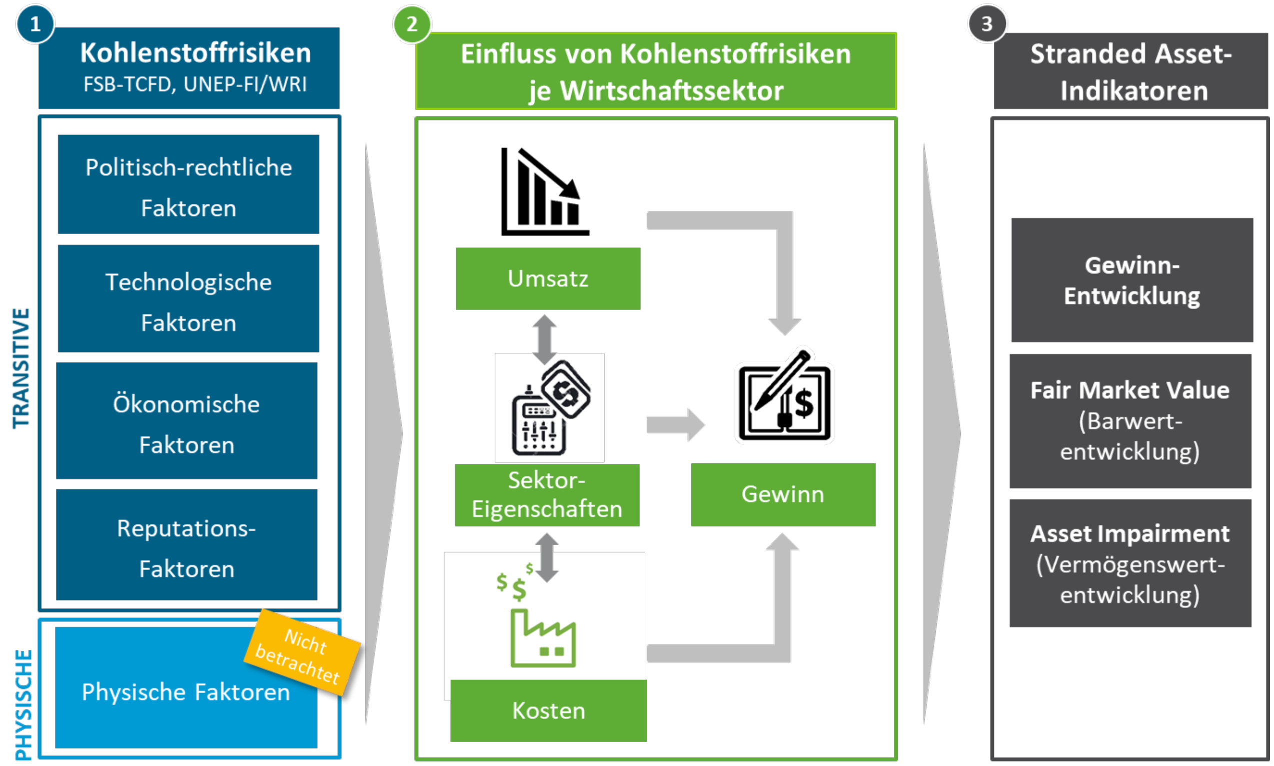
Für jeden Sektor wurde bewertet, wie sensibel deren finanzielle Performance auf Kohlenstoffrisiken **unter dem IEA** 2 °C[7] bzw. 1,5 °C[8] **Klimaszenario im Jahr 2030 im komparativ-statischen Vergleich zum Jahr 2015** reagiert. Beispiele für solche Kohlenstoffrisiken sind steigende CO_2-Preise, Emissionsgrenzwerte und ein Rückgang der Nachfrage nach Energie und Produkten mit einer emissionsintensiven Herstellung. Abhängig von der Anpassungsfähigkeit eines Sektors werden die Kohlenstoffrisiken auf Sektorenebene berechnet und in sogenannte Stranded Asset Indikatoren übersetzt: so schätzt der Stranded Asset Indikator „Gewinnentwicklung“ zum Beispiel die Entwicklung von Gewinnen aufgrund von Kohlenstoffrisiken ab. **Der finanzielle Verlust bzw. Gewinn eines Sektors infolge einer potenziellen Materialisierung von Kohlenstoffrisiken wird verwendet, um die Sensibilität eines Sektors gegenüber der Dekarbonisierung abzuschätzen.**

Abbildung 1-1 veranschaulicht die grundlegende Methodik zur Ermittlung des Einflusses von Kohlenstoffrisiken auf die finanzielle Performance von Wirtschaftssektoren. In einem ersten Schritt werden unterschiedliche Arten von Kohlenstoffrisiken basierend auf den Transformationspfaden unter dem 2 °C bzw. 1,5 °C Klimaszenario der IEA identifiziert. In einem zweiten Schritt wird der Einfluss dieser Kohlenstoffrisiken auf die finanzielle Performance einzelner Wirtschaftssektoren untersucht. In einem dritten Schritt wird der Einfluss auf die finanzielle Performance von Sektoren durch sogenannte Stranded Asset Indikatoren ausgedrückt.

[7] Beyond 2 °C Scenario (B2DS)

[8] 2 °C Scenario (2DS)

Abbildung 1-1: Methodischer Ansatz zur Ermittlung des Einflusses von Kohlenstoffrisiken auf die finanzielle Performance von Wirtschaftssektoren



Quelle: Eigene Darstellung, Navigant - A Guidehouse Company.

Die Ergebnisse der Analyse der Auswirkungen von Kohlenstoffrisiken auf Wirtschaftssektoren in Deutschland unter dem 2 °C Klimaszenario der IEA[9] zeigen beispielhaft, dass **die folgenden fünf deutschen Branchen den höchsten Kohlenstoffrisiken und damit auch einer negativen Gewinnentwicklung (gemessen an der Änderung der Profitmarge) ausgesetzt sind** (siehe Abbildung 1-2):

- **Kohle.** Der Kohlesektor in Deutschland ist der Sektor mit der negativsten Gewinnentwicklung zwischen 2015 und 2030. Getrieben wird dieser Verlust vor allem durch einen starken Umsatzrückgang in Höhe von 68 %, der durch den deutlichen Rückgang der Kohlenachfrage im Rahmen des IEA 2 °C Klimaszenarios verursacht wird.
- **Zement & Kalk.** Der Sektor Zement & Kalk in Deutschland weißt ebenfalls eine stark negative Gewinnentwicklung zwischen 2015 und 2030 auf. Trotz steigender Umsätze aufgrund einer zunehmenden Nachfrage, wird die Profitmarge im Jahr 2030 stark sinken[10]. Der Grund dafür liegt in der deutlichen Erhöhung der Emissionskosten aufgrund steigender CO_2-Preise sowie der Kosten für die Minderung der Emissionen, um die Emissionsobergrenze im Rahmen des IEA 2 °C Klimaszenarios zu erfüllen.
- **Nicht-erneuerbare Stromversorgung.** Die nicht-erneuerbare Stromversorgung umfasst die konventionellen Kraftwerke, die Kohle, Gas und Erdöl zur Stromerzeugung nutzen. Die Profitmarge des Sektors wird von 2015 bis 2030 um ~13 Prozentpunkte sinken. Dies ist das Ergebnis eines Umsatzrückgangs um 50 % aufgrund einer Verringerung der Nachfrage nach

[9] Die Ergebnisse unter dem 1,5 °C Klimaszenario werden in dieser Zusammenfassung nicht explizit aufgeführt.

[10] Hierbei ist wichtig zu beachten, dass im Rahmen dieser Studie keine Preiserhöhungen verkaufter Produkte der untersuchten Branchen angenommen werden, i.e. reale Preise sind konstant.

konventionellem Strom sowie einer Erhöhung der Emissionskosten im Rahmen des IEA 2 °C Klimaszenarios.

- **Integrierte Hochofen-Route (BF/BOF) Eisen & Stahl.** Die Profitmarge der integrierten Hochofenroute (Blast Furnace (BF)/Basic Oxygen Furnace (BOF)) im Eisen- und Stahlsektor wird von 2015 bis 2030 voraussichtlich um ~11 Prozentpunkte fallen. Haupttreiber dafür ist ein Umsatzrückgang von 11 % aufgrund geringeren Produktionsoutputs, da die Produktionsroute BF/BOF Eisen & Stahl teilweise durch die Eisen- und Stahlproduktionsroute des Elektrolichtbogenofens (Electric Arc Furnace (EAF)) ersetzt wird. Zudem steigen die Emissionskosten im Rahmen des IEA 2 °C Klimaszenarios signifikant.
- **Tierhaltung.**[11] Unter dem IEA 2 °C Klimaszenario wird die Profitmarge des Sektors Tierhaltung voraussichtlich um ~5 Prozentpunkte sinken. Während die Einnahmeseite aufgrund der gestiegenen Wirtschaftsleistung um 12 % steigt, werden die Kosten voraussichtlich um 17 % zunehmen, wobei hiervon 10 Prozentpunkte aus dem erhöhten Produktionsoutput und 7 Prozentpunkte aus erhöhten Emissionskosten resultieren.

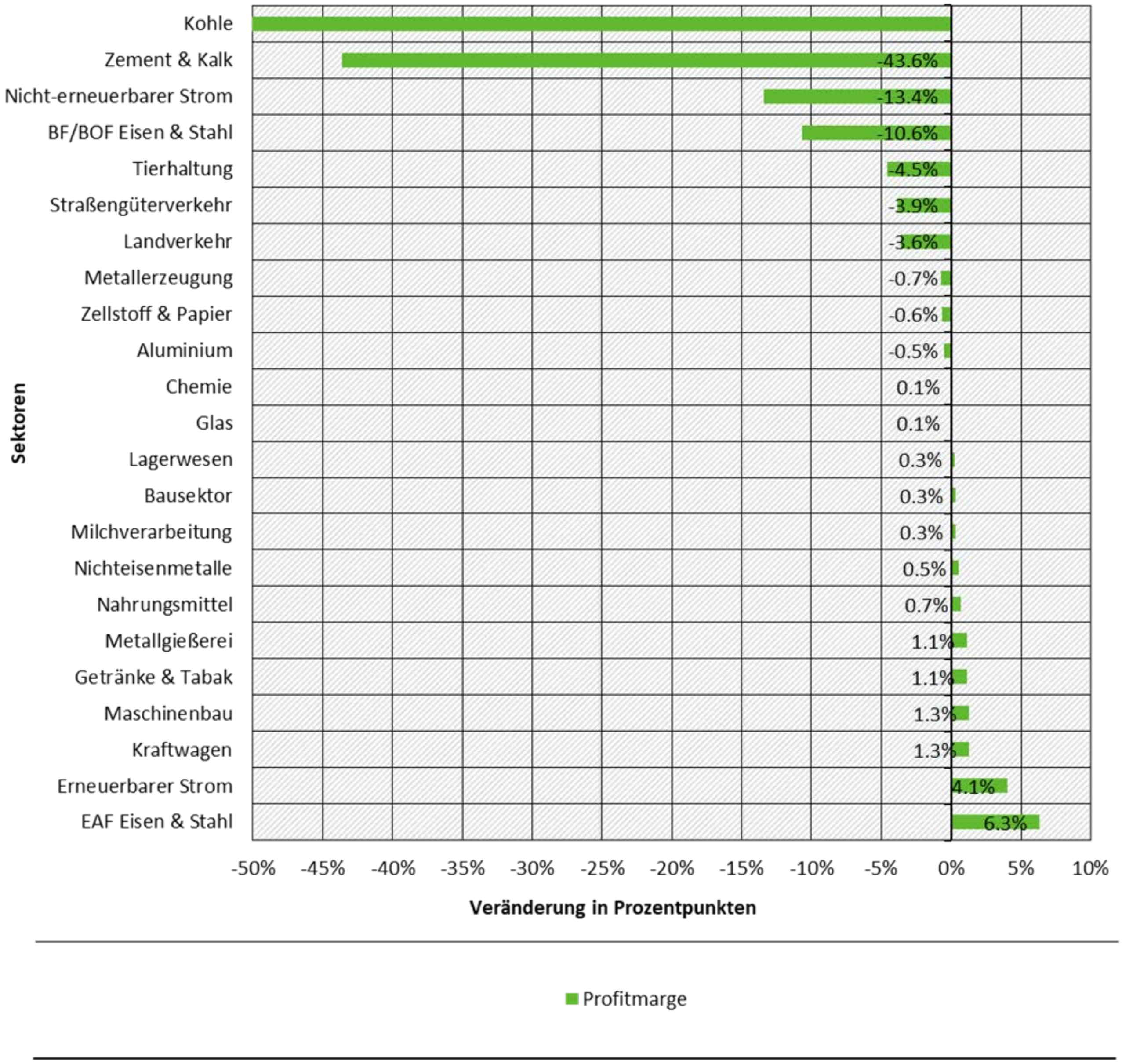
Gleichzeitig gibt es mehrere Sektoren, deren Gewinn nicht oder nur geringfügig negativ/positiv von den Änderungen unter dem IEA 2 °C Klimaszenario betroffen sind. Diese Sektoren sind Metallerzeugung, Zellstoff und Papier, Aluminium, Chemikalien, Glas, Lagerwesen, der Bausektor, Milchverarbeitung, Nichteisenmetalle, Lebensmittel, Getränke & Tabak und Metallgießerei.

Zwei Sektoren profitieren hingegen stark; für sie ergibt die Szenarienanalyse eine starke Erhöhung des Gewinns bis 2030. Diese sind die Sektoren EAF Eisen & Stahl und erneuerbarer Strom. Die positive Entwicklung wird im Wesentlichen durch die positiven Auswirkungen des wirtschaftlichen Wandels auf das Produktionsniveau der jeweiligen Sektoren verursacht.

Die beschriebenen Ergebnisse stehen **im Wesentlichen im Einklang mit den Ergebnissen der Moody`s Heat Map**, die unter anderem die Kreditauswirkungen von Kohlenstoffrisiken weltweit auf 86 Branchen qualitativ bewertet.

[11] Für die Branche Tierhaltung ist zu beachten, dass im Rahmen dieser Studie ein verbindlicher CO2-Preis angenommen wurde, trotz der Tatsache, dass diese Branche derzeit nicht im EU Emissionshandel einbezogen wird. Dies wurde getan, da ansonsten keine finanziellen Auswirkungen von klimabedingten Transitionsrisiken für diese Branche hätten geschätzt werden können.

Abbildung 1-2: Änderung der Profitmarge in Prozentpunkten im Rahmen des IEA 2 °C Klimaszenarios, 2015 und 2030 im Vergleich



Quelle: Eigene Darstellung, Navigant - A Guidehouse Company.

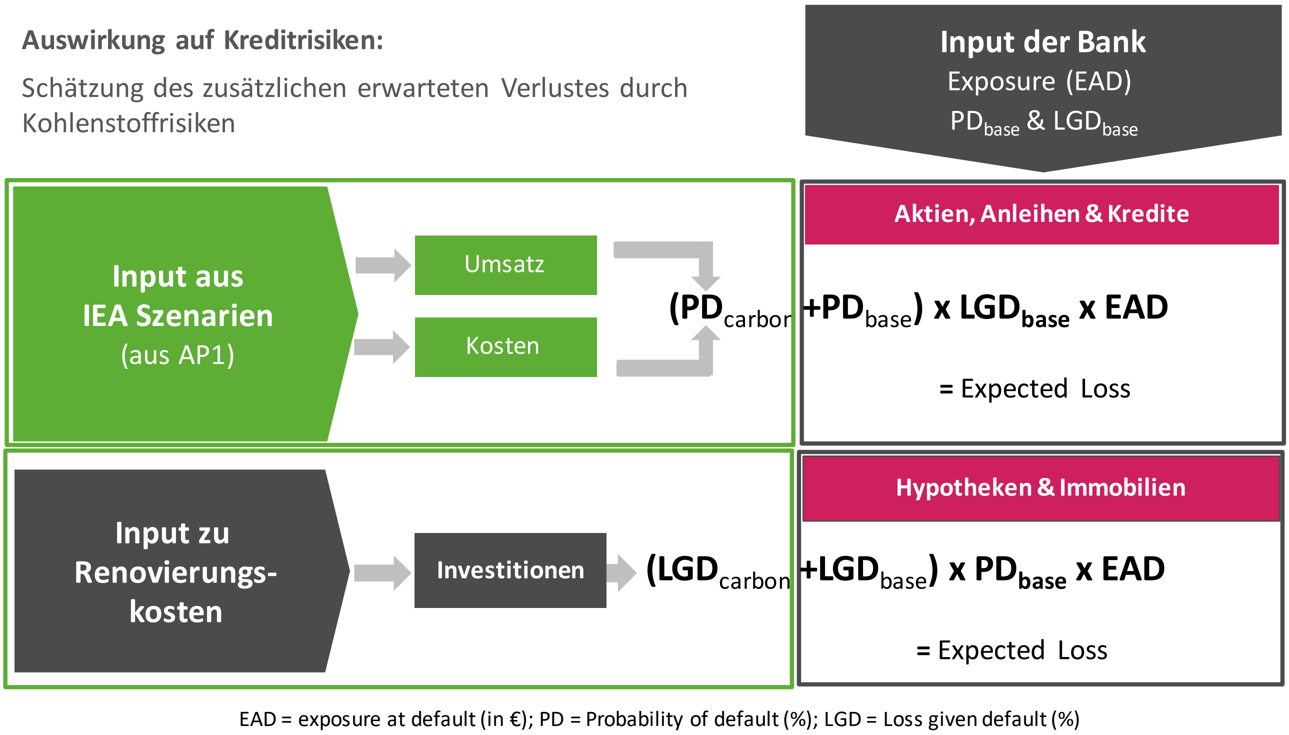
Teil 2: Kohlenstoffrisiken für die deutsche Finanzwirtschaft

Die in Teil 1 identifizierten Kohlenstoffrisiken in der Realwirtschaft können potenziell auch Risiken für die Finanzwirtschaft bedeuten. Daher wird in Teil 2 ein Ansatz zur Messung der finanziellen Relevanz von Kohlenstoffrisiken für den Finanzmarkt untersucht und ein Klimarisikoscanner entwickelt. Hauptziel des zur Verfügung gestellten Tools ist es, mögliche Expositionen deutscher Finanzinstitute gegenüber klimabedingten finanziellen Risiken zu identifizieren und zu bewerten und Finanzinstitute bei der Umsetzung der Empfehlungen der Task Force on Climate-related Financial Disclosures (TCFD) zu unterstützen.

Zunächst wurde eine ausführliche Literaturanalyse zu bereits existierenden Methoden erstellt. Es wurde festgestellt, **dass sich die bestehenden Methoden und Werkzeuge bisher entweder auf bestimmte geographische Regionen, spezifische Anlageklassen, einzelne Sektoren oder spezifische Arten von klimabedingten Risiken konzentrieren.** Bei der Entwicklung **des Klimarisikoscanners berücksichtigen wir demgegenüber eine Vielzahl wirtschaftlicher Sektoren und**

Anlageklassen. Das Tool ist ein Szenarien-basiertes Portfolioanalysemodell, in dem klimapolitische Szenarien mit möglichen finanziellen Auswirkungen für Investoren verknüpft sind. Das Tool steht im Einklang mit dem Vorschlag der TCFD sowie der Arbeitsgruppe von UNEP FI und 16 Banken zur Umsetzung der TCFD-Empfehlungen. Es wendet die Empfehlungen auf den deutschen Kontext an und konzentriert sich auf die relevantesten Wirtschaftssektoren in Deutschland. Folgende Anlageklassen wurden aufgenommen: Aktien, Unternehmensanleihen, Kredite, Staatsanleihen und Hypotheken. Der Klimarisikoscanner beruht auf der Berechnung des „Erwarteten Verlusts“ und ermittelt den zusätzlichen erwarteten Verlust aufgrund von Kohlenstoffrisiken, wie in Abbildung 1-3 dargestellt. Bei Aktien, Krediten sowie Unternehmens- und Staatsanleihen wird eine zusätzliche Ausfallwahrscheinlichkeit (Probability of Default - PD) angenommen. Diese steigt bei einer Verstärkung der Kohlenstoffrisikotreiber, wie z. B. einer Kostensteigerung (CO_2-Preis) und einem Umsatzrückgang. Bei Hypotheken wird eine zusätzliche Verlustquote (Loss Given Default – LGD) angenommen, welche mit dem Anstieg der energetischen Sanierungskosten zunimmt.

Abbildung 1-3: Methodischer Ansatz der Risikoermittlung in der Finanzwirtschaft



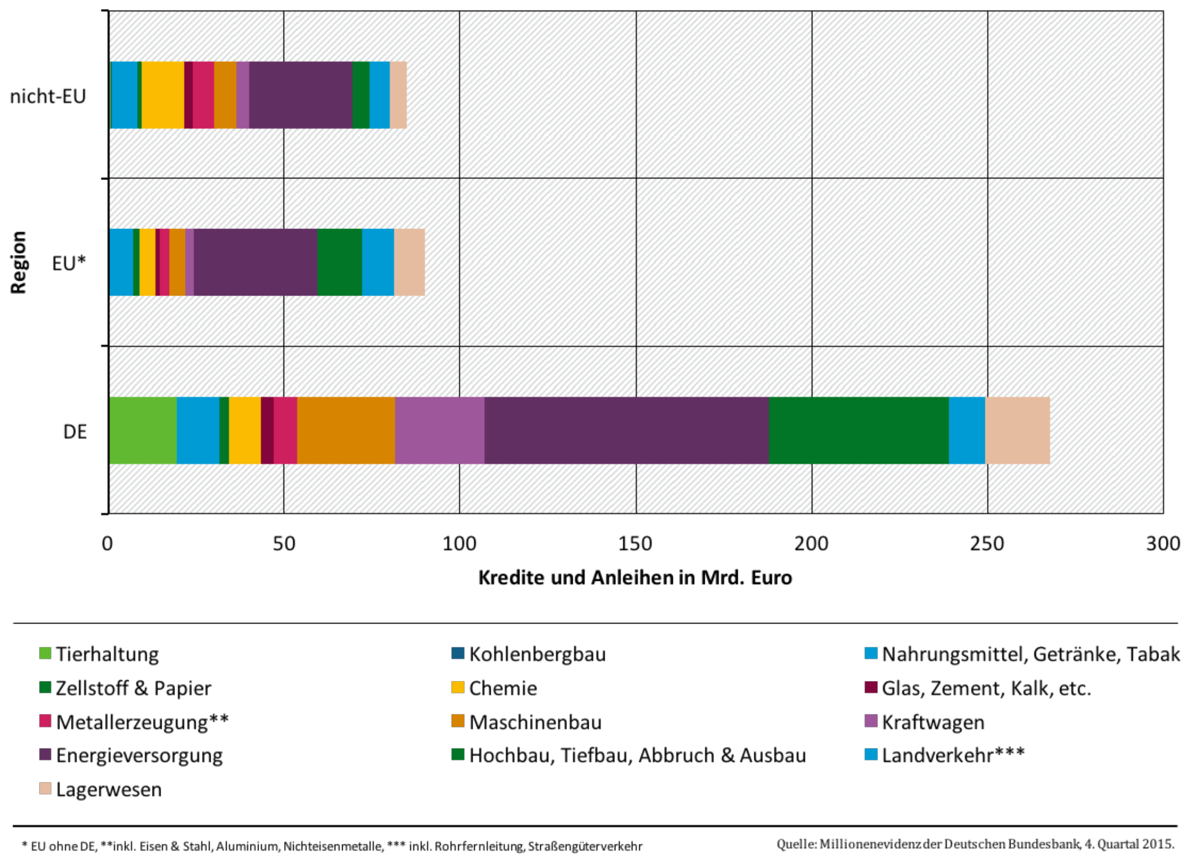
Quelle: Eigene Darstellung, Global Climate Forum.

Bei einer generellen Betrachtung der Finanzanlagen deutscher Institute wird deutlich, dass Banken vor allem über Fremdkapitalbeteiligungen (Kredite und Anleihen) exponiert sind und Investment- und Pensionsfonds hingegen stärker über Eigenkapitalbeteiligungen exponiert sind.

Eine Untersuchung der vergebenen Kredite und Anleihen deutscher Finanzinstitute hat eine Risikoexposition (Exposure) in Höhe von **443 Mrd. Euro** gegenüber den in Teil 1 identifizierten Sektoren ergeben (ca. die Hälfte davon in Deutschland), wie in Abbildung 1-4 zu sehen. **Der wichtigste Wirtschaftszweig**, gemessen an diesen Fremdkapitalbeteiligungen, ist die **Stromversorgung, welche gleichzeitig ein hohes Kohlenstoffrisiko aufweist. Die Fremdkapitalbeteiligungen im Kohlesektor, welcher ein sehr hohes Kohlenstoffrisiko trägt, sind im Gegensatz hierzu gering. Weitere relevante Sektoren sind der Maschinenbau, das Baugewerbe, die Fahrzeugindustrie sowie die chemische Industrie, welche ein vergleichsweise niedrigeres Kohlenstoffrisiko haben.**

Aus dieser Analyse lassen sich schließlich die **Top 5 Sektoren mit hohem Kohlenstoffrisiko und/oder hoher Risikoexposition aus Sicht des deutschen Finanzmarktes** ableiten. Diese werden in Abbildung 1-5 dargestellt.

Abbildung 1-4: Bankkredite und Anleihen deutscher Banken und Versicherungen in emissionsintensiven Sektoren in Deutschland, der EU und nicht-EU Ländern (in Mrd. Euro)



Quelle: Eigene Darstellung, Global Climate Forum, basierend auf der Millionenevidenz der Deutschen Bundesbank.

Abbildung 1-5: Top 5 Sektoren mit hohem Kohlenstoffrisiko und deren Kredit- Exposition (Exposure)

Sector	Transitionsrisiko (Dt. Wirtschaft)	Kredit-Exposure (Dt. Banken)
Kohle	Hoch	Gering
Stromerzeugung	Hoch	Hoch
Eisen & Stahl	Hoch	Moderat
Zement & Kalk	Hoch	Moderat
Landverkehr, Tierhaltung	Moderat	Moderat

Gering Moderat Hoch

Quelle: Eigene Darstellung, Global Climate Forum.

Ein großer Teil der Vermögenswerte, die von Finanzinstituten gehalten werden, wird über Beteiligungen an Investmentfonds und den Interbankenmarkt durch andere Finanzinstitute ausgegeben, wie in Battiston et al (2017) diskutiert. Dies bedeutet, dass es für die Finanzinstitute ebenso wichtig ist, verstärkt Einblicke in die klimabedingte Exposition ihrer Geschäftspartner zu gewinnen. An dieser Stelle werden Zweitrunden oder systemische Effekte nicht weiter betrachtet.

Teil 3: Integration von Kohlenstoffrisiken an den Finanzmärkten

Aufbauend auf den Erkenntnissen aus Teil 1 und Teil 2 wurde eine umfassende Analyse derjenigen Regulierungsinstrumente durchgeführt, die der Integration von Kohlenstoffrisiken an den Finanzmärkten dienen und die für eine Umsetzung im deutschen Finanzmarkt am geeignetsten erscheinen. Dies soll Regierungen und Regulierern helfen, durch Kohlenstoffrisiken hervorgerufene Finanzmarktrisiken früh zu erkennen und Maßnahmen zur Reduktion dieser Risiken zu entwickeln.

Es wurden 21 Instrumente mit hohem Potenzial für die erfolgreiche Einführung in den deutschen Finanzmarktkontext identifiziert. Diese Instrumente wurden anhand mehrerer Kriterien bewertet:

- Unterstützung des Kohlenstoffrisikomanagements in Finanzinstituten
- Implementierbarkeit
- Auswirkungen auf den Klimaschutz

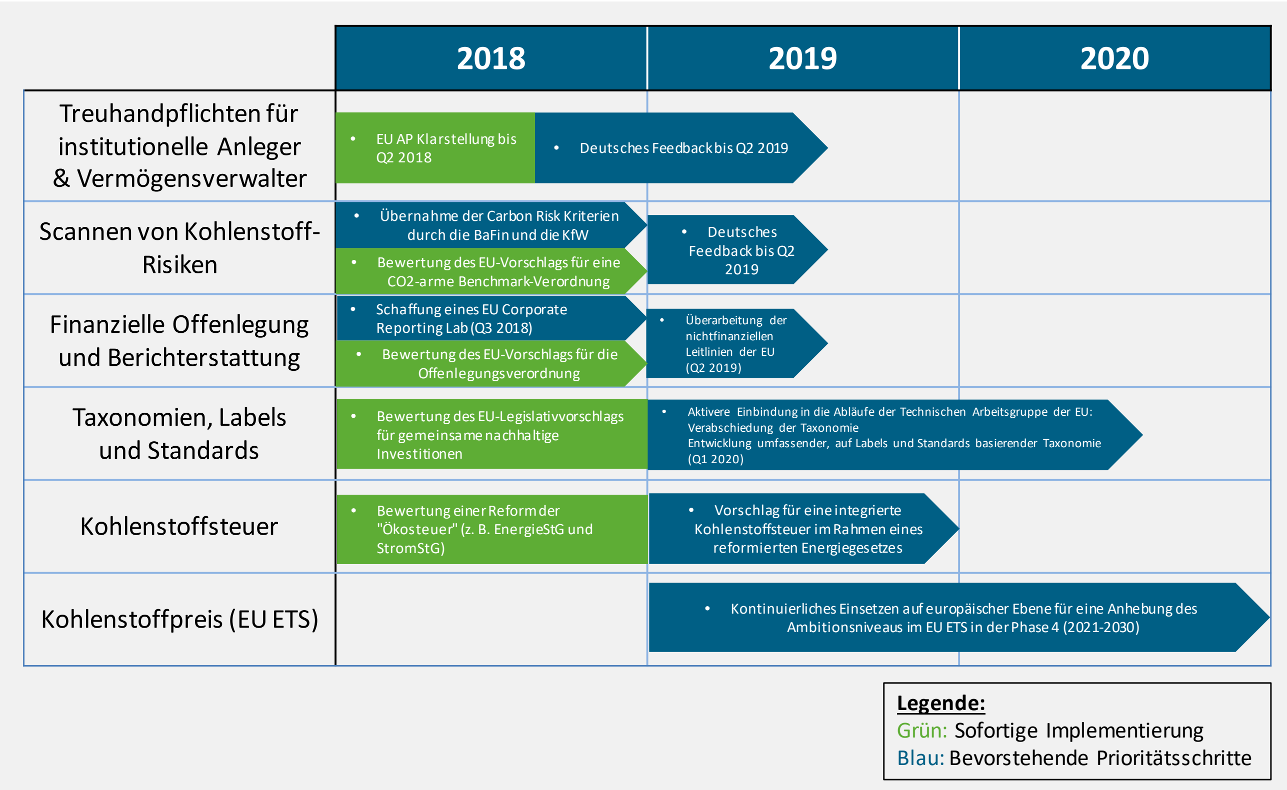
Anhand der Rückmeldungen von Regulierungsbehörden und Akteuren der Industrie wurden sechs prioritäre Regulierungsinstrumente identifiziert und im Kontext des deutschen Finanzsektors vertiefend analysiert. Die Analyse resultierte in einem Fahrplan für die mögliche Umsetzung der geeigneten Instrumente (siehe Abbildung 1-6). Diese vorrangigen Instrumente und die dazugehörigen Empfehlungen lauten:

- **Treuhänderische Pflichten institutioneller Investoren und Vermögensverwalter:**
  Deutschland sollte die Treuhandpflichten erweitern bzw. präzisieren, um konkrete Auswirkungen einer Investition auf Klimawandel/Klimaschutz und eine angemessene Berücksichtigung von Kohlenstoffrisiken aufzunehmen. Anpassungen der nationalen treuhänderischen Pflichten können durch die Einbindung von Elementen aus dem BaFin MaRisk, dem Deutschen Corporate Governance-Index und dem EU-Aktionsplan vorgenommen werden. Eine strikte Auslegung und ehrgeizigere Umsetzung der nicht-finanziellen Berichterstattung auf EU-Ebene 2014/95/EU (CSR-RUG) würde zusätzliche Transparenz schaffen. Die gesetzlichen Haftungsregelungen im Falle eines Verstoßes gegen die Berücksichtigung von Klimarisiken in den treuhänderischen Pflichten sollten ausgeweitet werden.
- **Kohlenstoffrisiko-Scanning:**
  Deutschland sollte sich Initiativen anschließen, die klimabezogene Szenarioanalysen und Stresstests insbesondere über die Europäische Zentralbank (EZB) (inklusive dem Europäischen Ausschuss für Systemrisiken (ESRB)) und über die europäische Bankenaufsichtsbehörde (EBA) untersuchen und diese aktiv vorantreiben. Diese Forderung steht in Übereinstimmung mit den Empfehlungen der EU High Level Expert Group on Sustainable Finance (HLEG). Eine weitere Möglichkeit ist eine verstärkte Koordination mit der deutschen Regulierungsbehörde BaFin und der KfW, um einen gemeinsamen Stresstest-Rahmen in Deutschland zu schaffen.
- **Finanzielle Offenlegung und Berichterstattung:**
  Deutschland sollte eine internationale Arbeitsgruppe initiieren und auf konkrete Ergebnisse hinwirken, um die Konvergenz und breitere Annahme der Offenlegung innerhalb eines obligatorischen internationalen aufsichtsrechtlichen Rahmens zu fördern. Dieser sollte auf den Empfehlungen der TCFD, des Financial Stability Board (FSB), des EU-Aktionsplans (EU-AP, Aktion 9) oder des französischen Energiewendegesetzes (Art. 173) beruhen. Dies soll eine Vereinheitlichung der verschiedenen Ansätze und eine bessere Vergleichbarkeit sicherstellen. Die TCFD-

Empfehlungen und die Vorschläge der EU-Offenlegungsverordnung (EC, 2018/0179 (COD)) sollten als Hauptvorlagen dienen.

- **Taxonomien, Labels und Standards:**
Deutschland sollte die Entwicklung einer gemeinsamen Taxonomie auf EU-Ebene (EU-AP Aktion 1 & 2) in Zusammenarbeit mit Branchenführern in Bezug auf ESG-Bewertungen wie z. B. den UN Principles of Responsible Investment (PRI) vorantreiben. Zentral ist hier, durch die Verankerung von Paris-kompatiblen Transformationspfaden einen dynamischen, zukunftsgerichteten Ansatz zu entwickeln, der eine Entwicklung von ESG-kompatiblen Geschäftsmodellen und Produkten innerhalb der mit den Klimazielen vereinbarten Pfade ermöglicht. Die Erstellung von EU Taxonomie-Vorlagen sollte von Deutschland gemeinsam mit der Privatwirtschaft wie etwa der Deutschen Börse und ESG-Analysten begleitet und kommentiert werden.
- **Kohlenstoffsteuer:**
Deutschland sollte die deutsche(n) „Öko-Steuer(n)“ in einem gemeinsamen Rahmenwerk bündeln, den Klimazielen anpassen und ausweiten, um eine Hebelwirkung auf den Finanzsektor zu entfalten und so die gleichen Resultate wie eine reine Kohlenstoffsteuer zu erzielen.
- **EU Emission Trading Scheme & Kohlenstoffpreis:**
Deutschland sollte seinen politischen Einfluss nutzen, um die europäischen Entscheidungsträger und Partner bei der Überarbeitung des EU ETS-Systems anzuspornen, und sich kontinuierlich auf europäischer Ebene für eine Anhebung des Ambitionsniveaus im EU ETS in der Phase 4 (2021-2030) einsetzen.

Abbildung 1-6: Empfohlene Zeitachse zur Umsetzung der Instrumente zur Integration von Kohlenstoffrisiken an den Finanzmärkten



Quelle: Eigene Darstellung, Oxford University.

1 Introduction

The Paris Agreement of 2015, signed and ratified by more than 170 countries, and its commitment to restrain global warming to a maximum of 2°C, require the transformation of the world's economies. Against this background, in recent years the European Union has been working towards building a financial system that supports sustainable development in line with the climate agreement.

As already highlighted by the IPCC (2014) and World Bank President Jim Yong Kim (World Bank 2014), climate risks and thus the systemic risk of investments in carbon-intensive sectors are increasing. Climate risks are often divided into physical risks and transition risks. While the former relate to floods, droughts or storms, for example, transition risks include climate-related risks that can be traced back to political, legal, technological and economic changes, such as the introduction or increase of a CO2 price.

In a speech by the Governor of the Bank of England to the insurance industry (Carney, 2015), Mark Carney discussed the link between financial risk and carbon risk. He called climate change the "tragedy of the horizon" because most risks and costs lie beyond economic cycles, political cycles and the cycles of central banks. He also argued that the financial sector must better understand and price these risks in order to ensure a smooth decarbonization (and thus overcome the tragedy of the horizon). Shortly thereafter, the G20 Financial Stability Board launched a Task Force on Climate-related Financial Disclosure (TCFD) led by Mark Carney and Michael Bloomberg, consisting of industry representatives from the manufacturing and financial sectors as well as think tanks and advisory firms. In addition, a Green Finance Study Group (GFSG) was set up under the Chinese G20 Presidency with the support of the Bank of England to address the challenges of a transition to a climate-friendly economic and financial system. Both initiatives have led to broader awareness of the issue and to the development of appropriate measures. The final report contains recommendations on the disclosure of climate-related financial risks (TCFD, 2017), divided into four topics: Governance, strategy, risk management and metrics and objectives. Against this background, there is now an increased interest in the role of policies and financial market regulation in building a sustainable financial system that supports the shift towards a prosperous low-carbon economy.

At the EU level, the recommendations of the High Level Expert Group on Sustainable Finance (HLEG) of January 2018 (EU HLEG, 2018) and the Action Plan on Financing Sustainable Growth (EU-AP) of March 2018 (EU-AP, 2018) illustrate these essential efforts of the European Commission.

Germany has started one of the most ambitious national transformations towards a low-carbon economy: the so-called "Energy Transition" (Energiewende). The Energy Transition aims to reach a share of renewable energy in gross electricity consumption of 35 % by 2020, 40 - 45 % by 2025, 55 - 60 % by 2035 and 80 % by 2050 (European Climate Foundation 2016). In addition, following the nuclear accident in Fukushima in 2011, Germany decided to withdraw from nuclear energy and establish itself worldwide as a leading nation in the field of renewable energies and the transition to a green economy (Schäfer 2017). In November 2016, the German Federal Government also adopted the Climate Protection Plan 2050 as a German long-term strategy for implementing the Paris Agreement. The climate protection plan contains non-binding sector-specific reduction targets (2030) for all greenhouse gas-emitting sectors (energy, buildings, transport, industry, agriculture) according to the source principle, i.e. the allocation of emissions to their place of origin.

Since the financial sector itself is not an emitter of large amounts of greenhouse gases, it has no specific reduction target. As a cross-cutting sector, however, it is of great importance for the reduction of emissions in all sectors and plays a decisive role in the decision which assets will be financed in the future. In addition to physical climate risks, which are of relevance for the insurance industry, transition risks in particular have the potential to confront the financial sector with considerable market distortions (e.g. abrupt exit from coal mining) and thus devaluations. Transition risks can have a direct impact on the financial market (first-round effects) or an indirect impact via investments or loans to other financial institutions (second-round effects). A study by South Pole Group (2016), which examined the transition risks for listed equity investments in the German financial market, found that the maximum losses could amount to 262 to 600 billion euros (2 - 5 % of the financial market). The report concluded that in the short to medium term - in a period up to 2030 - the physical effects of climate change pose an extremely low threat to financial market stability in Germany. The report emphasizes that specific sectors such as the coal/oil and gas industries as well as the transport sector are exposed to higher risks (South Pole, 2016). Combined with other risks such as the unexpected introduction of higher CO2 prices, this could destabilize the financial market. The danger of a so-called "carbon bubble" on the capital market, i.e. an overvaluation of companies dependent on fossil fuels, such as the fossil energy industry or greenhouse gas-intensive industries, is therefore increasingly important.

Against this background, a strategic reorientation of Germany is necessary in the short to medium term in order to prepare the German economy and its financial sector for future transition risks and to avoid the "stranding" of assets (Greenpeace 2014, ESRB 2016). The ability to adequately assess new climate-related risks and opportunities is the key to avoiding losses and to efficiently channel capital into different uses.

While carbon risks are likely to be material across the entire investment chain, they remain poorly understood and are not integrated into financial decision-making. In 2015, the G20 already questioned whether investments in fossil-fuel-dependent infrastructure could lead to global financial risks in the form of a 'carbon bubble'. As G20 president, the German government by means of the German Environment Agency (UBA) therefore commissioned a consortium of Navigant – A Guidehouse Company, University of Oxford (Smith School of Enterprise and the Environment), Triple A Risk Finance, Global Climate Forum, University of Zurich (Finexus) and Germanwatch with the support of Allianz Climate Solutions to analyze and evaluate the risk of a ‘carbon bubble’ in the German financial system.

The objective was (1) to assess the carbon risks in the German economy, (2) to conduct a carbon stress test for German financial institutions and (3) to develop regulatory instruments to mitigate carbon risks in financial markets in Germany and beyond. This will enable the German government to detect, understand and mitigate the carbon risks in the German economy and will support German financial institutions in assessing the carbon risks in individual financial portfolios. The following study is the result of this assignment. It is composed out of three work packages (WP) following the three aims above:

- WP1: Carbon risks in the German economy
- WP2: Carbon stress test for financial institutions (Carbon Quick Scan Tool)
- WP3: Integration of Carbon Risks in Financial Markets

In chapter 2 (WP1), Navigant – A Guidehouse Company, developed an Operator Carbon Risk Tool for UBA, which is an instrument that allows UBA to assess the impacts of such carbon risks on the financial performance of sectors that are of central relevance for the German economy. The tool estimates the sensitivity of these sectors to carbon risks such as the development of CO2 prices and emission caps, the future energy demand or expected production outputs under the IEA 2 °C and 1.5 °C climate scenario. Depending on the adaptability of a sector, sector-level carbon risks are calculated and translated into stranded asset indicators: for example, the indicator profit change estimates the change in profits due to carbon risks over the timespan from 2015 and 2030.

In chapter 3 (WP2), the University of Zurich, the Global Climate Forum, Triple A Risk Insurance, Germanwatch and the Allianz SE developed the Carbon Quick Scan Tool, which links the climate stress test of the Operator Carbon Risk Tool to potential financial impacts for the financial sector. The focus is not on transition risks for the German industry but on the risks for the financial sector. The carbon quick scan tool transfers the corporate risks on sector-level into financial risks on portfolio-level. The purpose of this tool is to create more awareness for climate-related risks among financial institutions and to provide them with an instrument to assess potential overvaluation of carbon-intensive assets. In this study, this carbon stress test is conducted for selected sectors and asset classes.

In chapter 4 (WP3), the University of Oxford reviewed and evaluated existing instruments used by regulators to integrate carbon risks into the decision making of financial institutions. Benefits and advantages of these instruments are outlined. Furthermore, recommendations on how to improve the current integration of these risks is provided. The assessment focuses on the German case, although other countries are considered were appropriate.

2 Carbon risks in the German economy

To better understand the risks that stem from the transition to a low carbon economy, the following chapter aims to identify and assess the carbon risks and their impact on the German economy for a large number of sectors. The following chapter will first determine the most relevant sectors to be assessed. Secondly. it will introduce the methodology to assess the carbon risks in the German economy. Thirdly, the key results will be illustrated and analyzed. The chapter will close with a summary of the key results of the assessment of carbon risks in the German economy.

2.1 Sector selection

As assessing the carbon risks for all German sectors would be too time-consuming, the research team and UBA agreed to focus on those German industries that are of high relevance for the economy and that are likely to be most exposed to carbon risks.

Therefore, the research team performed a pre-selection of German sectors from a longlist of all sectors based on three criteria: gross value added, emissions and profit margin.

- **Gross value added (million €):** If a sector contributes a lot to Germany's total value added, it is more relevant for the German economy than if its value added is low.
- **Scope 1& 2 emissions (kt CO2e)[12]:** If a sector has high scope 1 and 2 emissions, it is more exposed to carbon risks such as increasing CO2 prices than a sector with less emissions.
- **Profit margin (%):** If a sector has a low profit margin, its capacity to cope with higher production costs due to carbon risks such as increasing CO2 prices is lower.

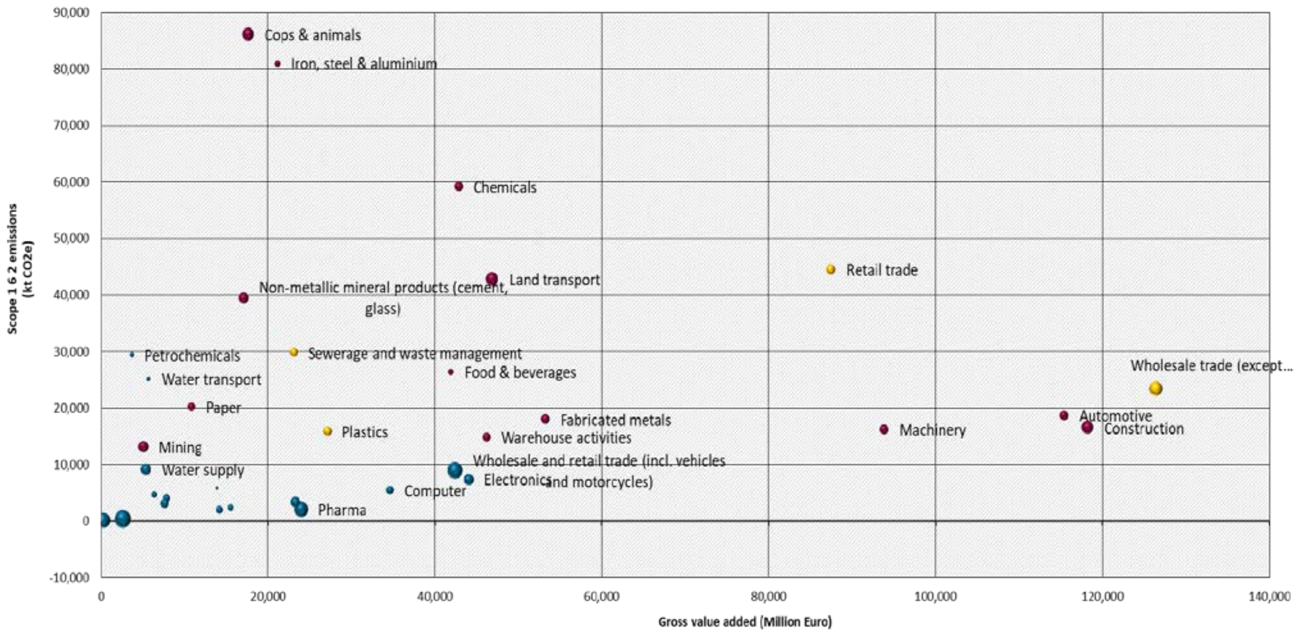
Gross value added thus helps to identify a sector's relevance for the German economy, while the criteria emissions and profit margin help to identify the level of potential exposure to carbon risks. Figure 2-1 shows the result of this sectoral analysis. For each German sector (NACE2-Level), the gross value added, the scope 1 & scope 2 emissions and the profit margin (i.e. size of the bubble) are shown. In collaboration with UBA, the research team classified the red highlighted sectors in Figure 2-1 as highly relevant for the German economy and/or highly exposed to carbon risks. It is important to note that the electricity supply sector is also considered highly relevant but it is not shown in Figure 2-1 as including the sector in the figure would make it unreadable due to its high emissions. The yellow highlighted sectors in Figure 2-1 are special cases, which seem relevant but which will not be further analysed in this study for the following reasons:

- The retail trade and wholesale trade (except vehicles and motorcycles) sectors seem relevant in terms of gross value added and emissions. However, as availability of statistical data on these sectors is low and as both sectors' emissions are mostly indirect scope 2 emissions from electricity (and thus easier to reduce), these two sectors are omitted from further analysis.

[12] Scope 1 emissions are direct emissions that are caused by the sector's activity (process emissions, burning of fossil fuels). Scope 2 emissions are indirect emissions that are caused by the sector's electricity and heat energy consumption.

- The waste sector is omitted from further analysis as availability of statistical data on this sector is too low to allow for meaningful results.
- The plastics sector was excluded from further analysis as this sector was already analysed in-depth by a complementary study commissioned by UBA[13]. Therefore, it was decided to omit this sector from further analysis.

Figure 2-1: German industries that are of importance for the economy and that are likely to be most exposed to carbon risks



Note: Electricity supply sector is also considered highly relevant but is not shown here as including the sector in the figure would make it unreadable.

Source: Own representation, Navigant – A Guidehouse Company.

Based on the results above and further discussions with UBA, the research team selected 23 sectors for an in-depth analysis of carbon risks. Table 6-1 shows each sector providing its respective NACE code and NACE name as all statistical databases (Eurostat, DESTATIS) rely on this NACE sector classification. For two sectors, i.e. Manufacture of basic iron and steel and of ferro-alloys (NACE 2410) and Electric power generation, transmission and distribution (NACE 3510), the research team decided to isolate and develop two sub-sectors each for which no individual NACE code exists.

Manufacture of basic iron and steel and of ferro-alloys (NACE 2410) is sub-divided into two different iron and steel production routes: the Blast Furnace (BF)/Basic Oxygen Furnace (BOF) production route and the Electric Arc Furnace (EAF) production route. The subdivision is done as the former one is difficult to be decarbonized, while the latter can be more easily decarbonized (e.g. through green electricity). Hence, carbon risks differ between both production routes meaning that only analyzing the aggregate sector, i.e. Manufacture of basic iron and steel and of ferro-alloys (NACE 2410), would be less meaningful.

Electric power generation, transmission and distribution (NACE 3510) is sub-divided into Non-RES Electric power generation, transmission and distribution and RES Electric power generation,

[13] https://www.2gradwirtschaft.de/wp-content/uploads/2018/09/Studie_Der-Weg-in-die-unter-2-Grad-Wirtschaft.pdf

transmission and distribution into two regions for a very similar reason. While Non-RES electricity production route will face very high carbon risks, the RES electricity production route will benefit from the continued decarbonization of the electricity system.

Table 2-1: Sectors selected for in-depth analysis of carbon risks

#	Sector code (NACE)	Sector name (NACE)	Sector name Abbreviation
1	0140	Animal production	Animal production
2	0500	Mining of coal and lignite	Coal
3	1000-1200	Manufacture of food products; beverages and tobacco products	Food
4	1000	Manufacture of food products	Food, beverages & tobacco
5	1050	Manufacture of dairy products	Dairy
6	1700	Manufacture of paper and paper products	Pulp & paper
7	2000	Manufacture of chemicals and chemical products	Chemicals
8	2310	Manufacture of glass and glass products	Glass
9	2350	Manufacture of cement, lime and plaster	Cement & lime
10	2400	Manufacture of basic metals	Basic metals
11	*2410 BF/BOF*	BF/BOF Manufacture of basic iron and steel and of ferro-alloys	BF/BOF iron & steel
12	*2410 EAF*	EAF Manufacture of basic iron and steel and of ferro-alloys	EAF iron & steel
13	2440	Manufacture of basic precious and other non-ferrous metals	Non-ferrous metals
14	2442	Aluminum production	Aluminum
15	2450	Casting of metals	Casting of metals
16	2800	Manufacture of machinery and equipment n.e.c.	Machinery
17	2900	Manufacture of motor vehicles, trailers and semi-trailers	Motor vehicles
18	*3510 Non-RES*	Non-RES Electric power generation, transmission and distribution	Non-RES power
19	*3510 RES*	RES Electric power generation, transmission and distribution	RES power
20	F	Construction	Construction
21	4900	Land transport and transport via pipelines	Land transport
22	4940	Freight transport by road and removal services	Road freight transport
23	5200	Warehousing and support activities for transportation	Warehousing

Note: Two sectors, i.e. Manufacture of basic iron and steel and of ferro-alloys (NACE 2410) and Electric power generation, transmission and distribution (NACE 3510), are sub-divided into two sub-sectors each for which no individual NACE code exists. Source: Own representation, Navigant – A Guidehouse Company.

2.2 Description of methodology

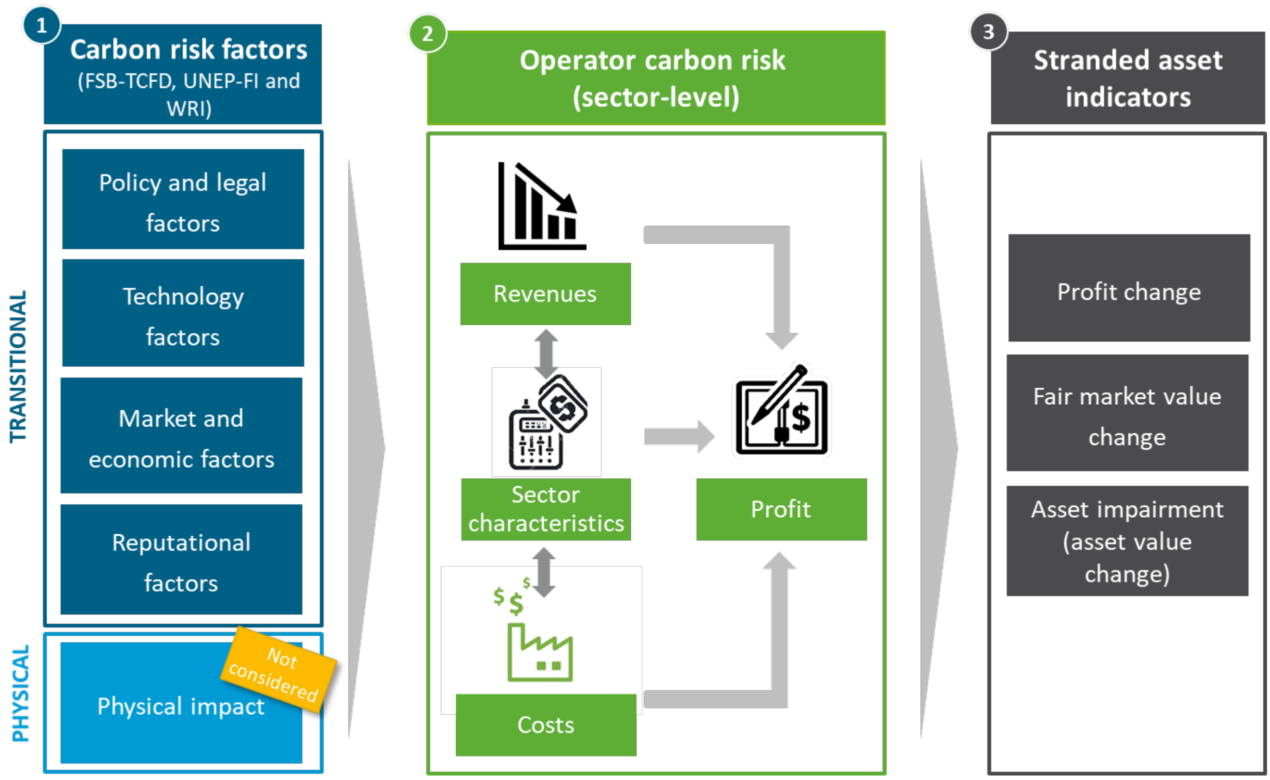
The general methodical framework used to estimate the impacts of carbon risks on the financial performance of sectors, i.e. the so-called operator carbon risk, can be easiest described conceptionally in three steps (see Figure 2-2):

In a first step (1st step), carbon risks being derived from the low-carbon transformation pathways of IEA 2 °C and 1.5 °C climate scenario are identified. Carbon risks, which were firstly defined by UNEP-FI (2012) and which are also referred to as transition risks according to the TCFD (2017), refer to climate-related risks resulting from policy and legal, technology, market and economic as well as reputational factors. In contrast to physical risks themselves such as flooding, droughts etc., carbon risks are the society's answers to such physical climate risks. Examples for such carbon risks can be increase of CO2 prices, a steep emission reduction path, a reduction in energy consumption or a reduction in output. The carbon risks introduced within this assignment are dependent on the climate scenario assumed. It is important to note that this assignment only focusses on carbon risks. Physical risks are thus not covered.

In a second step (2nd step), the impacts of such carbon risks under the IEA climate scenario above are translated into sector-level operator carbon risks, i.e. the impact of carbon risks on the financial performance of sectors due to the materialisation of these carbon risks. This financial performance is determined by the development of two variables, "revenues" and "costs", both being dependent on certain sector characteristics (see chapter 2.2.2). The difference in profits (revenues minus costs) between today and the future low carbon world (i.e. under the climate scenario) represent the operator carbon risk.

In a third step (3rd step), the operator carbon risk is expressed by means of three stranded asset indicators: profit change, fair market value change and asset impairment. Each stranded asset indicator is further explained in chapter 2.2.3.

Figure 2-2: Methodological approach determining the impact of carbon risks on the financial performance of sectors



Source: Own representation, Navigant – A Guidehouse Company.

2.2.1 Step 1: Carbon risks under the IEA climate scenarios

IEA 2 °C (2DS) and 1.5 °C (B2DS) climate scenario serve as the major underlying scenario. The reason for this is that the scenario is both, closely in line with former and current international climate agreements/pledges as well as one of the most accepted and used scenarios in the scientific and non-scientific community. It is based on the so-called Energy Technology Perspectives (ETP) assessments of the IEA. Under the IEA 2°C climate scenario, the IEA analyses how clean energy technologies and policies (e.g. CO2 prices, energy demand) need to develop to limit global warming to a 2°C temperature increase. A more detailed explanation of how the IEA ETP model works and what assumptions it applies is provided in the annex (see Annex 6.3).

The ETP assessment of the IEA provides robust data on how certain economic/energy/environmental parameters develop from now to 2030 to limit global warming to a 2°C and 1.5 °C temperature increase. The most important data points provided by IEA are the following:

1. CO2 emissions
2. CO2 prices
3. Energy demand
4. Production output

The development of these data points determines the transition pathway towards a decarbonized economy, and thus the level of operator carbon risks in German sectors. They therefore represent key inputs for the calculation of the operator carbon risks.

Figure 2-3 shows how sectoral GHG emissions and CO2 prices as well as sectoral energy demand and sectoral production output will develop under the IEA 2°C climate scenario. For example, GHG emissions will need to reduce across all sectors meaning that sectors are confronted with increasing emission abatement costs. At the same time, CO2 prices will increase meaning that sectors will have increasing costs for their remaining (i.e. non-abated) GHG emissions. Energy producing sectors such as coal will face decreasing revenues due to a reduction in energy demand. Changes in production output such as for example for steel produced by the Blast Furnace (BF)/Basic Oxygen Furnace (BOF) production route will also affect the revenue of sectors.

Overall, this shows that the developments under the IEA climate scenarios are crucial to determine the sectoral operator carbon risks, i.e. impact of carbon risks on the financial performance of sectors.

Figure 2-3: Transformation pathways under the IEA 2°C climate scenario as central input for the assessment of the operator carbon risk

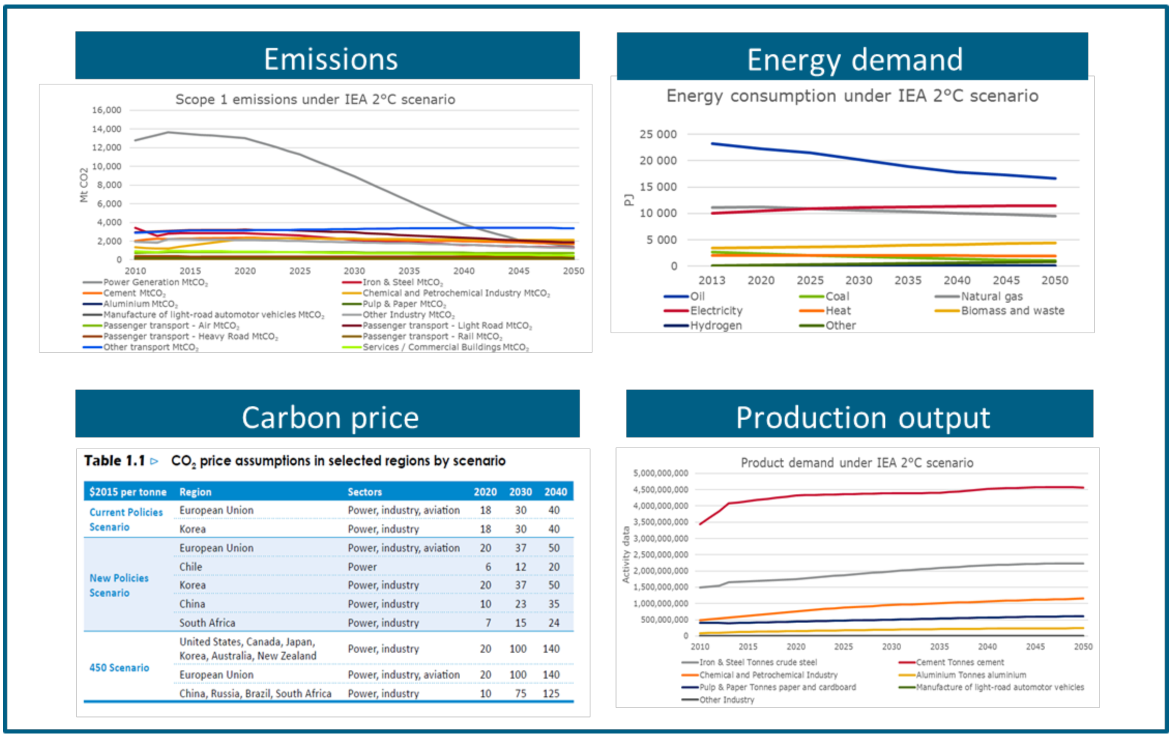


Table 1.1 ▷ CO_2 price assumptions in selected regions by scenario

$2015 per tonne	Region	Sectors	2020	2030	2040
Current Policies Scenario	European Union	Power, industry, aviation	18	30	40
	Korea	Power, industry	18	30	40
New Policies Scenario	European Union	Power, industry, aviation	20	37	50
	Chile	Power	6	12	20
	Korea	Power, industry	20	37	50
	China	Power, industry	10	23	35
	South Africa	Power, industry	7	15	24
450 Scenario	United States, Canada, Japan, Korea, Australia, New Zealand	Power, industry	20	100	140
	European Union	Power, industry, aviation	20	100	140
	China, Russia, Brazil, South Africa	Power, industry	10	75	125

Source: Own representation, Navigant – A Guidehouse Company.

2.2.2 Step 2: From carbon risks to operator carbon risks

The level of a sector's operator carbon risk is strongly dependent on the adaptability of the sector, which is described by so-called sector characteristics. These sector-characteristics directly mitigate or aggravate the impacts of carbon risks on the revenues or costs of a sector and are therefore of particular importance. The following sector characteristics were considered for each sector:

- **Revenues at risk:**
  This sector characteristic indicates how much % of an observed sector's revenue is generated from sectors with a very high carbon risk. These were defined to be the sectors that extract fossil fuel, i.e. the coal, oil and gas sector. For example, if the chemical sector earns 10% of its revenue from these fossil fuel extracting sectors, 10 % of the chemical sector's revenues are at risk and will likely be lost or at least diminish[14].
- **Own pass-through ability:**
  This sector characteristic indicates how much % of an observed sector's scope 1 emission[15] costs can likely be passed-through downstream (to other sectors). We use the current share of sector free EU ETS allowances to approximate this value for the following reason: The European Commission determines the share of sector free allowances based on the carbon leakage risk of a sector[16].

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[14] Note that in latter calculations, we assume that all revenues from fossil fuel extracting sectors are lost until 2030 (i.e. set to 0) to assess the maximum revenue at risk exposure of the the respective sector under observation.

[15] Scope 1 emissions are direct emissions that are caused by the sector's activity (process emissions, burning of fossil fuels).

[16] According to tETS Directive (Article 10a), a sector or sub-sector is deemed to be exposed to a significant risk of carbon leakage if:

- direct and indirect costs induced by the implementation of the directive would increase production cost, calculated as a proportion of the gross value added, by at least 5%, and the sector's trade intensity with non-EU countries (imports and exports) is above 10%.
- the sum of direct and indirect additional costs is at least 30% or the non-EU trade intensity is above 30%.

Therefore, if a sector gets a high free allowance share it has a high carbon leakage risk (i.e. emission costs have a significant effect on production costs and the sector has a high trade exposure). In theory, in the absence of a free allowances scheme, the sector could inversely very likely only pass through a low share of its emission costs downstream, e.g. as trade intensity would not allow to pass-through the increased costs. For example, if the steel sector got 80% of emission allowances for free, it would only be able to pass-through 20% (1-80%) of its emission costs.

- **Supplier pass-through ability:**
  This sector characteristic indicates how much % of an observed sector's scope 2 and upstream scope 3 emissions[17] costs could be passed-through to the observed sector. It is dependent on the sector's purchase volumes from upstream sectors (inputs) as well as the upstream sectors' carbon intensity and own pass-through ability. For example, let's assume that the construction sector's total scope 3 emissions are caused by 80% in the cement sector. If the cement sector can pass-through 10% of its emission costs, 8% (=10% x 80%) of total scope 3 emissions will materialise and will need to be borne by the construction sector.
- **Abatement capability:**
  This sector characteristic indicates the capability to reduce carbon emissions at costs per abated tonne lower than the carbon price per tonne. It is calculated by the % share of cost savings induced by abatement measures in total theoretical maximum abatement costs ("fictive carbon costs"), the latter being calculated as emissions to be reduced times the future carbon price (seeFigure 2-4). These fictive carbon costs are those costs that would need to be paid if no abatement measure was implemented but only CO_2 certificates purchased instead. If the value of abatement capability is 40%, for example, this means that the sector's costs to reduce emissions are 40% lower than the fictive carbon costs. At the same time, if cost savings are higher than the abatement cost (the value of the abatement capability is >100%), a sector saves more than it spends for abatement, meaning that the sector has in fact negative abatement costs.

A more detailed explanation of the mathematics behind the calculations can be found in annex 6.1. The data underlying the modelling can be found in annex 6.2.

Figure 2-4: Explanation of the sector characteristic "abatement capability"

Source: Own representation, Navigant – A Guidehouse Company.

[17] Scope 2 emissions are indirect emissions that are caused by the sector's electricity and heat energy consumption. Scope 3 emissions are indirect emissions that are caused by other sector's activity (purchase of goods and services, business travel etc.).

2.2.3 Step 3: Stranded asset indicators

Three stranded asset indicators were used as part of the project to operationalise the operator carbon risk. These show the change in the financial performance of a sector as a result of the transformation towards a low-carbon economy.

The most important financial measure used as a stranded asset indicator is the profit change of a sector, i.e. the difference between turnover and costs. The reasons for choosing this indicator are its simple comprehensibility and communicability as well as its widespread use in the financial sector. In order to also take account of the time value of money and the development of gross investment assets, two further indicators were included in the study: fair market value change (present value development of profit) and asset impairment (asset value change). It is important to note that the latter two indicators are less reliable and meaningful than the profit change indicator due to the unavailability of sufficient data at sector level. Profit change is therefore considered the most robust Stranded Asset indicator. In the following, the three Stranded Asset Indicators are now defined in more detail:

Profit change
The profit change is the difference between the current profit in 2015 and the future profit in 2030 under the 2 °C and 1.5 °C scenarios of the IEA.

Fair Market Value change (Present value development of profit)
Fair market value change is the difference between the present value of future profits until 2030 assuming constant profits until 2030 at the level of 2015 - it is assumed that profits in the period from 2015 to 2030 will remain constant at the level of 2015 - and the present value of future profits below the 2 °C or 1.5 °C scenario of the IEA (discounted cash flow method).

Asset impairment (asset value change)
Asset performance is the difference between the asset in 2015 and the asset in 2030 below the IEA's 2°C and 1.5°C scenarios, respectively. To calculate the asset in 2030 under the 2 °C or 1.5 °C scenario of the IEA, the asset is adjusted in 2015 by the relative change in the above fair market value development.

2.3 Methodological limitations

The methodology used to estimate and assess the sector-level operator carbon risks for German industrial sectors has several limitations. The most relevant are the following:

Limitations to the scenario

- We fully rely on the data provided under the IEA 2 °C climate scenario.
- We solely focus on the following developments (i.e. carbon risks) under the IEA 2 °C scenario:
  - CO2 emissions
  - CO2 prices
  - Energy demand
  - Production output

  Consequently, other developments such as for example increasing or decreasing energy prices are not covered.

Scoping limitations

- **Geography**: we only cover production in Germany. Consequently, no production of German companies outside of Germany are covered.
- **Sectors:** we only cover those sectors that are of relevance for Germany. Consequently, those sectors with a high value added and/or a high carbon intensity are covered.
- **Time:** we only compare current values from 2015 with 2030 and do not go beyond 2030.

Limitations to the quantification of operator carbon risk

- We focus on sector level operator carbon risk. Company operator carbon risk is not assessed.
- We often focus on higher-level sectors (i.e. NACE2 level) meaning that we are not able to display the operator risks for the subsectors of these sectors. [18]
- We only focus on operator carbon risks and not on "operator carbon opportunities" (e.g. benefits due to the energy transition).
- Only upstream Scope 3 emissions are considered. Downstream Scope 3 emissions are not included in the profit function due to methodological restrictions[19] and limited data availability.[20]
- For the sector-specific feature "Revenue at risk", we assume, for reasons of simplification, that all revenues of a sector earned from sectors that extract fossil fuels will be lost by 2030. This is to take into account the maximum value of revenues at risk of the sectors concerned in the model, which is consistent with the objectives of a stress test.[21] This is not the case in reality, at least for the oil and gas sector.

It is important to keep these limitations in mind when analysing and interpreting latter results.

2.4 Impact of carbon risks on sectors in Germany

In the following, the results of the transformation towards a decarbonized economy per sector are described and analyzed using the previously defined stranded asset indicators. The results are presented as examples for the 2 °C (2DS) climate scenario of the IEA. The results of the 1.5 °C (B2DS) climate scenario of the IEA can be found in Annex 6.4.

Since all indicators are significantly influenced by the emission development paths of the climate scenarios per sector, these emission developments are illustrated below for all sectors examined.

2.4.1 Emission change

Figure 2-5 shows the change in scope 1, scope 2 and upstream scope 3 emissions under the IEA 2°C climate scenario comparing 2015 with 2030. Out of the 23 sectors, there are 7 sectors, which need to reduce their total emissions by more than 40%. Non-RES power (-68%), coal (-66%) and pulp & paper (-56%) need to reduce the strongest. In addition, there is a strong scope 1 emission reduction burden for BF/BOF iron & steel (around -33%), land transport (around -14%) and road freight transport (around -18%).

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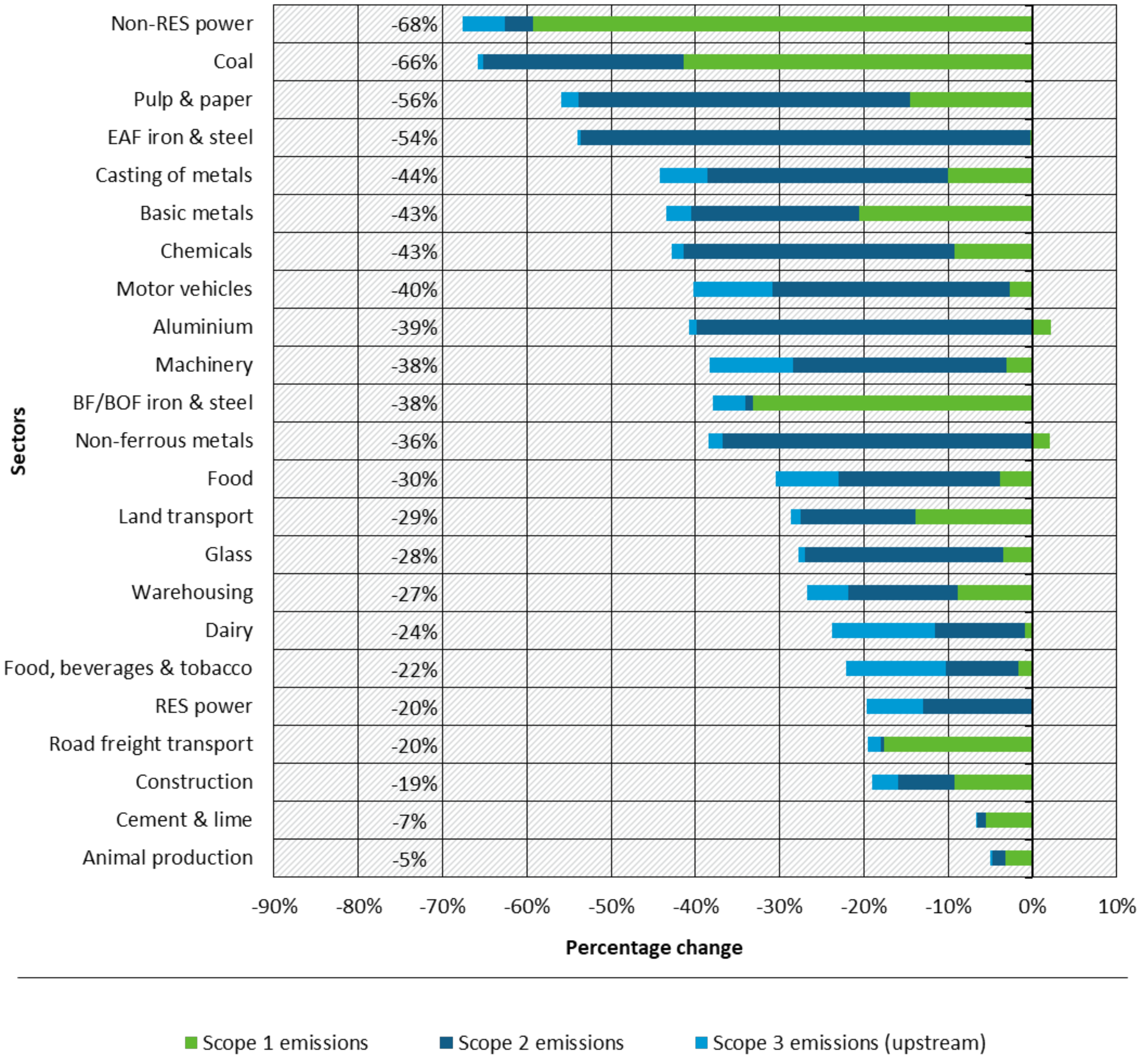
[18] A prominent example is the chemicals sector. It includes subsectors such as chlorine and ammonia, which are highly electricity and natural gas intensive (and thus also carbon-intensive), but also sectors such as paints or soaps, which are less carbon-intensive. Consequently, the operator carbon risks of these subsectors would differ from each other quite substantially. When assessing the aggregated sector of chemicals, these differences cannot be displayed.

[19] This is due in particular to the fact that the en-vironmentally-extended input-output tables used to estimate Scope 3 emissions do not allow direct conclusions to be drawn about downstream Scope 3 emissions.

[20] Also note that in practice downstream scope 3 emissions costs would very likely not be able to be passed upstream to the producer of the product. Instead, customers, which emit the downstream scope 3 emissions when using the product (as part of their scope 1 emissions), would very likely rather shift from the carbon-intensive product (e.g. fossil fuel car) to a low-carbon-intensive product (e.g. electric car). This is covered by the change in product demand under the IEA 2° climate scenario.

[21] For example, if the chemical sector generates 10% of its revenues from these sectors, 10% of the revenues of the chemical sector will be lost.

Figure 2-5: Change in emissions (scope 1, scope 2 & upstream scope 3 emissions) under the IEA 2°C climate scenario comparing 2015 with 2030



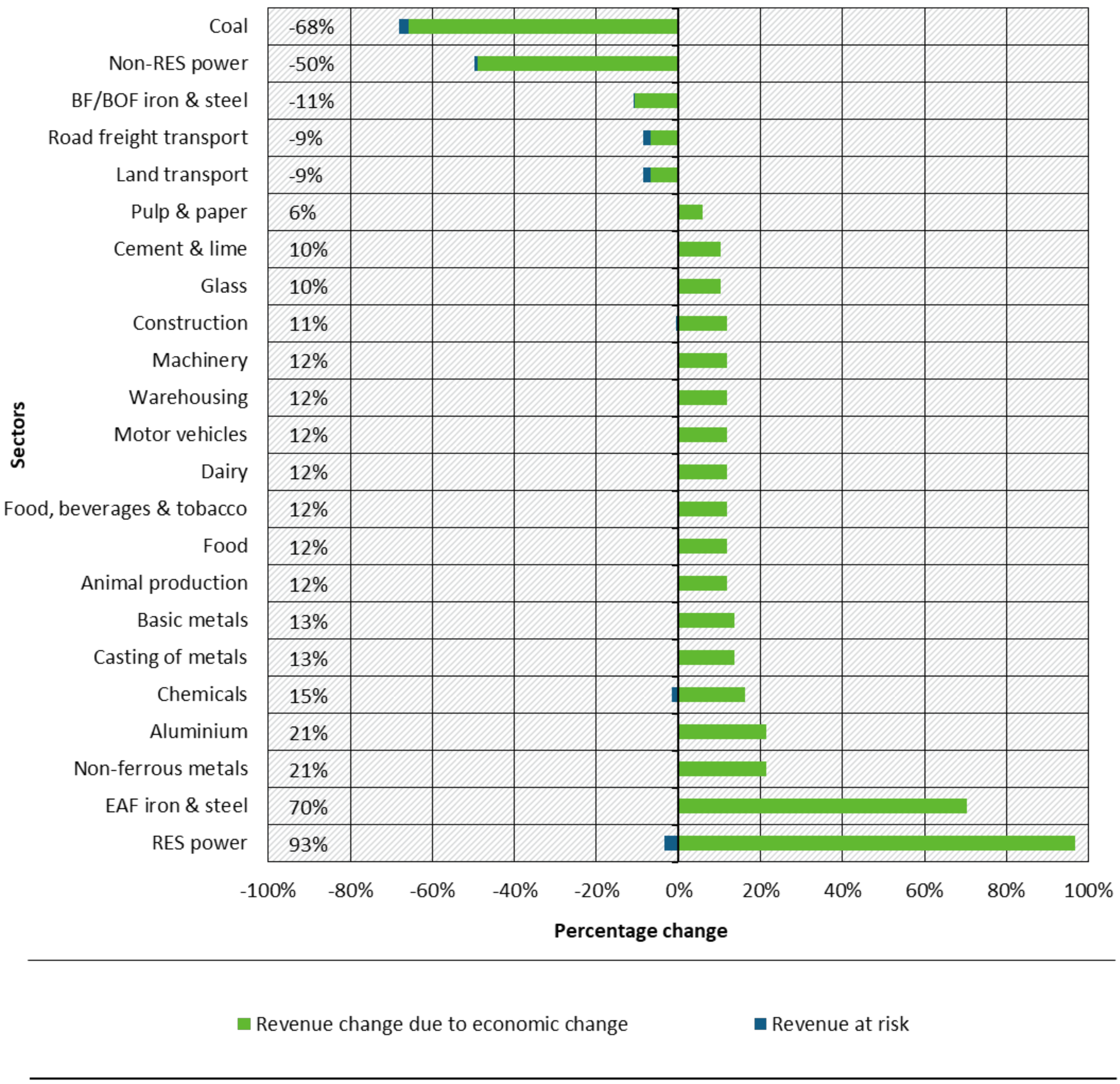
Source: Own representation, Navigant – A Guidehouse Company.

2.4.2 Profit change

2.4.2.1 Revenue change

Figure 2-6 shows the change in revenue under the IEA 2°C climate scenario comparing 2015 with 2030. Out of the 23 sectors, there are five sectors, which face decreasing revenue under the IEA 2°C climate scenario due to decreasing demand. These are coal (-68%), non-RES power (-50%), BF/BOF iron & steel (-11%) as well as the road freight and land transport (-9% each). Some sectors such as the chemicals, land transport, road freight transport and RES power sector lose part of their revenue, which they have earned from the coal, oil and gas industry. For all these sectors, this loss in revenue of between 2 to 3% is, however, over-compensated by increasing demand due to economic change (e.g. sale of new products). In contrast, revenues in the renewable electricity (+93 %) and EAF iron & steel (+70 %) sectors will increase significantly between 2015 and 2030.

Figure 2-6: Change in revenue under the IEA 2°C climate scenario comparing 2015 with 2030

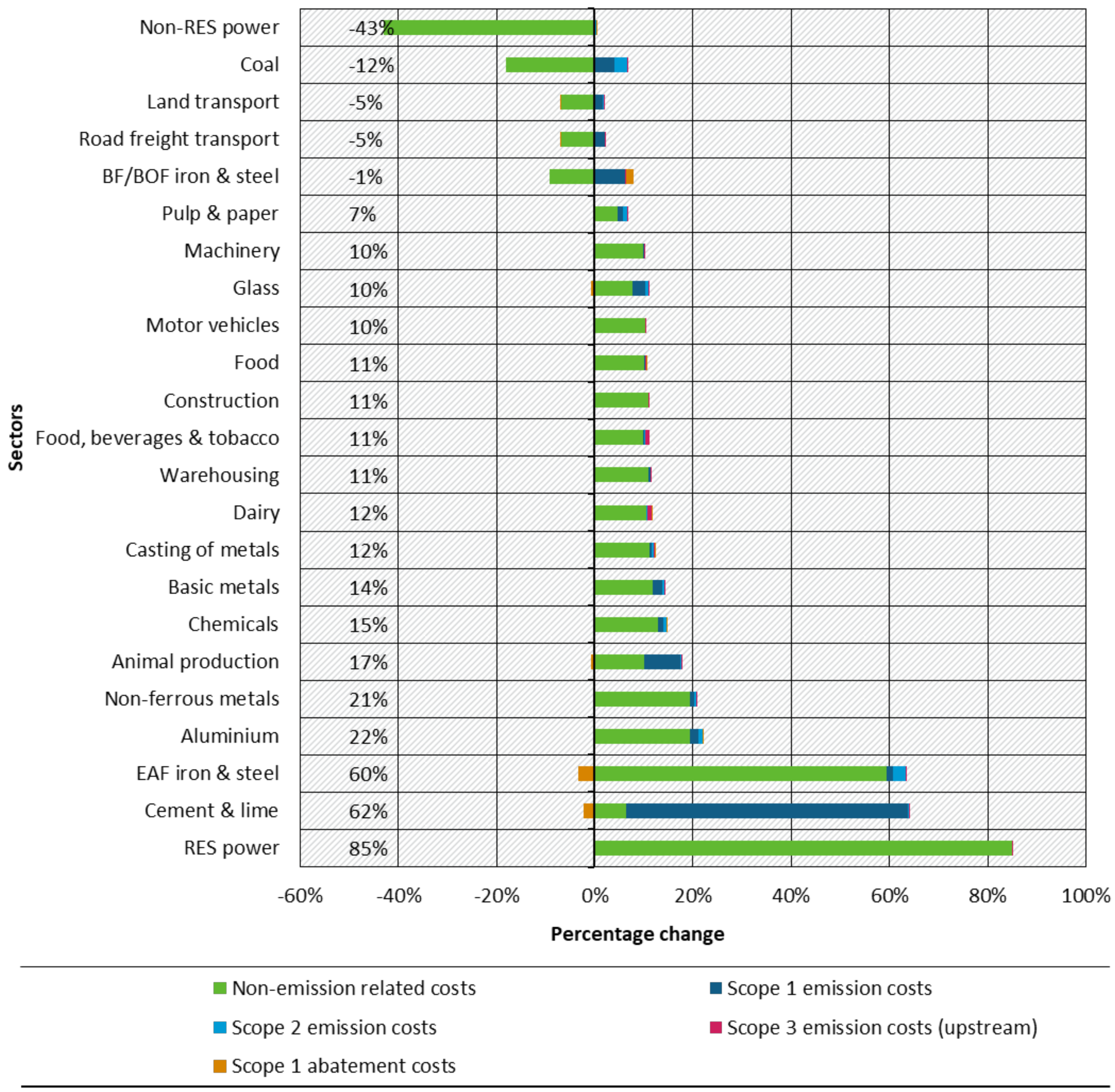


Source: Own representation, Navigant – A Guidehouse Company.

2.4.2.2 Cost change

Figure 2-7 shows the change in costs under the IEA 2°C climate scenario comparing 2015 with 2030. Out of the 23 sectors, there are five sectors, which face decreasing costs under the IEA 2°C climate scenario due to decreasing demand. These are non-RES power (-43%), coal (-12%), land and road freight transport (each -5%) and BF/BOF iron & steel (-1%). All other sectors face increasing costs, which is to a large extent caused by increasing demand and thus higher output levels (see non-emission related costs in Figure 2-7). This holds in particular true for RES power, which faces increasing costs (+85%) as more electricity is produced by RES. Animal production and cement & lime are obviously those sectors, which have to bear high cost increases due to increasing emission costs. For animal production, 7 percentage points out of the total increase of 17% is caused by scope 1 emission costs. For cement & lime, 57 percentage points out of the total increase of 63% is caused by scope 1 emission costs. This corresponds to more than 91% of the total cost increase for cement & lime.

Figure 2-7: Change in costs under the IEA 2°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

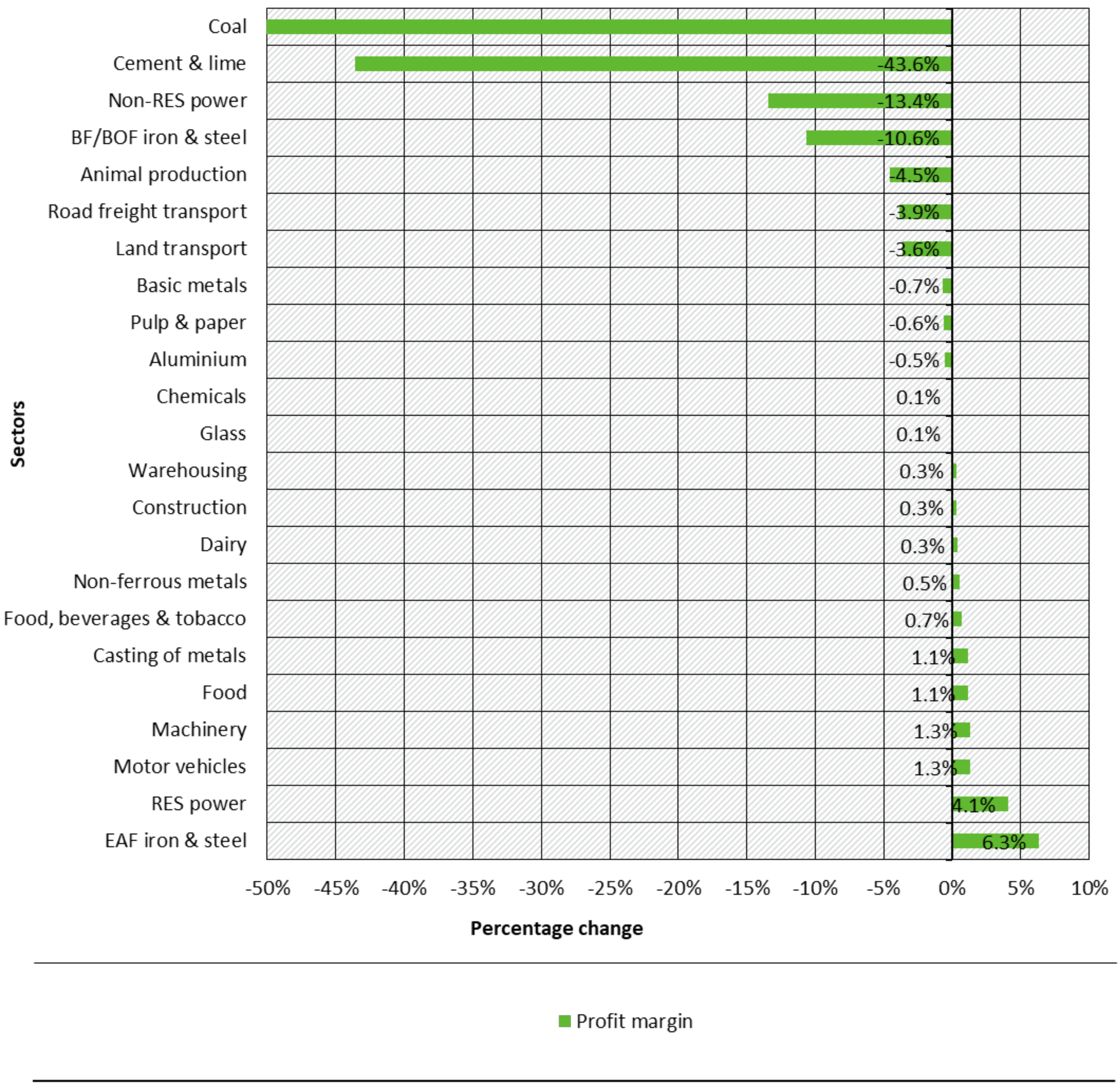
2.4.2.3 Profit margin change

The profit development of the sectors under consideration is assessed on the basis of the change in the profit margin. Figure 2-8 shows the change in profit margin (in percentage points) under the IEA 2°C climate scenario comparing 2015 with 2030. For example, if the change is -4.5 percentage points as it holds for animal production, then the future profit margin in 2030 is 4.5 percentage points (pp) lower than the current profit margin in 2015. The profit margin change shown is calculated by subtracting costs from revenue.

Less than half of all sectors analyzed (i.e. 10 out of 23) face a negative profit margin change. The largest change in profit margin is perceived by the coal (-271.5pp), cement & lime (-43.6pp), Non-RES power (13.4pp) and BF/BOF iron & steel (-10.6pp) sector. These sectors thus face severe negative impacts in their profit margin. Animal production, road freight transport and land transport are also negatively affected between 3.0 to 4.5pp.

In the contrary, sectors such as RES power and EAF iron & steel making face significantly increasing profit margins by 6.3pp and 4.1 respectively. The chemicals, glass and nonferrous metals sector, which are relatively carbon-intensive sectors, also face an increasing profit margin. The machinery, automotive and construction sectors, which belong to the largest German sectors in terms of gross value added, are also having a positive profit margin change.

Figure 2-8: Change in profit margin in percentage points under the IEA 2°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

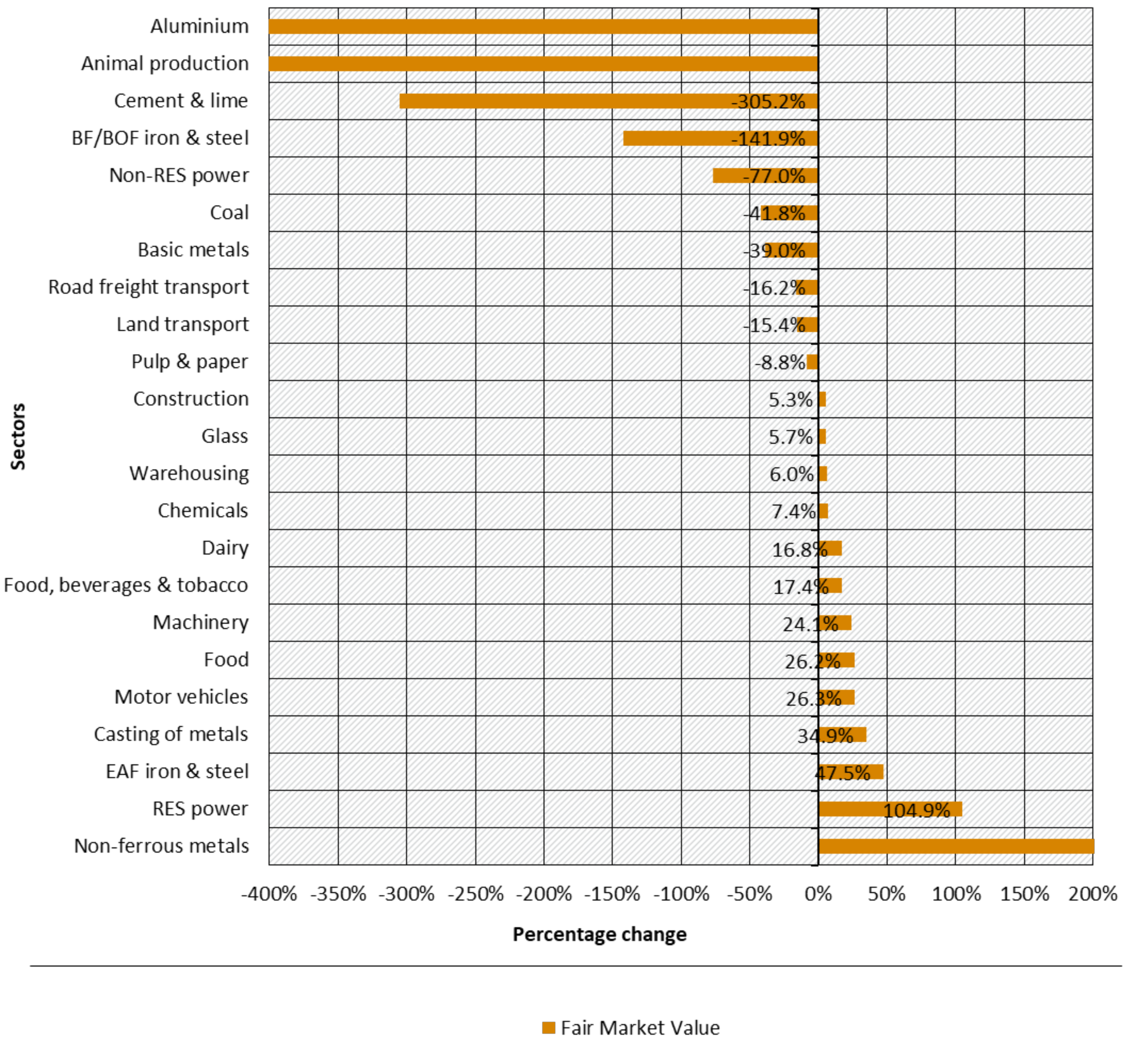
2.4.3 Fair market value change

Figure 2-9 shows the change in fair market value under the IEA 2°C climate scenario. It shows the difference between the sector's future discounted cash flows (DCF) assuming constant 2015 profits from 2015 to 2030 and the sector's future discounted cash flows (DCF) assuming profits under the IEA 2°C climate scenario from 2015 to 2030. For example, if the change is -8.8% as it holds for pulp and paper, then the DCF of profits under the IEA climate scenario from 2015 to 2030 is 8.8% lower than the DCF of constant 2015 profits from 2015 to 2030. The calculation of the fair market value is calculated using the profit changes, which were derived under the stranded asset indicator “profit change”.

As for the profit margin change, the sectors cement & lime, BF/BOF iron & steel, non-RES power and coal face significant reductions in the fair market value. In case of fair market value change, other than for profit margin change, also aluminum and animal production are strongly negatively affected. The reason for this is caused by the way the percentage DCF change is calculated. The aluminum and animal production sector have very low profit margins being close to 0% in 2015. As absolute profits today are therefore close to zero the DCF of constant profits to 2030 is also close to 0. According to chapter 2.4.2.3, under the IEA 2°C climate scenario, the annual profit margin is reduced constantly by -0.5 (aluminum) and -4.5pp (animal production) respectively up to 2030 leading to negative annual profits from 2015 to 2030. As a consequence, the DCF of profits under the IEA 2°C climate scenario is negative. Comparing now the two DCFs of profits with each other results in a high negative percentage change as the denominator is close to zero (making the fair market value also highly sensitive). The absolute changes in comparison to the relative percentage change are, in contrast, much less significant.

The same argumentation but in the other direction also holds for the non-ferrous metals sectors, which observes a significant increase in its fair market. The sector has a profit margin close to 0%, while at the same time observing increasing profits under the IEA 2°C climate scenario from 2015 to 2030. Comparing now the two DCFs of profits with each other results in a high positive percentage change as the denominator is close to zero (making the fair market value also highly sensitive).

Figure 2-9: Change in fair market value under the IEA 2°C climate scenario



Source: Own representation, Navigant – A Guidehouse Company.

2.4.4 Asset value change

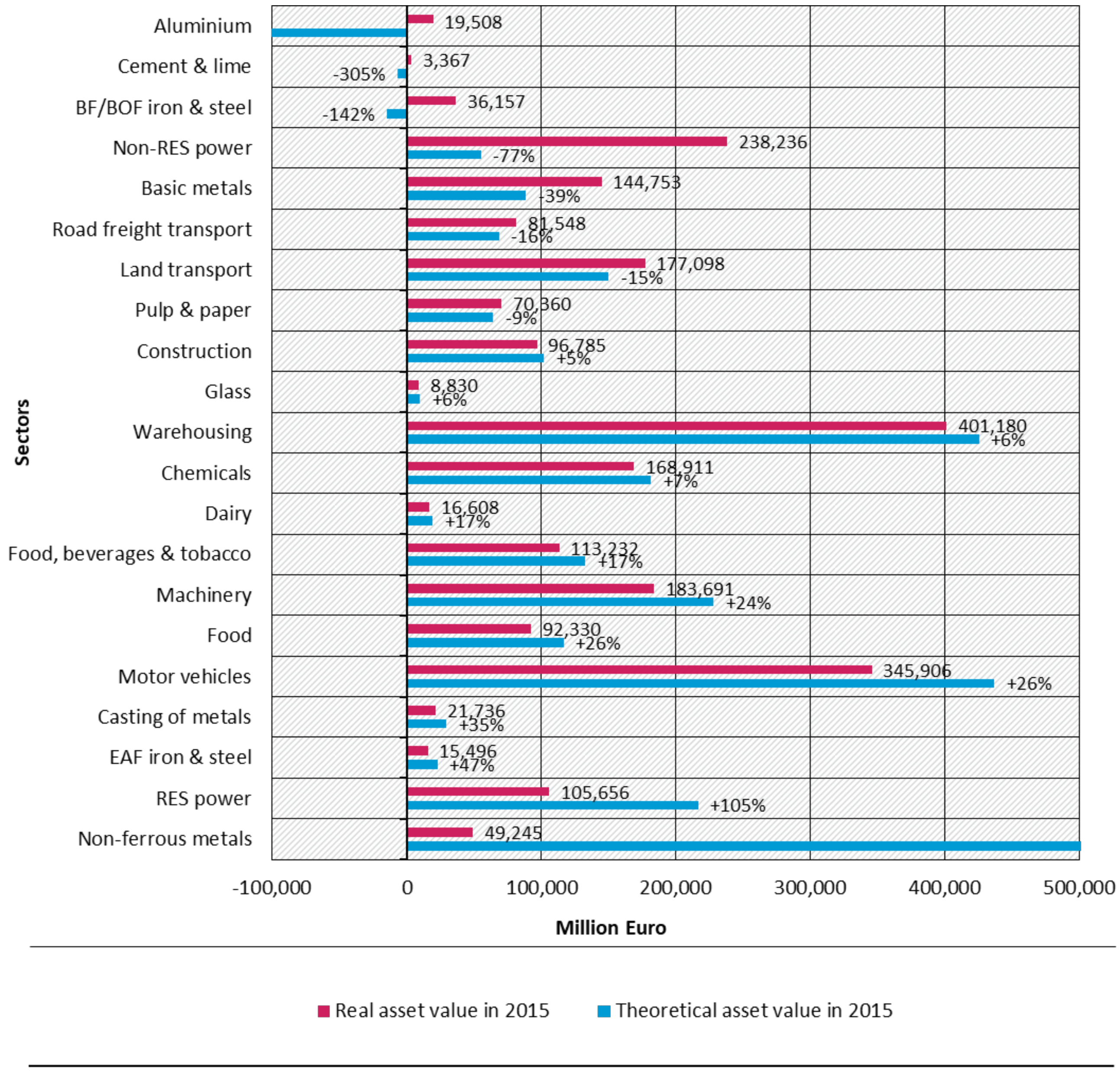
It is important to note that the stranded asset indicator „asset impairment" introduced here is a very simplistic and rough indicator for the change in asset value in German sectors under the IEA 2°C climate scenario. The reason for this is the following: within the scope of this project, it was neither feasible nor intended to build an inventory of capacities in each sector from 2015 to 2030. We were thus not able to provide a projection of planned capacity additions, capacity closures and capacity age structure for each German sector from 2015 to 2030 under the IEA 2°C climate scenario. However, to allow for a thorough analysis of asset value development and thus asset impairment, in reality, such data analysis is indispensable.

To nonetheless allow for some statements on the potential asset value development in German sectors under the IEA 2°C climate scenario, it was decided to develop a very simplistic and rough "asset impairment" indicator. This stranded asset indicator shows the difference between the sector's real asset value in 2015 (taken from statistics) and the sector's theoretical asset value in 2015 assuming investors anticipate future asset devaluation under a low carbon scenario. The theoretical asset value in 2015 is calculated by revaluing the 2015 asset value with the relative change of the fair market value under the IEA 2°C climate scenario. For example, if the fair market value change is -8.8% (rounded to 9% in Figure 2-10) as it holds for pulp and paper, then the theoretical asset value in 2015 is 8.8% lower than the real asset value in 2015. This would mean that the assets of the sector are currently higher valued than they would be if investors anticipated a low carbon scenario. Note that as asset impairment is derived from the change in fair market value, the % change in asset value is identical to the fair market value change.

For the reasons above, the indicator "asset impairment" shall be treated and interpreted with high caution.

Under the IEA 2°C climate scenario, the aluminum, cement & lime and BF/BOF iron & steel sectors are affected the worst. As the fair market value change for these sectors is higher than 100% (see chapter 2.4.3, the theoretical asset value in 2015 would be negative. Consequently, if investors anticipated a low carbon development, capacities in these sectors would reduce/close from 2015 to 2030 and thus the existing asset value in these sectors written off. Sectors such as casting of metals, EAF iron & steel, RES power and non-ferrous metals, in contrast, have a significantly higher theoretical asset value than the real asset value. Consequently, if investors anticipated a low carbon development, capacities in these sectors would increase from 2015 to 2030, increasing the asset value in these sectors (i.e. higher production).

Figure 2-10: Change in asset value under the IEA 2°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

2.5 Evaluation of the impact of carbon risks on sectors in Germany

In the following, the results of the analysis of the effects of carbon risks on economic sectors in Germany under the 2 °C climate scenario of the IEA from chapter 2.4 are summarized. The results under the 1.5 °C climate scenario are presented in Annex 6.4. First, the five German sectors with the highest carbon risks and thus also a strongly negative profit trend (measured by the change in profit margin) are presented in descending order. The sectors with low negative/positive profit development are then identified. Finally, the sectors with positive earnings development are highlighted.

2.5.1 Sectors with a highly negative profit development

Coal. The coal sector in Germany is the sector with the most negative profit development. The profit margin of the sector will be reduced by ~271 percentage points by 2030 compared to 2015.[22] This loss is mainly driven by the decline in revenues, which is estimated at 68%. Most of this decline can be attributed to economic change accounting for 66 percentage points. The energy mix to satisfy the energy demand across sectors might also help to explain this decline, as under the 2 °C climate scenario, the average coal usage of the current coal using sectors decreases by 20%[23]. Revenues at risk - i.e. revenues generated by the coal, oil and gas industries - account for only 2 to 3 percentage points of the overall decline. The costs of the coal sector will fall by 12%, as rising costs for Scope 1 and 2 emissions compared to 2015 will be overcompensated by falling variable costs due to falling output volumes.

Cement & lime. The cement & lime sector in Germany is also showing a strongly negative development in profits. The sector's profit margin will be reduced by ~44 percentage points by 2030 compared with 2015[24]. Looking at the revenue side we see that there will be an increase of revenues by 10 %. Additionally, there will be little to no revenue at risk as the cement & lime sector is not exposed to any industries set at risk. However, the increase in revenues is not sufficient to offset the increase in the total costs by 62%. which are majorly caused scope 1 emission costs.

Non-RES power. The non-renewable electricity supply comprises the conventional, power-generating power plants (coal, natural gas and crude oil). The sector's profit margin will be reduced by ~13 percentage points by 2030 compared to 2015[25]. This loss is expected to be the result of a decrease in revenues by 50%. According to the IEA climate scenario, the Non-RES power sector experiences a negative economic change of 49% (i.e. output decrease by 49%). The revenue at risk can practically be neglected as it only causes a revenue decrease of 1 %. Looking at the cost side, we see a decrease of 43%. Again, this is driven by the output reduction due to economic change. The cost reduction, however, is not sufficient to compensate for the loss of revenue, as the costs fall less sharply than revenues due to rising Scope 1 emission costs.

BF/BOF iron & steel. The sector's profit margin will be reduced by ~11 percentage points by 2030 compared to 2015[26]. The main driver for this is the revenue decrease of 11%. This decrease stems from economic change as the BF/BOF iron & steel production route is replaced by the EAF iron & steel production route. Looking at the cost, we see a total decrease of 1%. The significant cost reduction in the category other variable costs with 9% is mostly offset by an increase in scope 1 emission costs by 6% and increasing abatement costs.

Animal Production. The sector's profit margin will be reduced by ~5 percentage points by 2030 compared to 2015[27]. The revenue side increases by 12 % with no revenue at risk. At the same time, the cost structure is expected to increase by 17% with 10 percentage points coming from other variable cost and 7 percentage points coming from scope 1 emission costs.

2.5.2 Sectors with low or no negative/positive profit development

When looking at the stranded asset indicator profit change, there are several sectors whose profit margin is not or slightly negatively/positively affected by the changes set out in the IEA low carbon scenario. These sectors are basic metals, pulp & paper, aluminium, chemicals, glass, warehousing, construction, dairy, non-ferrous metals, food, beverages & tobacco and casting of metals. When looking at the profit composition of these sectors there is no significant change when adapting for the low carbon environment parameters. The cost and revenue

[22] Note that the profit margin changes from -52.3% to -323.8%.

[23] (taken from worksheet data IEA 2° scenario Cell S193-201)

[24] Note that the profit margin changes from 6.7% to -36.9%.

[25] Note that the profit margin changes from 5.2% to -8.2%.

[26] Note that the profit margin changes from 3% to -7.7%.

[27] Note that the profit margin changes from 0.1% to -4.4%.

increase across these sectors vary between 10-20%, which can be traced back to economic change and thus sector growth.

2.5.3 Sectors with a positive profit development

As could be seen in Figure 2-8, there are two sectors with an extraordinary increase in the profit margin until 2030. These two sectors are EAF iron & steel and RES power. This positive development is caused by the positive impact on production levels driven by economic change. The RES sector is expected to grow by 97% (extraordinary growth rate for a sector still in its growth phase) and the EAF iron & steel sector by 14 % (extraordinary growth rate for a sector in its mature growth phase). The machinery and automotive, which belong to the largest German sectors in terms of gross value added, are also having a positive profit margin change of around 1.3%. It is important to note, however, that this development may not hold anymore if downstream scope 3 emissions were included in the operator carbon risk assessment. For example, car manufactures would in that case face much higher emission costs as they would be responsible for the emissions produced by their sold cars. This would certainly affect the profit margin substantially.

Comparison of Moody's Heat Map with the sectoral findings of WP1

In its so-called Heat Map, the credit rating agency Moody's **qualitatively** assessed the **credit impact** of **environmental risks** globally for **86 sectors**. The relative exposure of sectors is assessed in terms of **materiality and timing** of any likely credit effect.

The forward-looking scoring reflects the potential of environmental risk to affect credit rating, i.e. the impact on the **likelihood to default**, for example by reducing the expected cash flow generation. The effects of environmental hazards (**physical risk**), and the consequences of regulation to prevent or reduce those hazards (**regulatory risk**, **liability risk**) are considered. Furthermore, **mitigants to these risks**, such as the ability to pass through increased costs or time to adjust the business or financial model, are considered.

In addition to the overall credit risk, five subcategories of environmental risks were scored to identify key drivers of the overall score for each sector. In contrast to the overall scores, these subcategories were assessed based on the sector's general exposure to the particular environmental risk.

The five subcategories are:

1. Air pollution (excluding CO2 emission but including greenhouse gases that have been regulated as pollutants outside the climate regime, i.e. NOx)
2. Soil and water pollution and land use restrictions
3. Carbon regulation
4. Water shortages (including climate change induced droughts and water shortages)
5. Natural and man-made disasters (including climate change induced hazards)

The **Carbon regulation subcategory** assesses the impact of current and likely future policy initiatives to reduce CO2 and other greenhouse gas emissions at national and global level. It explicitly excludes physical risks of climate change, which are included in the water shortages subcategory and the disasters subcategory. Thus, this subcategory broadly matches with the scope of the present analysis. Furthermore, it is one of the two subcategories most frequently scored as high or very high exposure (together with air pollution) and is therefore a **key driver for the overall environmental risk score**.

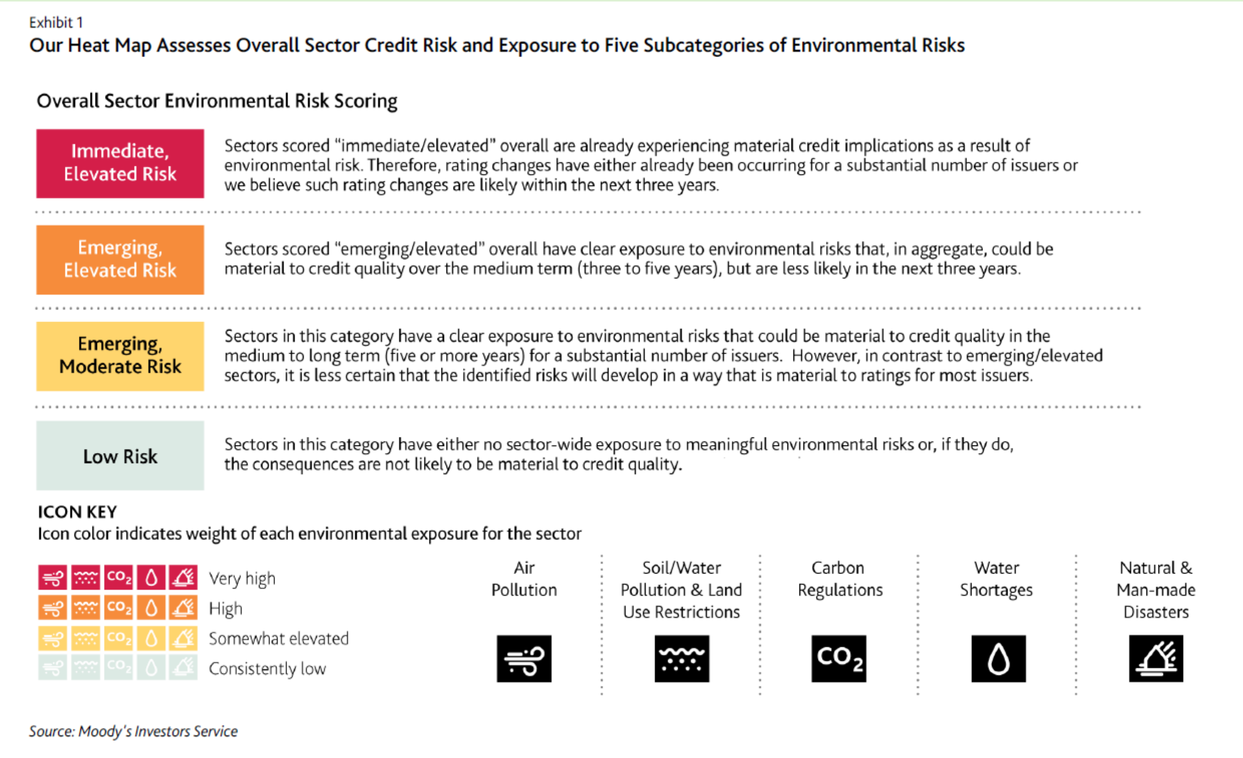
Overall, the Heat Map's credit risk is lower the more distant in future the environmental impact likely materialises, which is especially the case for climate change physical risks and future policies. In consequence, more time remains for sectors to adapt their business model / financial profile to the projected developments by **adopting mitigants to the risks**. Thus, **timing** and the **potentially material role of technology** has important influence on the assessment of the credit risk. For example, even if the automotive industry might be highly exposed to carbon regulation, the fact that there is currently no effective regulation in place, but new technologies are already being developed reduces the sector's credit exposure to likely future carbon policies.

Summary of key differences between the Heat Map and the approach described above (i.e. Carbon Bubble approach):

- Qualitative analysis
- Open-ended time horizon but rating reflects whether risk is immediate (now), emerging and elevated (in 3-5 years), emerging moderate (in 5+ years), or low (no timeframe specified)
- Assesses physical and regulatory environmental risk (including risk of liability/clean-up payments in case of hazards and disasters). But carbon regulation identified as most important driver.
- Timing of risk materialisation and risk mitigants considered – therefore considers opportunities and time to adapt the business model / financial profile (Carbon Bubble: only risks)
- Sectoral coverage:
    1. Focus on sectors that are relevant for credit markets, global – therefore more focus on oil and gas (Carbon Bubble: sectors that are relevant for Germany)
    2. Covers as well financial products (i.e. Covered Bonds) and financial sector actors (i.e. Securities Industry and Financial Intermediaries, Life insurances)
    3. In total more sectors (86) but less differentiated in terms of technology (iron&steel, power generation)

Rating categories

Figure 2-11: Rating categories in Moody's Heat Map Assessment



Source: Moody's Investor Service 2015: Heat Map Shows Wide Variations in Credit Impact Across Sectors.

Rating compared with the Carbon Bubble WP1 rating:

There are two ways of assessing whether the Heat Map sectoral assessment aligns with the Carbon Bubble WP1 ranking. First, to look at the overall Heat Map assessment, i.e. the environmental risk assessment. Second, to focus on the carbon regulation subcategory, which will be done in the following. However, since carbon regulation is one of the two most important drivers of the overall environmental risk scoring, results are similar with either approach.

Overall, the Heat Map sectoral assessment aligns with the Carbon Bubble WP1 sectoral assessments (details see below). Differences that are to be found mainly root into the **different sectoral boundaries**. The Heat Map, due to its focus on credit impact, looks at sectors based on the **business model/financial profile**. The Carbon Bubble project rather differentiates sectors amongst main **technologies**.

Overall, the three sectors in the "**Very High Risk**" category regarding the credit impact of carbon regulations in the Heat Map correspond to the Carbon Bubble results. The Heat Map categorizes rated debt in the coal sectors, i.e. **coal mining** and **coal terminals**, as being very highly exposed to carbon regulation risk. This is consistent with the Carbon Bubble findings, where there the **coal** sector is listed first as entailing the highest carbon regulation risk, i.a. in terms of expected profit loss.

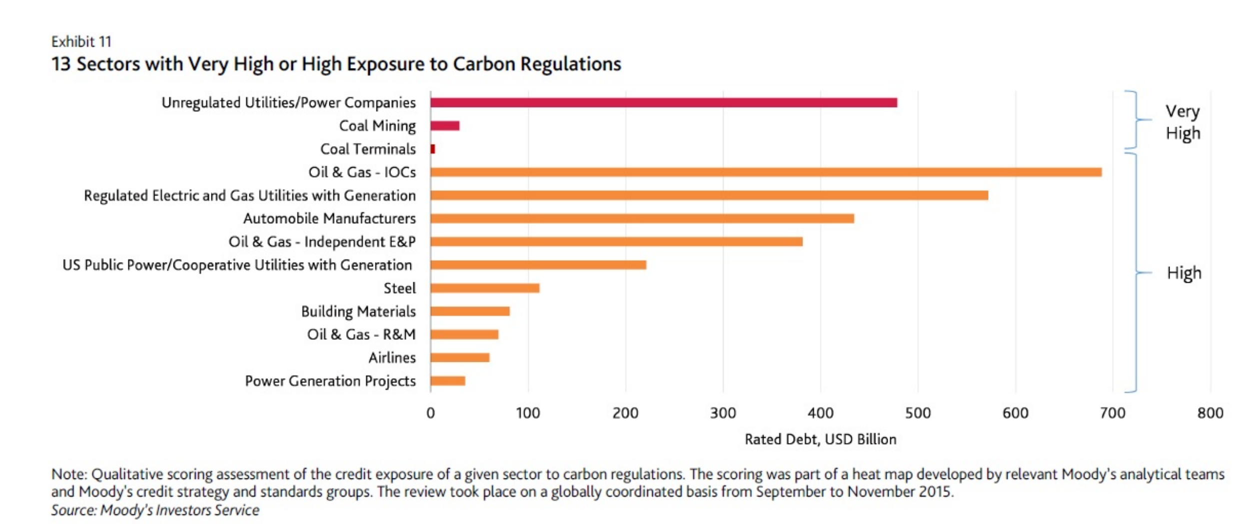
The large amount of debt in the **unregulated utilities and power companies** is very exposed to carbon regulation in the Heat Map ("**very high risk**"). The reason is the enormous economic pressure that competitive renewables exert on standard power companies' business models in unregulated energy markets. The Carbon Bubble rating differentiates **non-renewable power companies** from **renewable power**, ranking the former amongst sectors with the highest Carbon Operator risk while attributing a *positive* exposure to carbon regulation to the latter. Therefore, the findings match the qualitative reasoning of the Heat Map analysis.

A similar effect holds for the assessment of the **Iron and Steel sector**. This sector faces "high risk" of carbon regulation in the Heat Map. The Carbon Bubble rating, in contrast, differentiates between the very emission-intensive and therefore highly exposed **blast furnace (BF)/basic oxygen furnace (BOF) iron & steel** production (ranked fourth in the carbon regulation risk ranking) and **electric arc furnace (EAF) iron & steel** production. Emissions in the latter can be reduced much more easily, such that it even features a positive exposure to carbon regulation in the Carbon Bubble assessment.

For **Automobile manufacturers** in contrast, the assessment differs slightly. These feature the "**High risk**" category in the Heat Map. For **automotive supplier**, the credit risk from carbon regulation is only "**somewhat elevated**". The Carbon Bubble assessment does not find a profit loss for **machinery** and **motor vehicles**. The Heat Map assumes that the automotive suppliers sector has more opportunities to adapt to carbon regulation and make use of new technologies and markets.

The **largest difference in the assessment** is found between the assessment of **animal production** in the Carbon Bubble analysis (amongst top 5 highest operator carbon risk) and the **protein and agriculture** sector in the Heat Map (consistently low carbon regulation risk). However, in the Carbon Bubble assessment, Food, Beverages and Tobacco as well as Dairy both have a neglectable carbon operator risk. Therefore, the difference arises likely due the more aggregated view on this sector in the Heat Map.

Figure 2-12: Sectors with very high or high exposure to carbon regulations in Moody's heat map



Source: Moody's Investor Service 2016: Moody's To Analyze Carbon Transition Risk Based On Emissions Reduction Scenario Consistent with Paris Agreement

3 Carbon stress test for financial institutions

The carbon risks in the real economy, identified in Chapter 2, can potentially lead to risks for the financial sector. For this reason, the financial relevance of carbon risks for the financial market was examined and a climate risk scan tool was developed. The main objective of the tool is to identify and assess possible exposures of German financial institutions to climate-related financial risks and to support financial institutions in implementing the TCFD recommendations.

3.1 Background

3.1.1 Climate and carbon risks in the financial system

There are two parallel streams of research on climate-related financial risk. A stream of "gray" literature carried out by NGOs, think tanks and the industry has elaborated narratives on how risks could materialize and provided estimates of risk in relevant case studies. A stream of scientific literature, published on peer-reviewed journals, has provided science-based methodologies, statistics and quantitative models to assess climate risk.

In the gray literature, the role of stranded assets and climate related risks was estimated in specific countries or sectors. Several studies have investigated the role of stranded assets and climate related risks in specific countries or sectors. Weyzig et al, 2014, is the first study that carried an estimation of the risk of stranded assets to investors. The exposure (via equity, bonds and loans) to the fossil fuel industry was estimated to be 460-480 billion Euro for European banks **(1.4% of total assets),** 300-400 billion for European insurance companies **(4% of total assets)** and 260-330 billion Euro for European pension funds **(5% of total assets).** The European Systemic Risk Board (ESRB, 2016) discusses possible chains of transmissions of transition risks on the European financial system. In a study by the Dutch Central Bank (Schotten, 2016) the exposure of Dutch financial institutions to loans from the fossil fuel sector were estimated. The estimated exposure to the fossil fuel sector was Euro 39.7 billion for the three largest Dutch banks **(2% of the balance sheet**, almost entirely in loans), Euro 37.8 billion for the three largest Dutch pension funds (approx. **5.5% of the balance sheet**, in commodities, equities, bonds and others) and Euro 9.3 billion for the three largest Dutch insurances (approx. **1.2% of the balance**

sheet, mainly in bonds and some equity).

In the scientific literature, Dietz (2015) investigates the effect of climate change (physical risks) on asset values at global level. Battiston et al. (2017), the climate stress-test of the financial system, is the first scientific methodology to incorporate the knowledge from climate science and climate economics into forward-looking shocks and into standard metrics of risk for individual institutions and for the financial system as a whole. The empirical application extends the focus from fossil companies to utilities and energy-intensive industries into the analysis of listed equity holdings in Europe. Results show that between **4.4% and 12.9%** (depending on the type of investor) of equity portfolios are invested in the **fossil fuel industry**, and **26-33% in energy-intensive industries**. The study also included risks from so called second round effects, that can result from financial interactions, such as interbank lending. Such second-round effects, which were crucial in the financial crisis of 2008/09, can amplify positive and negative effects. Hence, they can decrease the accuracy of risk estimations and increase default rates.

Specific estimates of climate related financial risk for Germany do not yet exist. A first estimate of the exposure of German financial institutions to loans from emission-intensive sectors (Dombret, 2018) found a low exposure to the coal mining sector (Euro 840 million), a somewhat higher exposure to the extraction of natural gas and crude oil and the processing of coal and mineral oil (Euro 20 billion), and **Euro 157 billion** for energy supply. This corresponds to approximately 16% of loans to domestic companies or **4.7% of loans to non-financial institutions.** For individual banks, however, loans to these sectors account for a higher proportion of loans, e.g. individual institutions have up to 2% of their loans (above 1 million Euro) in coal mining and up to 6% in gas and oil production. Southpole (2016) investigated the equity funds in Germany and found similar results. Only about **0.7% of the equity portfolio** is invested in the **coal sector** and about **4% in the oil & gas sector,** but **22% is invested in power generation and industry (energy-intensive sectors**). Loans, bonds or private equity have not been analyzed so far.

3.1.2 Existing methods for the assessment of climate-related risks

Most scientific methods to assess climate-related risk build on Battiston et al. (2017) and the idea to integrate scientific knowledge about climate policy scenarios and climate economics into the assessment of financial risk. The classification of Climate Policy Relevant Sectors, introduced in Battiston et al. (2017) has been used by EIOPA in their Financial Stability Review of Dec. 2018 and by ECB in their Financial Stability Review of June 2019. Further, a stream of scientific work has extended the assessment of risk to a variety of asset classes and contexts. Monasterolo et al. (2018) focus on energy infrastructure loans and development finance. Roncoroni et al. (2019) extend the methodology of stress-testing to the context of investment funds. Stolbova et al. (2018) analyse the chains of distress amplification of climate policy risk at the macro-economic level. Finally, Battiston and Monasterolo (2019) develop a framework to formalize the investor's decision making under the uncertainty related to climate risks and provide a specific method to analyse climate risk on portfolios of sovereign bonds. All these methods are published and the details about assumptions and formulas are publicly available. See Battiston (2019) for a review.

There is also a set of methods and tools for assessing financial risks developed by NGO's or the industry. However, most tools are provided on a commercial basis. They include:

- The Carbon Asset Risk Framework by WRI and UNEP FI (2015) provides a comprehensive framework for Assessing Carbon Risk and Assessing and Managing Carbon Asset Risk. It shows how carbon risk exposure can be assessed at different levels and how stress-tests can be applied at the operator level or the portfolio level. A 2°II (2015) study provides an overview of climate and carbon stress tests, differentiating between bottom-up and top-down approaches. Bottom-up approaches work at the level of physical assets and/or financial assets and top-down approaches work at the level of individual portfolios or the financial system as a whole.

- The Cambridge Centre for Sustainable Finance (2016) prepared a study as input for the G20 Green Finance Study Group, which investigated how different financial institutions are taking climate risks (physical and transition risks) into account in their assessment of financial risks (business risk, credit risk, market risk and legal risk). They use 14 case studies as practical examples, showing assessments and tools for physical as well as transition risks. Regarding the valuation of financial impacts, most studies or tools focus on market[28] and credit risk[29]. Only one study looks into legal risks and three studies look into business risks.
- Stress-tests can be applied at the level of the operator or at portfolio level, or at the level of the financial system. Some methods specialize on specific risks (i.e. drought risk) or focus on specific asset classes (often either equity or loans/bonds). Only Mercer (2015) tries to include all major asset classes. The others seem to be more focused on specific asset classes. Moody's (2015a, 2015b) and S&P (2015) offer a more comprehensive approach for loans and bonds. SASB (2016), BNP Paribas (2016) and 2°ii & Co-Firm (2017) have developed risk frameworks for equity. ICBC (2016) has developed a tool with a regional focus on China. BNP Paribas however focuses on the impact of a carbon price. 2°ii and CO-Firm focus on listed equity and bonds in specific climate-related sectors. GIZ and UNEP FI (2017) have developed an excel-based tool but focusing on drought risks. Blackrock (2015) and Beyond Ratings are offering a framework for climate risks in sovereign bonds but have not yet developed a stress-test tool.
- The stress-test suggested by Battiston et al. (2017) is more comprehensive, as it also includes second round effects and therefore a methodology for assessing the effect on the financial system as a whole.
- A recent study, applying a similar risk assessment approach to the one chose in this study, is the "Extending Our Horizons" report (UNEP FI, 2018), published in April 2018. UNEP FI, together with leading international banks (representing more than USD 7 trillion in assets) developed the approach to promote climate transparency in financial markets and to enable banks to follow the TCFD recommendations.

3.2 Design and method of the Carbon Quick Scan tool

3.2.1 Description of the method

The aim of this tool is to create more awareness for climate-related risks and opportunities among financial institutions and to provide insights on where a potential overvaluation of carbon related assets (in light of more ambitious climate policy) might become a financial risk.

All major asset classes are taken into account: Equities, corporate bonds, loans, government bonds and mortgages. The selection of climate scenarios and industrial sectors for the **carbon quick scan tool** is based on the results of the **Operator Carbon Risk Tool** (Chapter 2) and on additional data for the asset classes mortgages and government bonds. The geographical focus is on Germany, but an extension to other countries is possible.

There are **three main drivers for operator carbon risks**: cost increase, demand reduction and increased investment costs. Figure 3-1 shows the extent to which different asset classes are affected by which drivers and what kind of data is used in the calculations. For the calculation of the change in

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[28] Market risks incorporate economy wide effects due to fluctuations in commodity prices (oil, coal, ...), food price shocks or technological breakthroughs

[29] Credit risks include the impact of carbon- and energy regulation on the financial performance of investees.

profit in Chapter 2, changes in costs (both fixed and variable) and revenues were considered separately. Since costs and revenues are directly related to profit, and in order to enable the user to understand the reason for the profit changes (revenues or costs), the distinction between cost increase and demand reduction was chosen. Since investment costs affect the value of the asset (and profit through depreciation), they are also considered separately.

Figure 3-1: Asset class, carbon risk drivers and data used

ASSET CLASS	CARBON RISK DRIVERS			DATA USED
	Revenue at risk	Costs	Economic change	Data used
Equity	☑	☑	☑	Industry (sub)sector averages
Corp. bonds/loans	☑	☑	☑	
Sovereign bonds		☑		Transition costs
Mortgages		☑		Renovation costs

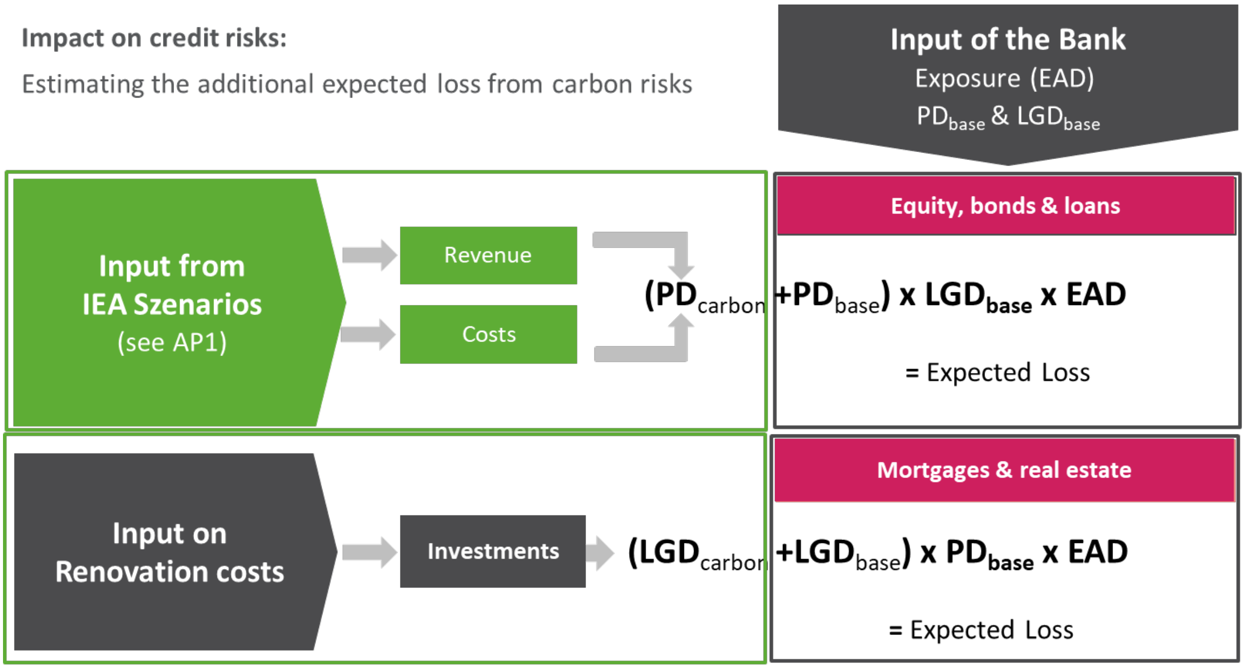
Source: Own Representation, Triple A – Risk Finance.

The carbon quick scan tool focuses on credit risks, where an **expected loss** is calculated for each asset class. The quantification of Expected Loss is common practice within the risk frameworks of banks. Furthermore, the report "Extending Our Horizons" (UNEP FI, 2018) which aims at providing methodological guidance on the assessment of transition-related risks and opportunities to banks, also uses the expected loss for the portfolio impact assessment.

Expected loss is the value of a possible loss times the probability of that loss occurring. The Expected Loss (EL) on an individual credit is equal to the probability of default (PD) multiplied by the bank's exposure in case of default (Exposure at default - EAD), further multiplied by the percentage of the exposure which will ultimately be taken as a loss should a default occur (Loss-given default - LGD).

The **carbon quick scan tool** determines the additional expected loss due to carbon risks, as shown in Figure 3-2. For equities, loans and corporate and government bonds, it determines an additional probability of default (PD), which increases with an increase in the carbon risk drivers: e.g. cost increase and decline in revenue. For mortgages, it calculates an additional loss given default (LGD), which increases with the required renovation costs.

Figure 3-2: Calculation of the expected loss in the climate risk scanner



EAD = exposure at default (in €); PD = Probability of default (%); LGD = Loss given default (%)

Source: Own representation, Global Climate Forum.

LGD is used in the calculation of capital requirements.

The financial impact per asset classes is measured in terms of a **delta in the Expected Loss (EL)** caused by the energy transition.

The expected loss due to transition risk for mortgages is defined as:

Expected loss transition risk = (expected loss including transition risk - Expected loss base)

$$EL_{transition\ risk} \quad = \quad EL_{base\ incl\ transition\ risk} - EL_{base}$$

For each asset class, three steps of analysis are performed:

- Step 1: determining **expected loss transition risks**, using industry data or individual bank data.
- Step 2: determining the **expected loss including transition risk**, using data resulting from different climate scenarios (changes in revenues, costs or asset values per sector and renovation costs for buildings).
- Step 3: determining the **delta in Expected Loss (EL)** derived in step 1 and step 2.

3.2.2 Example calculations

For the purpose of illustration, we use the portfolio of all German banks as an example portfolio to calculate the carbon-related risk. As reported, according to Deutsche Bundesbank (2016a), the aggregate of all German banks have 4223 bn Euro in loans to non-financial institutions (non-MFIs), of which **147 bn in loans and bonds to the electricity sector.**

For loans to the electricity sector, we assume that all loans and bonds are in the non-renewable electricity sector. We assume a PD (base) of 3% and LGD (base and transition) of 40%. We assume that the cost and revenue disruptions lead to a higher rate of defaults. LGD stays the same.

Step 1: determining expected loss without a transition:

EL base = 147 bn Euro* 3% * 40% = 1.764 bn Euro

Step 2: determining the expected loss under a fast transition scenario:

Given the IEA 2°C scenario, the change in revenue is -49.8% and the costs of the transition (related to scope 1, scope 2 and scope 3 emissions), corrected for the preparedness, leads to an additional shock for this sector of -40.5%. Furthermore, the estimated historical sensitivity between revenue and the absolute change in default is 0.54%.

Hence, the following adjustment in the PD rate is derived: (-49.8% (revenue shock) - -40.5% (cost shock)) x (-1) x 100 x 0.54% = **5.049%**

EL transition = EAD x PD x LGD (transition) = 147 bn Euro * (3% + 5.049%) * 40% = 4.732 bn Euro

Delta EL = EL transition - EL base = 4.732 – 1.764 bn Euro = **2.968 bn Euro**

2.968 bn Euro is equal to 2% of the total value of loans to the electricity sector (147 bn Euro).

For mortgages, we assume a PD (non-performing loans in base and transition scenario) of 3%, and LGD (base) of 10%. We assume that the probability of default remains the same for both scenarios. However, we assume that in the transition scenario all buildings need to be renovated to reach a 40% reduction of energy use. Hence, all mortgages have a lower market value (depending on the required investment for renovation), hence their loss given default (LGD) increases.

Step 1: determining expected loss without a transition:

EL base = EAD x PD x LGD(base) = 526 bn Euro * 3% * 10% = 1.578 bn Euro

Step 2: determining the expected loss under a fast transition scenario:

Given the German target of reducing energy use in buildings by 40% in 2030 (80% in 2050) and using average renovation costs of 19,700 Euro per unit (with an average floor space of 100m2) for a full renovation., we estimate average costs by 2030 to be 7,880 Euro. Assuming the average value of outstanding loans to be 150,000 Euro, renovation costs amount to 5.25% of the average outstanding value of a loan, increasing the potential loss given default (LGD).

EL transition = EAD x PD x LGD(transition) = 526 bn Euro * 3% * (10%+5.25%) = 2.406 bn Euro

Delta EL= EL transition - EL base = 2.406 – 1.578 bn Euro = **0.827 bn Euro**

0.827 bn Euro is equal to 0.15% of the total value of mortgage loans (526 bn Euro) but approximately a 50% increase in expected loss from mortgages.

For government bonds, the country's rating is used as the basis for the calculation. Based on the example of Germany, an LGD of 20% (for government bonds with an A rating) and a one-year default probability of 0.0149% (source: Bloomberg) are used.

Step 1: determining expected loss without a transition:

EL base = EAD x PD x LGD = 0.014886% * 20% * 20 billion Euro = 595,440 Euro

Step 2: determining the expected loss under a fast transition scenario:

For this purpose, the country's transformation capacity and the possible change in the theoretical PD must be determined. The "climate change performance index"[30] is used as an indicator of a country's transformation capacity. Germany has a value of 56.58 (of 60 points). The average transformation cost for all countries was calculated using IEA and IPCC data: Transformation costs between 0.15% and

[30] www.climate-change-performance-index.org

0.52% of global GDP are assumed. Based on data from Bloomberg on the ratio of a change in the country's GDP to a change in the probability of default, we obtain a rating sensitivity of 0.0038 % per 1 % GDP change. This range is used as a proxy for the costs for the different countries.

This leads to a change in the PD value from: **0.014886 % to 0.014964 %** (see documentation of the Carbon Quick Scan Tool for a more detailed description).

EL transition = 0.014964% * 20% * 20 billion Euro = 598,560 Euro

Delta EL = 598,560 – 595,440 Euro = 3,120 Euro

The risk for German government bonds is therefore considered to be very low.

These calculations are the basis of the **Carbon Quick Scan tool**. A separate documentation of the Carbon Quick Scan tool provides more details on assumptions behind the calculations.

3.3 Exposure of German financial institutions

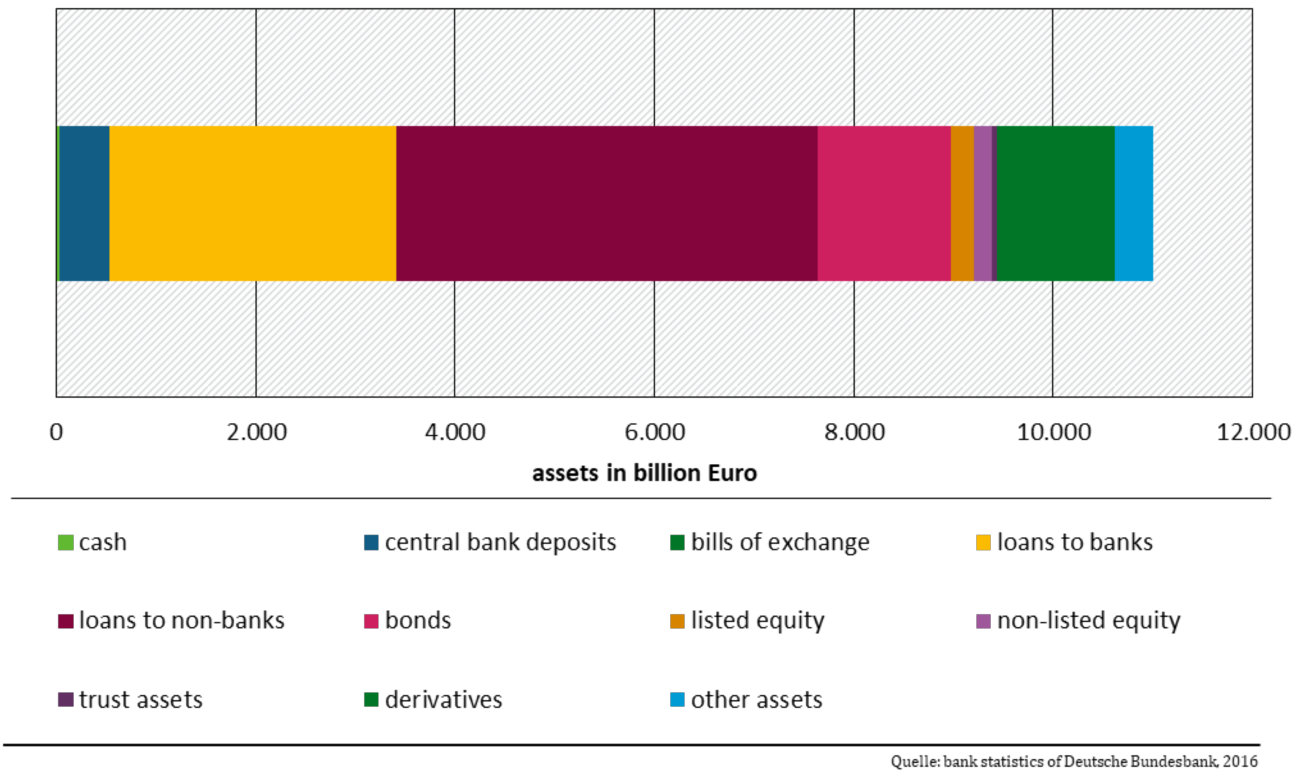
The previously described analysis illustrated the design and methodology of the **carbon quick scan tool**, **which can be used by financial institutions** to gain more insight into their exposure to transition risks. The economic sectors were selected on the basis of the Operator Carbon Risk Tool (Chapter 2). In addition to exposures to the economic sectors identified in the Operator Carbon Risk Tool, exposures to other financial assets such as mortgages and government bonds are also considered.

This chapter examines the exposures of German financial institutions to various asset classes and economic sectors.

3.3.1 Asset structure of German banks, pension funds and insurances

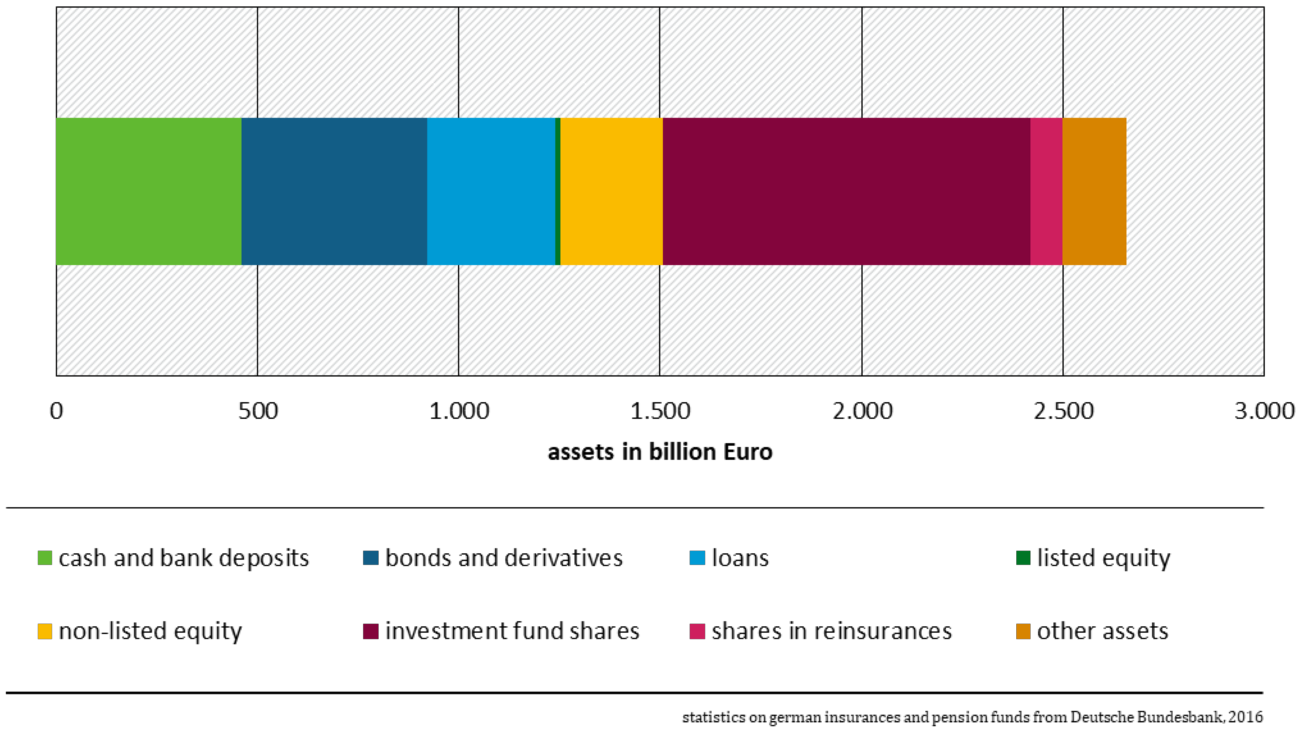
Before analyzing the exposure to climate-related sectors, it is crucial to understand through which financial instruments this exposure is realized. Taking a closer look at the financial assets of German institutions reveals that banks are primarily exposed via debt (loans to households and companies as well as government and corporate bonds), while investment funds and pension funds are more exposed via equity holdings (direct or indirect).

Figure 3-3: Assets of German banks in 2016 (aggregated)



Source: Own representation, Global Climate Forum, based on Deutsche Bundesbank (2016a).

Figure 3-4: Assets of German insurance and pension funds in 2016 (aggregated)



Source: Own representation, Global Climate Forum, based on Deutsche Bundesbank (2016b).

Figure 3-3 shows the asset allocation of German banks (aggregated) by asset class[31]. It should be noted that the German banking system has a very heterogeneous structure. There is a large proportion of regional public banks (Landesbanken), savings banks and cooperative banks (Sparkassen and Genossenschaftsbanken), which are characterized by different investment and lending structures. These banks predominantly hold loans to banks and non-banks as well as bonds and other fixed-income securities, while the exposure to equity is small. Credit banks and large banks hold a significant part of their balance sheet in the form of various types of derivatives and loans to other banks that do not fall within the scope of this project. However, as mentioned earlier, these instruments can become an important multiplier of first-round effects.

Figure 3-4 shows holdings of German insurance and pension funds across several financial instruments. It highlights the fact that the most important assets for insurance and pension funds are the shares in investment funds. It is therefore crucial to analyze their shares and investment fund holdings in order to analyze the exposure of insurance and pension funds to climate-relevant sectors.

3.3.2 Debt and equity exposure to carbon-intensive sectors

Banks are the largest financial institutions in Germany and loans are the most important financial instrument for them. Therefore, we provide additional insights on the exposure of various German banks to climate-sensitive sectors via fixed-income instruments.

As data on bank loans is usually not publicly available, we use Deutsche Bundesbank's "Millionenkreditmeldungen" (Large Credit Database reporting loans and bonds above 1 million Euro at the end of 2015). These numbers should be understood as an estimate, due to the fact that the large credit dataset only contains loans and bonds above 1 million Euro and only reports sectors at 2-digit level. The sectors identified for the purpose of this project were reported at 2 and 4-digit level. In the case of 4-digit level sectors, the higher-level sector (2-digit) was chosen. Therefore, the number of sectors is smaller than in Chapter 2. This shows that credit databases should be improved, to allow for a more detailed analysis of loans at sub-sector level.

A first estimation by Dombret (2018) showed that German financial institutions have outstanding debts in the **energy supply sector amounting to 157 billion Euro** (as well as 840 million Euro in coal mining and 20 billion Euro in the extraction and processing of fossil fuels). Our analysis of the loans and borrowings of German financial institutions confirms this estimate: the largest share (approx. **145.6 billion Euro**) of loans and borrowings is held in the **electricity and gas sector** in Germany and abroad (see Figure 3-5), a sector with high transition risks.

In addition, this report looks at other sectors (see Chapter 2) that may be affected by the transition. On the one hand, there are sectors with high transition risks, but which account for a smaller share of lending by German banks: **Coal mining** (685 million Euros), **glass, cement and lime** (7.7 billion Euro), **iron and steel** (15.3 billion Euro) and **animal production** (20.6 billion Euro). The shares in lending to these sectors add up to approx. **44.3 billion Euro** and can be found in Figure 3-5.

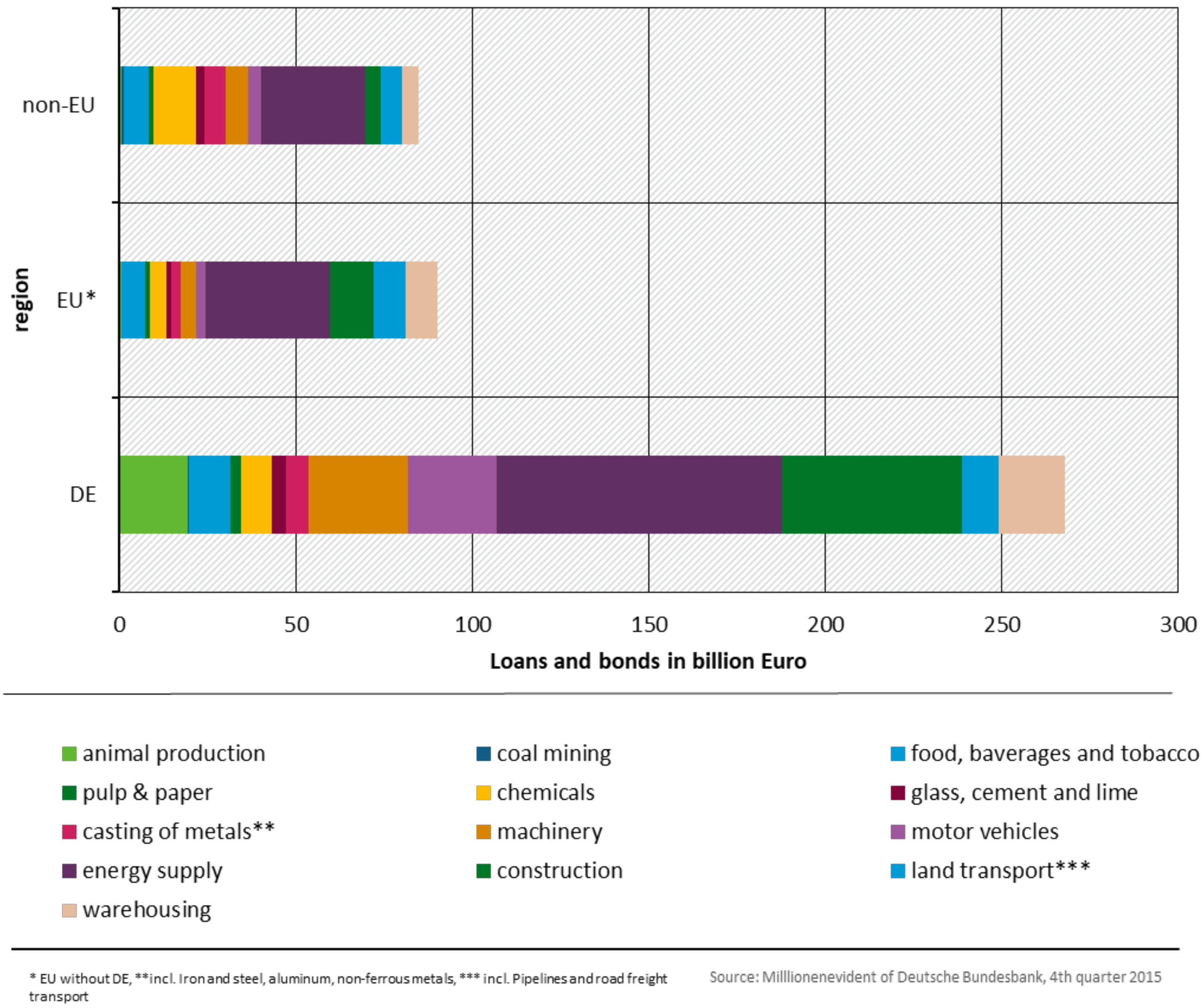
On the other hand, there are carbon-intensive sectors, which are considered more adaptable according to this study (moderate transition risk): the **construction sector** with 68 billion Euro, **mechanical engineering** with 38.6 billion Euro, **vehicle construction** with 31.5 billion Euro, **warehousing** with 32 billion Euro and **land transport and pipelines** with 25.5 billion Euro, **food and beverages** with 25.7 billion Euro, as well as the **chemicals sector** with 25.5 billion Euro. The shares in lending to these

[31] Bonds and other fixed income securities, cash, central bank deposits, derivatives, equity and other non-fixed income securities, holdings in affiliated undertakings, loans to MFI (MFI stands for Monetary Financial Institutions (e.g. banks)), loans to non-MFIs, notes payable, other fixed income assets, treasury bills, trust assets/property.

sectors add up to approx. **221.3 billion Euro** and can be found in Figure 3-5. However, according to this analysis, these sectors are less affected by transition risks.

Additionally (but not included in the Figure), exposures to the **real estate sector**[32] in Germany via loans and bonds are in the order of **EUR 371 billion and a further EUR 155 billion abroad**. This underlines the importance of a separate analysis of mortgages in the carbon quick scan tool.

Figure 3-5: Loans and bonds of German banks and insurances in emission-intensive sectors in Germany, EU and non-EU countries in 2015



Source: Own representation, Global Climate Forum, based on “Millionenevidenz” of Deutsche Bundesbank,(2015).

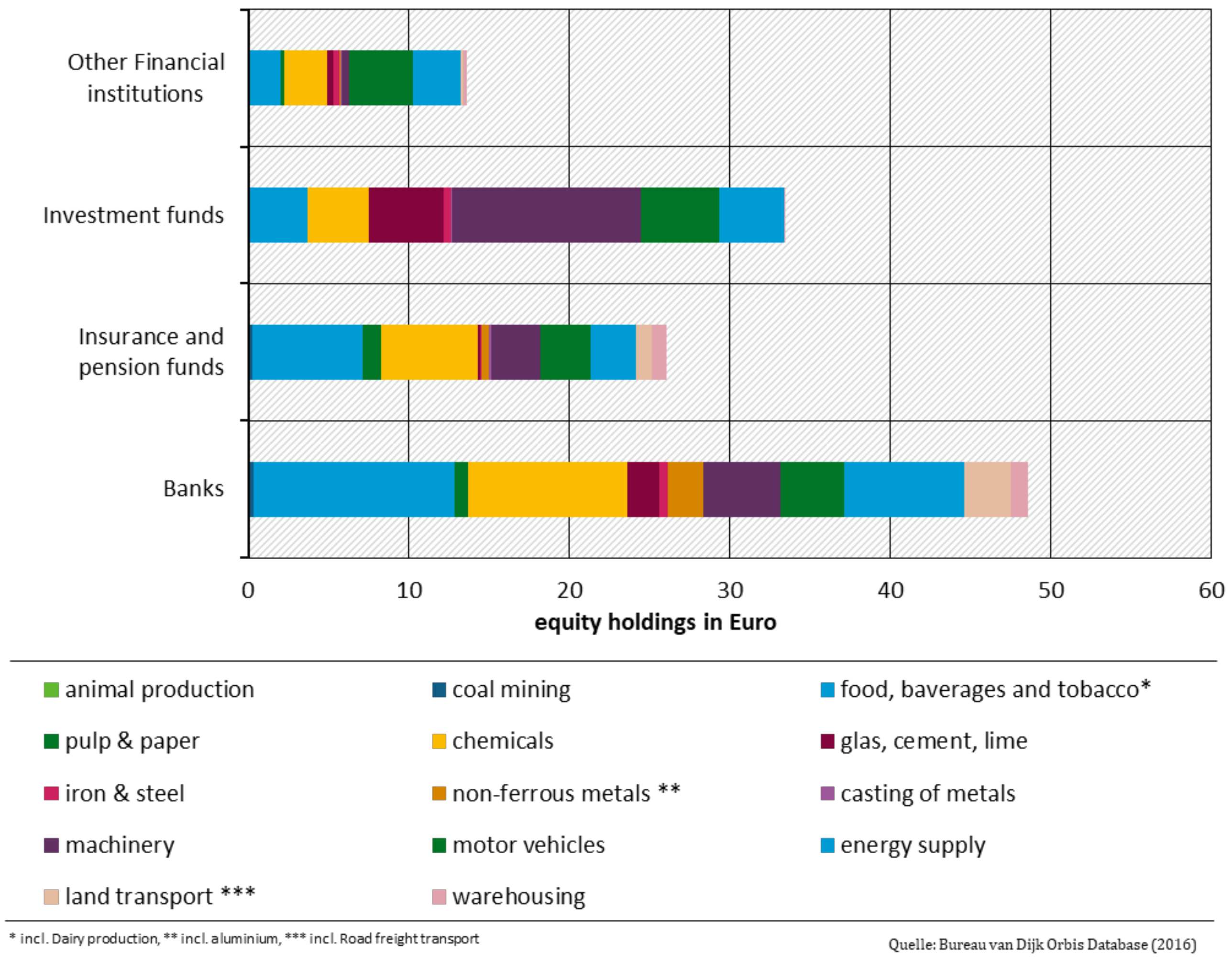
As highlighted in Chapter 3.3.1, equity holdings (direct and indirect) are the most important financial instrument for insurers and pension funds. For this reason, we provide additional insights into the exposure of various German financial institutions to emission-intensive sectors through their equity holdings. The charts are obtained by calculations and data consolidation carried out by Univ. of Zurich, based on data from the Bureau Van Dijk Orbis database (2016), which includes all listed companies

[32] Since the credit volume for residential property is often less than EUR 1 million, the credit database does not take into account a large proportion of real estate loans. On the other hand, real estate activities include all activities connected with the purchase, sale and management of land and buildings, as well as their leasing, letting and brokerage.

and their reported shareholders. The selection of sectors largely corresponds to those in Chapter 2. Sub-sectors (4-digit) have been assigned to sectors at 2-digit level (see Figure 3-6).

Figure 3-6 shows the exposure of different actors to emission-intensive sectors through their equity investments. The results show that **insurance companies and pension funds are invested in emission-intensive sectors with 26 billion Euro (approx. 16% of equity holdings), banks with 48 billion Euro (approx. 20% of equity holdings) and investment funds with 33 billion Euro (approx. 28% of equity holdings)**. The most important sectors are **power generation, food production, chemical production, mechanical engineering and the construction of vehicles**. The order of magnitude is comparable with Southpole (2016), which investigated equity funds in Germany, but for the entire equity market in Europe.

Figure 3-6: Equity holdings of German financial institutions in emission-intensive sectors in 2016



Source: Own representation, University of Zurich, based on Bureau van Dijk Orbis Database (2016).

The following conclusions can be drawn from the analysis of debt and equity holdings of German financial institutions:

- The **most important carbon-intensive economic sector**, measured in terms of debt and equity investments, is **electricity supply**, which at the same time has a transition risk. However, it should be noted that the electricity sector includes both electricity generation from renewable and fossil sources. This must be differentiated in further analyses, otherwise the risk is overestimated.

- Debt and equity investments in the **coal sector,** which carries a very high carbon risk, are low and thus less relevant in terms of the financial risk for the financial market in Germany.
- Other important sectors are **mechanical engineering, construction of buildings, the automotive industry and the chemical industry**, with higher exposures but moderate transition risks. Again, a closer look at the technologies and resources used is important to assess the financial risk.
- Another important sector in terms of debt holdings is the **real estate sector**. This underlines the importance of considering **mortgages** separately in the carbon quick scan tool.

The magnitude of the results corresponds to those of Wejzig et al (2016) and Schotten (2016), Soutpole (2016), as well as Battiston et al. (2017) and Dombret (2018). However, this study covers all major asset classes and financial actors.

4 Integration of carbon risks in financial markets

While carbon risks are likely to be material across the entire investment chain, they remain poorly understood by financial institutions and are not integrated into decision-making of financial institutions. However, there are many instruments that are available to regulators to enhance the integration of such carbon risks into the decision making of financial institutions.

The following chapter, therefore, provides an in-depth analysis of the different instruments available to regulators, outlining their benefits and disadvantages, in order to encourage the integration of climate-related transition risks into financial institution decision-making. The study places emphasis on the German case but also considers other countries whenever this helps the analysis.

4.1 The ambition of sustainable financial system

4.1.1 The EU ambition

In May 2018, the Commission presented its proposals for regulations for a uniform classification system for sustainable investments, for disclosure obligations for climate and sustainability risks and for benchmarks of climate-friendly and climate-friendly investments (European Commission, 2018).

In addition, the EU has also asked for stakeholder feedback on possible amendments to the MiFID II Directive in order to better integrate the topic of sustainability (including climate risks) into investment discussions in the future (European Commission, 2018). In the course of the consultations the Technical Expert Group (TEG), commissioned by the EU, will also discuss other EU directives relevant to the financial market in order to assess and address climate risks for asset managers, insurers and investment funds (European Commission, 2018).

4.1.2 The German ambition

In November 2016, the German Federal Government adopted the Climate Protection Plan 2050 as a German long-term strategy for implementing the Paris Convention. The climate protection plan contains sector-specific reduction targets (2030) for all greenhouse gas-emitting sectors (energy, buildings, transport, industry, agriculture) according to the source principle, i.e. the allocation of emissions to their place of origin.

4.2 Need for additional actions

To fully integrate climate protection into financial market decisions (2° II & UNEP Inquiry 2016), a "systemic approach that more effectively aligns the design and functioning of financial and capital markets to the needs of the transition to an inclusive, green economy" (UNEP Inquiry 2015a) is needed. In order to ensure the efficiency and resilience of the financial system (EU HLEG 2017), those characteristics of the financial system that influence financial intermediaries' investment and lending decisions need to be redesigned (IPCC, 2018). In order to better integrate climate and carbon risks in the financial markets and to transform them towards greater sustainability, the following financial market misalignments should be addressed in particular:

- **Time horizon:** The financial system is trapped in a "short-term and relatively narrow view of financial risk" and cannot take into account long-term problems arising from climate change (EU HLEG 2017). There are differences between "long-term projects, long-term embodiments of risks" and "short-term market commitments", which are responsible for the misalignment of business models (EU HLEG 2017). This aspect is currently being increasingly addressed again, for example by the EU action plan for financing sustainable growth.
- **Conception of risks:** The main difficulties in developing an adequate risk model include the uncertainty associated with the decarbonization of the economy, the lack of data and the long-term nature of the risks. The level and quality of disclosures are insufficient to reflect an adequate picture of risk and performance, to assess "sustainable financial flows" (EU HLEG 2017) at national and international level and thus to support "informed decision-making and supervision" (EU HLEG 2017). Transparency also suffers from a lack of common definitions and metrics. Furthermore, the level of sustainability competence and expertise "along the investment and credit chain" remains unsatisfactory (E3G 2017). More precisely, "mainstream risk assessment and management" still fails to properly integrate carbon risks (2° ii 2015). To date, the debt side of the balance sheet has mainly been analyzed for climate-related financial risks, while the asset side remains poorly analyzed due to established financial practices (2° II 2015). However, to capture climate risks in their entirety, debt as well as active and passive assets must be included in climate risk scenarios (UN PRI 2018; Beyond Ratings 2019).
- **Market structure:** The depth and strength of financial markets (e.g. bond markets) and the size and role of public and financial institutions may not be sufficient to promote innovation and decarbonization (UNEP study 2015a). Various experts see the "penchant" for short-term risk assessments in the capital markets as one of the biggest obstacles to effective climate change management (Thomä and Chenet 2017). There is also a trend towards more debt financing, which, according to the OECD, favors short-term thinking in the market and could thus hamper long-term climate risk management (OECD 2011).

This study builds on the UNEP analysis “UNEP Inquiry into the Design of a Sustainable Financial System” (UNEP Inquiry 2015b). The UNEP Inquiry was established to examine the potential for fiscal and monetary policy, regulations and standards to serve as drivers for sustainable development. UNEP concluded that the introduction of sustainability criteria can strengthen the resilience of the entire financial sector. In addition, it was noted that their introduction is currently failing primarily due to a lack of political will. In the context of this analysis, the authors have therefore decided to examine 21 instruments that stem from observed applications and could be used both at national and international level (UNEP Inquiry 2015a). The aim is to create a sustainable financial system that is characterized by a new balance between risk, reward and social responsibility and allows "mainstreaming" of "sustainable financial concepts and practices throughout the financial system" (Caldecott 2017).

4.3 German financial sector relevance

The German financial market is exposed to similar risks as other countries due to the intra-European and global networking of the financial system. The German financial market consists mainly of monetary financial institutions, pension funds and insurance companies, and open investment funds (Holtz, S., Germanwatch, 2010). Historically, the German financial market is based on banks, which is reflected in ownership interests in financial assets: in 2015, over 60% of financial assets in Germany were held by banks (South Pole, 2016). It is also important to emphasize that in the German banking sector limited companies have less dominant positions than is the case in other European countries.

Landesbanken and Sparkassen, often in municipal hands, make up an important part of German banking (Bundesverband deutscher Banken, 2017). This is important insofar as the rules on fiduciary duties or reporting are usually addressed to listed companies.

The pronounced versatility and multi-level nature of the German financial sector are mainly due to the federal structure of the Federal Republic of Germany (Hellenkamp, 2015). Despite the presence of large universal banks, insurers and investment companies, the German financial sector is much more heterogeneous than its European or transatlantic counterparts (Hellenkamp, 2015). Climate risks at the state or regional level have a different impact than, for example, those of major banks, which are regulated by BaFin. However, since Sparkassen, Volksbanken, Raiffeisenbanken and regional banks hold a substantial portion of the loans or corporate bonds of medium-sized companies (Hellenkamp, 2015), climate risk analyses must be variable and flexible enough to take sufficient account of the different risk factors and market conditions.

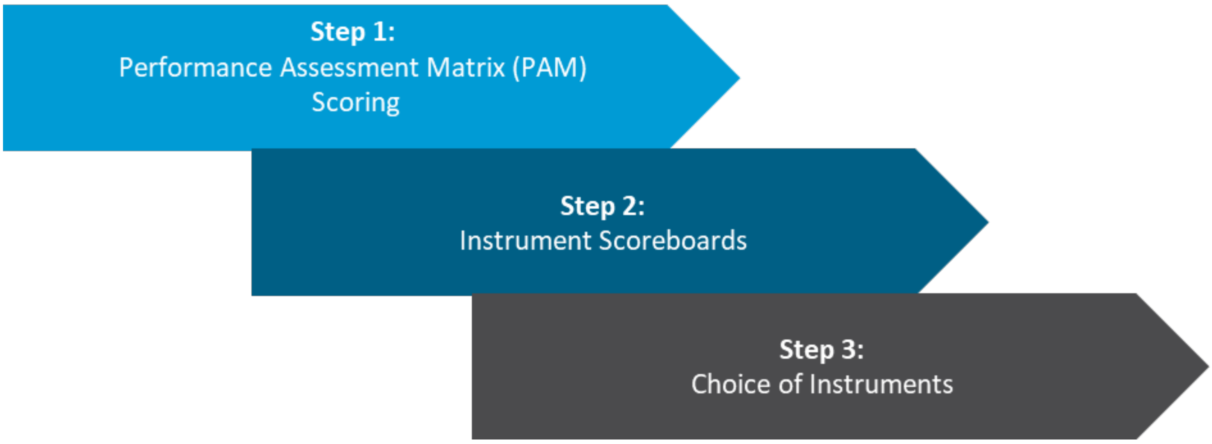
New regulations and the current lack of transparency or awareness of this issue are thus the most critical risks for the German financial sector. This is particularly important given that most of the momentum in the area of climate risk regulation comes from the EU (e.g. EU non-financial reporting or action plan for sustainable finance) or European countries (e.g. England or France) (WWF, Germanwatch, 2015; UN PRI, 2016) the current lack of preparation in the German financial center. Even if the Federal Government pursues various initiatives in terms of increased transparency and information duty with little vigour (Baerbock, A. et al., 2016), it is, however, the countries that drive standards in Germany. In Baden-Württemberg, the green-black government has anchored a "divest" strategy for the Landesbank in the coalition agreement. The city of Berlin has now also decided to take this step (2 Degree Investing Initiative, 2016). North Rhine-Westphalia has also drawn up a strategy for sustainable financial policy that includes budget-specific measures such as increased transparency, long-term development prospects and the issue of sustainability bonds (NRW, 2018). Hessen has also developed its own concept for a more sustainable financial policy. This included, for example, the creation of a task force to define climate indicators and targets, which are periodically updated (Hessen, 2018). The German Bundesbank and the BaFin have also warned against underestimating climate risks and are striving for an internationally harmonised regulatory framework (BaFin, 2018a and 2018b; Deutsche Bundesbank, 2017), which excludes national regulatory unilateral actions.

4.4 Methodology for the evaluation of instruments supporting the integration of carbon risks in the financial markets

To evaluate instruments that can be used to integrate carbon risk into the decision-making of financial institutions we have developed a new methodology that attempts to strike the right balance between several design parameters, including: accuracy, simplicity, repeatability, comprehensiveness, and customisability.

We propose using a three-step categorization process to assess each instrument objectively: (1) Preformance Assessment Matrix (PAM), (2) Instrument Scoreboards, and (3) Choice of Instruments (see Figure 4-1).

Figure 4-1: Steps to assess instruments for integrating carbon risks in financial markets



Source: Own Representation, Oxford University.

4.4.1 Step 1: Performance Assessment Matrix (PAM) scoring

In the first step, criteria for the evaluation of regulatory instruments for the integration of carbon risks in the financial markets are defined and quantitatively evaluated. The criteria are summarized in a Performance Assessment Matrix (PAM).

It assesses the extent to which the instrument is easy to implement and supports sound and efficient capital allocation for existing and new low-carbon investment opportunities. The applied criteria have been chosen on the basis of various existing rating procedures used by rating agencies, accounting firms and financial institutions to efficiently measure and integrate carbon risk. Table 6-3 in Annex 0 illustrates the criteria used in the evaluation of each instrument.

The selection of the criteria was guided by the specific characteristics of the German financial sector. Fundamental characteristics of all instruments are considered, and aspects are also looked at the micro level which, for example, affect Landesbanken or regional banks much more than, for example, nationally active universal banks. While banks under BaFin supervision or with significant investment banking, for example, attach more importance to market-relevant price signals or the creation of wide-ranging risk management products, simplicity, speed and costs of implementation are of the highest priority for smaller banks.

The criteria for each instrument are analyzed on the basis of a comprehensive literature search, which essentially deals with aspects relevant to the German financial market, taking into account the EU and global developments. Finally, all criteria were evaluated on a scale of 1 to 5, with 5 being the highest score. A detailed explanation of the quantitative assessment of the instruments for integrating carbon risks in the financial markets and the detailed results are given in Annex 6.8.

4.4.2 Step 2: Instrument scoreboard design

In the second step, so-called scoreboards are created for each instrument. These contain a summary and interpretation of the score from the previous step, a summary of the characteristics of each instrument (including the stakeholders involved) and recommendations. The scoreboards help to understand the potential of an instrument to integrate carbon risks in financial markets.

The evaluation of the potential is visualized using a traffic light system/heat map (red = low potential, orange = medium potential, green = high potential).

High potential signifies that an instrument has demonstrated its ability to integrate carbon risk into the decision-making of financial institutions in a cost-effective way and offers several positive aspects in terms of implementation. This instrument has been or could be integrated into the German regulatory or institutional frameworks without any or much delay.

Medium potential outlines that there are still certain issues/limits regarding the instrument's ability to help integrate carbon risk into the decision-making in a cost-effective way, and/or its contemporary implementation in Germany. However, with relatively minor developments, adaptations by regulators or institutions, and/or in combination with other instruments, this tool may be a good alternative in the near to medium-term future.

Low potential instruments likely incur substantial regulatory barriers or administrative obstacles, and/or have a limited efficacy in building a sustainable financial system. Only profound structural modifications can increase their potential.

This rating system has proven to be intuitive in that it provides a quick visual clue about the nature of the instrument. similar to those used by the government regarding the nutritional values of food and the potential health implications. It is used by credit-rating agencies in the environmental, social and corporate governance (ESG) and climate risk sectors. Breaking the system down into three tiers, we use the common heat map tool and reduce the gradations to three to allow for an immediate identification of the potential of each instrument.

Then after summing up the characteristics of the instrument, we will comment on its ability to effectively integrate carbon risk into the decision-making of financial institutions. If the instrument has potential but does not currently effectively integrate carbon risk, recommendations will be made on how to improve its efficacy.

4.4.3 Step 3: Choice of instruments

The third and final step is to select the instruments with the highest potential (i.e. highest score) for integrating carbon risks in financial markets from a list of 21 instruments taken from the UNEP FI study. These are referred to as priority instruments.

The table below shows the results for each of the 21 instruments for the three key criteria defined - i.e. (1) support for carbon risk management in financial institutions, (2) implementability and (3) impact on climate change.

Table 4-1: Summary of Weighted Instrument Ratings[33,34]

Instruments	1) Supports Carbon Risk Management in Financial Institutions (Potential)	2) Implementation Feasibility (Potential	3) Impact on Climate Change (Potential)	Final Rating
Fiduciary duties of institutional investors and asset managers	Medium	High	High	
Carbon Risk Scanning	Medium	High	Medium	
Financial Disclosure and Reporting	High	High	High	
Taxonomies, Labels and Standards	High	Medium	High	

33 It should be noted that the High, Medium and Low Potential ratings are classified on the basis of weighted numerical ratings, which are listed in full in the Annex.

34 Ratings Red = Low potential]; Orange = Medium potential; Green = High potential | Light beige = Priority instruments. For more details on the methodology, please see Annex.

Instruments	1) Supports Carbon Risk Management in Financial Institutions (Potential)	2) Implementation Feasibility (Potential	3) Impact on Climate Change (Potential)	Final Rating
Carbon Pricing (Taxation)	High	Medium	High	
Carbon Pricing (EU ETS)	Medium	Medium	High	
Incentives for investments/financial advisers and asset managers	Medium	Medium	High	
Capital Requirements	Medium	Medium	Medium	
Accounting Standards (IAS and IFRS)	High	Medium	High	
Indices and Ranking	High	Medium	High	
Credit and Sustainability Ratings	High	High	High	
Tax Credits	Medium	Medium	Medium	
Sustainability Mandates	Medium	Medium	Medium	
Green Investment Banks	Medium	High	High	
Central Bank Mandates	Medium	Low	Medium	
Extend Legal Liability Regimes for Investors	Low	Medium	Low	
Priority Sector Lending	Low	Low	Medium	
Targeted Sectoral Investment Prohibitions	High	Low	High	
Consumer and Regulator Capacity Building	Medium	High	High	
Codes of Conduct and Non-financial Guidance	Low	High	High	
Engagement	Low	Low	Low	

Source: Own Representation, Oxford University.

Subsequently, six priority instruments were selected on the basis of anticipated impacts, literature coverage, and most importantly additional feedback from regulators, policy-makers and industry stakeholders such as institutional investors:

- **Fiduciary duties of institutional investors and asset managers**: Clarification that duties to clients (including stewardship) include sustainability factors. Include requirements for knowledge and training on sustainability to undertake fiduciary responsibility.
- **Carbon Risk Scanning**: Development of scenarios to test the impact of environmental shocks on assets and business models. Introduction of requirements (i.e. criteria of TCFD scenario development) to develop scenarios usable for the financial industry to test the impact of transition towards climate-friendly business models on assets.
- **Financial Disclosure and Reporting**: Introduction of requirements for reporting on sustainability performance and risk outlook by implementing, for example, the TCFD recommendations

and proactively integrate the May 2018 EU proposal for a regulation on disclosure of information on sustainable investments and sustainability risks. This could include the introduction of mandatory disclosure, either based on the TCFD recommendations or without specifying the required method (such as Art. 173 French Energy Transition Law).

- **Taxonomies, Labels and Standards**: Encouragement of greater transparency in 'green' financial products. This could include the Introduction of mandatory application of a given standard such as Green Bond Principles and/&or Climate Bond Principles, and/or the Introduction of mandatory application of a given taxonomy such as the Chinese taxonomy (best in class approach).
- **Carbon Pricing (Carbon Taxation)**: Carbon pricing through taxation measures such as the introduction of a CO2 component in the energy tax (e.g. German 'Ökosteuer').
- **EU Emissions Trading Scheme**: Implementation of command and control regulation to establish a carbon price floor.

4.5 Instrument assessment

The evaluation of these six instruments is described in detail below.

4.5.1 Fiduciary duties of institutional investors and asset managers

Summary

Definition

Fiduciary duties are imposed upon a person or an organization that exercises some discretionary power in the interests of another person in circumstances that give rise to a relationship of trust and confidence. They are of particular importance in asymmetrical relationships; these are situations where there are imbalances in expertise and where the beneficiary has limited ability to monitor or oversee the actions of the entity acting in their interests.

Furthermore, the development of obligations to adjust fiduciary duty interpretation is particularly relevant to practitioners such as asset owners and asset managers. In this case, fiduciary duties will be amended to include sustainability considerations as a financial material risk in investment decision-making.

Fiduciary duties of institutional investors and asset managers lead to direct exposure to legal risks. They would support making the inclusion of sustainability and climate factors the new standard. They still require clarification that these include sustainability factors. The fact that climate litigation increasingly turns the previously abstract climate risks into more concrete risks, as well for investors, is a major driver to the need to clarify that acting in line with the fiduciary duties means to explicitly consider sustainability risks. Expanding fiduciary duties to include specific references to climate change and carbon risks should be envisaged. Addressing conflicts of short time horizons in modern corporate decision-making and the correlated long-term performance risks will not only benefit shareholders but also will ultimately strengthen the financial system by defining the best interests of financial institutions in relation to climate-related risks.

→ *High priority steps*: Adapt national fiduciary duty provisions for several legal frameworks e.g. VAG, BRSG, VersRückIG, KAGB, or KWG to implement carbon risk and ESG factors into existing fiduciary duty regimes. This can be achieved by incorporating elements from the BaFin MaRisk, the German Corporate Governance Index, and the EU Action Plan (EU-AP Actions 7 & 8, p.8-9) as templates. A strict interpretation and ambitious transposition of the EU-level Non-Financial Reporting Directive 2014/95/EU would strengthen disclosure and transparency rules. Germany has transposed the Directive to a large degree without significant changes in the "CSR-Richtlinie-Umsetzungsgesetz", which leaves room for stricter provisions. To date, adaptations occurred in the domain of public interest entity definitions, disclosure format and non-compliance penalties.

→ *Medium priority steps*: Extending legal liability regimes in case of breach of climate-related duties of loyalty, care, and disclosure could be achieved through the facilitation of legal rules of standing and evidence. This would help reduce legal recourse asymmetries between directors and shareholders/civil society stakeholders.

→ *Key Attributes:* Necessary, Suitable for implementation by the German Federal Government, Effective

Who will implement the instrument?
Financial Institutions, investors.

Who benefits from implementation?
Investors, beneficiaries

Who bears the costs of implementation?
Financial Institutions, investors.

Pros and Cons
(+) Adjustment of fiduciary duties is a particularly strong means of incentivizing broader and active carbon risk management.
(+) Numerous initiatives at various international, regional, and national levels provide numerous templates for regulatory implementation.
(+) Will enable individuals, such as pension savers, to take investment decisions reflecting future risks
(+) Instrument is generally in line with Prudent Person Principle promoted by PRI to which variety of institutional investors and financial institutions are already signatories

(-) Already implemented for several industries/cases, but no specific reference to carbon emissions or climate change as of now.
(-) Requires legal framework revisions that can be hard to implement in short-term.

Recommendations
Expanding fiduciary duties to include specific references to climate change and carbon risks should be envisaged. Addressing conflicts of short time horizons in modern corporate decision-making and the correlated long-term performance risks will not only benefit shareholders but will ultimately strengthen the financial system by defining the best interests of financial institutions in relation to climate-related risks.

4.5.2 Carbon risk scanning

Summary

Definition
Carbon risk scanning tools such as stress tests for financial institutions can be used at various levels: disclosure of risk exposure for assets/companies/sectors; assessment of required capital and risk materiality at the portfolio/balance sheet/asset levels; and assessment of systemic risk.
Stress tests are broadly implemented in the financial system, though they may not all account for carbon risk. There is a possibility for a near-term large-scale implementation of stress-tests integrating carbon risk. Stress tests can be performed in-house which reduces potential costs. Stress-testing is part of scenario modeling and thus an integral part of the climate-related risk disclosure process.

Carbon Risk Scanning by corporates, financial institutions and supervisors enables measurement of carbon risks, a prerequisite to managing them. Scenarios should take raising CO2-prices and Paris-Agreement-compatible long-term goals into account, i.e. be based on the mechanism of raising ambition, as outlined in the Paris Agreement. International cooperation is a requisite to improve stress test designs and applications as well as to standardize initiatives and approaches. It is critical to adapt global disclosure and transparency standards besides accounting for global interlinkages between institutions and systemic risk. The accuracy of stress-test results depends on the quality and level of disclosure from institutions and companies. A German-led task force including, for example, the Bank for International Settlements and the Financial Stability Board and financial institutions, in charge of creating key standards, could work on these issues.

High priority steps: In accordance with EU regulation proposal 2016/1011 on low carbon benchmarks, German-led initiatives should inform EU regulators approaches to climate-related scenario analysis and stress-testing, notably for the European Central Bank (ECB), the European Banking Authority (EBA), and the European Systemic Risk Board (ESRB) in line with EU HLEG key recommendation 8 (p.41).

→ *Medium priority steps*: Coordinate with German regulator BaFin and the KfW to create implement carbon risk into their stress-test frameworks, for example on the basis of the Carbon Bubble project's WP2 template.

→ *Key Attributes:* Fast working (highly effective), Efficient

Who will implement the instrument?
Financial institutions/central banks/insurance providers/regulators

Who benefits from implementation?
Society through better financial resilience

Who bears the costs of implementation?
Regulators/financial institutions

Pros and Cons
(+) Stress tests are of high relevance to the German heterogeneous and interconnected financial system.
(+) Stress tests have the potential to increase transparency and the integration of climate-related risk (and therefore time-horizon) considerations in current disclosure and transparency standards.

(-) Stress tests suffer from a lack of consistency/transparency on their assumptions and features (risks factored-in, scenario/shock type, and impact valuation approach: top-down or bottom-up approach), which may cause a mis-assessment of carbon risk.

Recommendations
International cooperation is a requisite to improve stress test designs and applications as well as to standardise initiatives and approaches. It is critical to adapt global disclosure and transparency standards and to account for global interlinkages between institutions and systemic risk. The accuracy of stress-test results depends on the quality and level of disclosure from institutions and companies.

A task force including, for example, the Bank for International Settlements and the Financial Stability Board and other key standards and financial institutions, could work on these issues.

4.5.3 Financial disclosure and reporting

Summary

Definition
Reporting refers to the disclosure of financial and non-financial (e.g. ESG) information that can be used to assess the sustainability performance of a company, as well as the sustainability risks and opportunities it

faces, and its strategy towards a low-carbon economy. Reporting may include specific standards, principles or guidelines, and include specific metrics such as: green/brown capital, carbon footprinting, and forward-looking strategies including disclosure and risk assessments.

Financial Disclosure and Reporting - Mandatory financial disclosure and introduction of requirements for reporting will drive mainstreaming, demand capabilities and eventually lead to legal standardization. Reporting standards should be aligned with the TCFD recommendations for corporations and financial institutions. Reporting should be forward-looking and include the results of climate stress-tests, i.e. the impact of raising CO2-prices and Paris Agreement-compatible long-term goals. Adopting reporting policies should be relatively cost-efficient and rapid due to existing (voluntary) structures and initiatives. However, the monitoring of the way ESG factors or sustainability criteria are integrated into investment decisions and risk management might be expensive. Disclosure policies should tackle the potential lack of transparency in sustainability risks and opportunities, as well as in the strategic approach to the low-carbon transition. Disclosure is needed across all asset pools and is critical to enhancing the mitigation power of all other instruments. Disclosure policies should be designed to enforce the accountability of ESG factors as well as the factoring in of long-term time horizons. However careful consideration must be given to ensure that widening and deepening disclosure does not complexify banking and financial regulations or deteriorate the efficiency and competitiveness of markets as well as their ability to innovate.

→ *High priority step*s: An international working group led by Germany should evaluate the May 2018 EU proposal for a *regulation on disclosure of information on sustainable investment and sustainability risks* (2018/0179), which would amend the Directive (2016/2341). In addition, Germany should promote convergence and wider introduction of disclosure within a mandatory international supervisory framework that takes into account the EU regulation proposals or the TCFD recommendations of the FSB. The results of the study on the legal comparison between the Federal Republic of Germany and France with regard to Art. 173 of the French Energy Turnaround Act should be taken into account.

→ *Medium priority steps*: Federated entities could envision modifications to their respective Landesbankengesetze to transpose the TCFD recommendations and the EU-AP Action 9 (p.10) provisions.

→ *Key Attributes:* Necessary, Suitable for implementation by the German Federal Govt., Effective, Efficient

Who will implement the instrument?
Main:
Corporates, financial institutions, central banks, regulators, rating agencies, exchanges, and investors.
Secondary:
Corporate representatives, NGOs, labour groups, and 'society at large'.

Who benefits from implementation?
Significant benefits for all actors across the financial sector, mostly investors through more reliable access to decision-relevant information.

Who bears the costs of implementation?
Corporates, financial institutions, central banks, regulators, rating agencies, exchanges, and investors.

Pros and Cons
(+) Reporting is key to facilitate informed capital allocation and investment decisions. Efficient markets rely on information to allow prudential management of risks across the investment/supply chain and assume responsibility.
(+) Germany has already started working towards improving disclosure regulation (e.g. the Insurance Supervision Act of 2002 and the 2011 German Sustainability Code).

(-) There are varying disclosure regulations across jurisdictions and supply chains creating a disparate and ambiguous regulatory environment.
(-) Can be difficult to monitor the quality of disclosures.

Recommendations
Adopting policies of reporting should be relatively cost-efficient and rapid due to existing (voluntary) structures and initiatives. However, the monitoring of the way ESG factors or sustainability criteria are integrated into investment decisions and risk management might be expensive.

We recommend the creation of a German-led international task force should be set up to foster the convergence and broader adoption of disclosure within a mandatory international prudential framework based on the final recommendations of the FSB's TCFD or the French Energy Transition Law (art. 173). This will avoid redundant multiplication of frameworks.
We recommend the creation of a German-led international task force should be set up to foster the convergence and broader adoption of disclosure within a mandatory international prudential framework based on the final recommendations of the FSB's TCFD or the French Energy Transition Law (art. 173). This will avoid redundant multiplication of frameworks.
We recommend the creation of a German-led international task force should be set up to foster the convergence and broader adoption of disclosure within a mandatory international prudential framework based on the final recommendations of the FSB's TCFD or the French Energy Transition Law (art. 173). This will avoid redundant multiplication of frameworks.

4.5.4 Taxonomies, labels and standards

Summary

Definition
The definition is derived from EU High-Level Expert Group on Sustainable Finance (2017). Taxonomies complement labels and standards for 'green' financial products and processes. Taxonomies are a 'core reference for product standards' as they capture all suitable definitions of 'sustainability' and list the underlying sustainable assets (objectives and sectors) that can be invested in by a sustainable product. On the other hand, labels offer investors the assurance that the provisions of a given product standard (e.g. Novethic Green Fund label, French Green, and Luxflag Climate label) or process one (e.g. French public SRI label and Luxflag ESG label) are fulfilled by a specific product. Moreover, compliance with product standards attests that a financial product meets specific criteria (e.g. allocation of an equity fund in firms meeting specific characteristics in terms of green activities). Finally, compliance with process standards ensures that certain procedures (aligned with ESG criteria) have been used throughout the investment process. Taxonomies, labels, and standards are critical in the design of the characteristics of both 'green' and 'brown' asset classes, in order to adequately inform the provision of financing for sustainability-oriented projects.

Taxonomies, Labels and Standards would benefit greatly from a single EU classification of sustainable assets. Establishing a credible EU taxonomy will enable the creation of common labels and quality standards in support of the EU's environmental policy objectives. Systems of classification, labelling, and standardisation are critical to aligning the interests of investors, industry, and governments for the scaling up of low-carbon investment. Additional work is still required over a short- to medium-term horizon to widen, deepen, and control the characteristics of these instruments as well as their use. Improved clarity on these instruments would reinforce investor confidence in markets; free up capital for the sustainable economy; increase risk awareness; spur innovation; improve the risk/return profile; generate new business opportunities; soften the regulatory adjustment. It could also reduce transaction costs on due diligence and registration costs; annihilate the costs related to verifiers or assurance providers; and speed up the administrative treatment. Global cooperation between the committees is critical to ensure comparability and consistency on a global scale.

→ *High priority steps*: The development of the common taxonomy at EU level (EU-AP Action 1 & 2, p. 4-5) should be actively supported by Germany on the basis of the proposals on the *establishment of a framework ("taxonomy") to facilitate sustainable investments* (2018/0178 (COD)) and *amendment of Regulation (EU) 2016/1011 with regard to reference values for low-carbon investments and reference values ("benchmarks") for investments with a favourable carbon footprint (2018/0180 (COD))*. This should be done in partnership with industry leaders on ESG principles such as G20-FSB, UN PRI and MSCI.

→ *Medium priority steps*: Collaborate with industry practitioners such as Deutsche Börse and ESG analysts to refine, complement and inform the proposals of the EU technical expert group on sustainable finance developing the taxonomy of climate change mitigation and adaptation, and other environmental activities.

→ *Key Attributes:* Necessary (= Taxonomies and Standards), Additional (= Labels), Effective, Efficient

Who will implement the instrument?
Main:
Issuers and investors.
Secondary:
Policy-makers and NGOs.

Who benefits from implementation?
Financial institutions, investors, regulators and society by having access to uniform definitions and standards

Who bears the costs of implementation?
Financial institutions, regulators, investors.

Pros and Cons
(+) The European Commission is encouraged by the HLEG to support a single EU classification of sustainable assets and to establish credible EU labels and quality standards to help the achievement of EU environmental policy objectives. Such system of classification, labelling, and standardization is critical to align the interests of investors, industry, and governments for the scaling up of low-carbon investments.

(-) Various taxonomies, standards, and labels have been created by leading industry, associations, public institutions, and member states; without any control by market supervisors, industry associations, or public regulators. This generates uncertainty in the market.
(-) New costs may appear (e.g. issuance costs, label/standard application & production costs, and opportunity costs) but they should be low.

Recommendations
Additional work is still required over a short- to medium-term horizon to widen, deepen, and control the characteristics of these instruments as well as their use. Improved clarity on these instruments would reinforce investor confidence in markets; free up capital for the sustainable economy; increase risk awareness; spur innovation; improve the risk/return profile; generate new business opportunities; soften the regulatory adjustment. It could also reduce transaction costs on due diligence and registration costs; annihilate the costs related to verifiers or assurance providers; and speed up the administrative treatment. Global cooperation between the committees is critical to ensure comparability and consistency on a global scale.

4.5.5 Carbon taxation (Carbon Pricing)

Summary

Definition

A carbon price floor in the form of a tax, often labelled as carbon tax, energy tax, or green tax, serves to increase the cost of brown capital. By imposing a mandatory levy on each tonne of carbon emitted, carbon taxation represents an indiscriminate fiscal policy tool that would specifically target carbon-intensive assets and investments.

Carbon Pricing via Carbon Taxation is one of the most efficient instruments, as a more meaningful price signal would drive investment decisions and starts at top of the food chain. It provides a strong investment signal either in the form of an effective carbon tax to generate a stronger carbon floor price. The price signals need predictable steady increase (i.e. in line with the recommendations by the High-Level Economic Commission on Carbon Prices - start at 30 USD per t CO2e today, increases to 60-80 USD per t CO2e by 2020 and to 80-100 USD per t CO2e by 2030 (upper end of estimates recommended since Germany is a developed country)).

→ *High priority steps*: Carbon taxation is one of the most efficient and effective tools of carbon risk management, given that it increases the cost of brown assets and evens the level playing field for green assets, often a comparative disadvantage due to higher costs. Albeit Germany does not possess a pure carbon tax, the German “eco-tax(es)” are a concept that has been applied to several existing taxes in Germany since 1999 with the "ecological tax reform act" ("Gesetz zum Einstieg in die ökologische Steuerreform"). The act applies to energy taxes (i.e. lead to an amendment of the energy taxes act (EnergieStG) and introduced the German electricity tax (StromStG). CO2 pricing, such as the EU ECTS as well as taxes, should be addressed via a holistic approach when moving forward and energy tax-rates should be linked to the carbon intensity.

→ *Key Attributes:* Suitable for implementation by the German Federal Government, Effective

Who will implement the instrument?

Companies and investors.

Who benefits from implementation?

Society as a whole, government as recipient of carbon tax receipts.

Who bears the costs of implementation?

Companies and investors.

Pros and Cons

(+) Carbon tax is easy to implement by incorporation into existing tax code.
(+) Efficient and indiscriminate across the economy as pure carbon emissions are taxed.
(+) Little administrative and regulatory adjustments required.
(+) Tax receipts could be used to fund other sustainable developments.

(-) Carbon price unpopular as other forms of taxation.
(-) In many jurisdictions tax polices need to gain legislative approval, whereas command-and-control regulatory measures such as emissions trading can be passed by the executive.

Recommendations

Carbon taxation is one of the most efficient and effective tools of carbon risk management, given that it increases the cost of brown assets and evens the level playing field for green assets, often a comparative disadvantage due to higher costs. Albeit Germany does not possess a pure carbon tax, the German “eco-tax(es)” are a concept that has been applied to several existing taxes in Germany since 1999 with the "ecological tax reform act" ("Gesetz zum Einstieg in die ökologische Steuerreform"). The act applies to energy taxes (i.e. lead to an amendment of the energy taxes act (EnergieStG) and introduced the German electricity tax (Strom-StG). Energy tax-rates should be linked to the carbon intensity.

4.5.6 EU emissions trading scheme

Summary

Definition

Emissions trading schemes (ETS), also known as “Cap-and-Trade” schemes are a command-and-control regulatory instrument to set a carbon price floor. Whereas carbon taxation sets a fixed price floor per ton of carbon emitted, and ETS differs in that it determines the total number of emissions for a certain period (usually annual) and then the price will fluctuate based on development on offer and demand for emissions certificates. Companies can trade these certificates, resulting in high-emitting ones to buy additional certificates from low-emitting ones if their original allowances do not cover their emissions. The regulator will then revise the maximum total emissions allowances in accordance with the political carbon reductions goals, thus, in theory, incentivizing companies to reduce their carbon footprint.

Carbon Pricing via the EU ETS is one of the most efficient instruments, as a more in case of reasonable credit allocations provide an efficient carbon floor price that would drive investment decisions. This refinement of the EU ETS would generate a stronger carbon floor price.

→ *Medium priority steps:* The political preference for market-based carbon price floor mechanisms notwithstanding, ETS in their current form are either inefficient due to administrative complexity or lack certificate allocation rigidity. At the moment, the EU ETS is without alternative given the significant efforts already having been made over the past decades. For it to develop to its full potential, it needs to be extended to include more carbon-intensive industries and the amount of annual certificate allocations by Member states needs to be reduced to raise the carbon price floor. Germany should utilize its political clout to influence European decision-makers and partners to revise the ambitions of the EU ETS scheme during the Phase 4 (2021-2030) rollout.

→ *Key Attributes:* Sufficient, Suitable for implementation by the German Federal Government, Effective

Who will implement the instrument?

Regulators and investors

Who benefits from implementation?

Society through progressive emissions reductions.

Who bears the costs of implementation?

Regulators and investors

Pros and Cons

(+) Efficient tool of carbon risk management by successively adjusting carbon emissions limit in line with political and scientific factors.

(+) Fixed annual carbon emissions cap that can be freely traded and thus permit more flexibility than other forms of carbon pricing such as carbon taxation.

(+) Higher public acceptance than fiscal measures including carbon taxes.

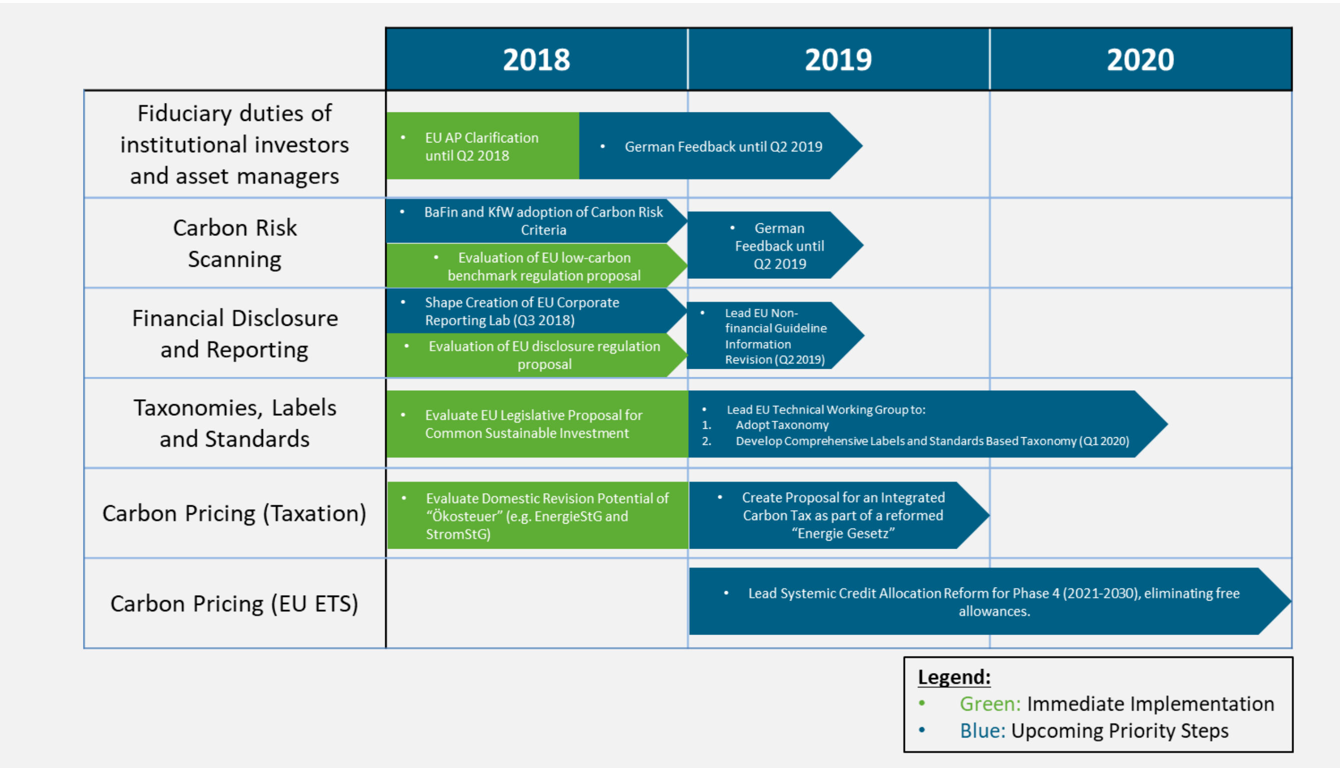
(-) High administrative burden for overall scheme implementation and operation.
(-) Higher risk of abuse through flaws in trading platforms
(-) EU ETS inefficient through overallocation of emissions certificates

Recommendations
The political preference for market-based carbon price floor mechanisms notwithstanding, ETS in their current form are either inefficient due to administrative complexity or lack certificate allocation rigidity. At the moment, the EU ETS is without alternative given the significant efforts already having been made over the past decades. For it to develop its full potential, it needs to be extended to include more carbon-intensive industries and the amount of annual certificate allocations by Member states needs to be reduced to raise the carbon price floor. Germany should utilize its political clout to influence European decision-makers and partners to revise the EU ETS scheme. Germany should utilize its political clout to influence European decision-makers and partners to revise the ambitions of the EU ETS scheme during the Phase 4 (2021-2030) rollout.

4.6 Recommendations for the German government

The German government is recommended to advance the six selected priority instruments for integrating carbon risks into the decision-making process of financial institutions in the following way (see Figure 4-2).

Figure 4-2: Recommended instrument implementation timeline



Source: Own Representation, Oxford University.

5 Conclusions

The analysis of carbon risks in Germany and their impact on the German economy highlighted that out of the 23 selected sectors there are five specific sectors that will very likely be significantly affected by a low-carbon transition in line with the 2 °C climate scenario of the IEA from 2015 to 2030:

- coal,
- cement & lime,
- non-RES power,
- BF/BOF iron & steel and
- animal production.

From 2015 to 2030, these German sectors will be affected by decreasing economic output due to lower demand (e.g. less coal demand in the economy) and/or by increasing emission costs and emission abatement costs due to higher CO2 market prices and emission caps.

It is critical to understand that the operator carbon risks of these sectors will not only affect businesses operating in these sectors but also all financial institutions being invested in these sectors. The analysis before showed that the exposure of the financial sector to these sectors is still substantial. Financial institutions providing finance such as equity, corporate bonds/loans, sovereign bonds or mortgages to these sectors are therefore likely to face increasing carbon asset risks (e.g. higher probability of default). In case no clear and strong actions are taken by the financial industry, this could lead to a carbon bubble on the financial markets that may negatively shake the German and international financial markets in the future.

A consequence, it is highly critical that the German government addresses these carbon asset risks in the financial markets before it is too late to address them effectively. The German government should do so by introducing new or reforming existing regulatory instruments that are most appropriate for implementation into the German financial market. Our analysis and active collaboration with regulators and industry stakeholders revealed that there are a number of priority instruments that the German government should address in the short and medium term to increase the resilience of the financial sector against the adverse effect of carbon asset risks. In short, the priority instruments and core recommendations are as follows:

- **Fiduciary duties of institutional investors and asset managers**:
  Germany should extend or specify the fiduciary obligations in order to include concrete effects of an investment on climate change/climate protection and an appropriate consideration of carbon risks. The national fiduciary duties can be adjusted by incorporating elements from the BaFin MaRisk, the German Corporate Governance Index and the EU Action Plan. A strict interpretation and more ambitious implementation of non-financial reporting at EU level 2014/95/EU (CSR-RUG) would create additional transparency. The legal liability regulations in the event of a breach of the consideration of climate risks in the fiduciary duties should be extended.
- **Carbon Risk Scanning**:
  Germany should join initiatives to investigate and actively promote climate-related scenario analyses and stress tests, in particular via the European Central Bank (ECB) (including the European Systemic Risk Board (ESRB)) and the European Banking Authority (EBA). This requirement is in line with the recommendations of the EU High Level Expert Group on Sustainable Finance (HLEG). Another possibility is to strengthen coordination with the German regulatory authority BaFin and KfW in order to create a joint stress testing framework in Germany.
- **Financial Disclosure and Reporting**:
  Germany should initiate an international working group and work towards concrete results to promote convergence and wider adoption of disclosure within an obligatory international

supervisory framework. This should be based on the recommendations of the TCFD, the Financial Stability Board (FSB), the EU Action Plan (EU-AP, Action 9) or the French Energy Turnaround Act (Art. 173). This should ensure uniformity of the different approaches and better comparability. The TCFD recommendations and the proposals of the EU Disclosure Regulation (EC, 2018/0179 (COD)) should serve as the main templates.

- **Taxonomies, Labels and Standards**:
  Germany should promote the development of a common taxonomy at EU level (EU-AP Action 1 & 2) in cooperation with industry leaders on ESG assessments such as the UN Principles of Responsible Investment (PRI). The key here is to develop a dynamic, forward-looking approach by anchoring Paris-compatible transformation paths that will enable the development of ESG-compatible business models and products within the paths agreed with the climate targets. The development of EU taxonomy templates should be accompanied and commented by Germany together with the private sector such as Deutsche Börse and ESG analysts.
- **Carbon Pricing (carbon taxation)**:
  Germany should bundle the German "eco-tax(es)" in a common framework, adapt it to the climate targets and expand it in order to have a leverage effect on the financial sector and thus achieve the same results as a pure carbon tax.
- **EU Emission Trading Scheme:**
  Germany should use its political influence to spur European decision-makers and partners on the revision of the EU ETS system and should work continuously at European level to raise the ambition level of the EU ETS in Phase 4 (2021-2030).

6 Annex

6.1 Modelling of operator carbon risks

To calculate the sector-level operator carbon risk, i.e. the financial loss of a sector due to the materialisation of carbon risk, we need to set up a formula that describes a sectoral profit function using microeconomics.

The formulas below show the development of the profit function of a sector with the index “i” (note that “i” is not shown explicitly in the formula below) and is applicable to any point in time t (e.g. today t=2015 to future t+1=2030).

A general sectoral profit function is composed of revenues and costs:

Profit = revenue – costs

$$\pi_t = R_t - C_t$$

Costs can further be distinguished between fix costs and variable costs; the former being independent of the sector output level and the latter being dependent on the sector output level:

Profit = revenue – fix costs – variable costs

$$\pi_t = R_t - C_t^F - C_t^V$$

Variable costs can be further split into emission costs, emission abatement costs (i.e. abatement costs) and all other variable costs:

Profit = revenue – fix costs – [emission costs + abatement costs + all other variable costs]

$$\pi_t = R_t - C_t^F - [\; C_t^E + C_t^A + C_t^O \;]$$

The emission costs can be further split into direct scope 1 emission costs plus indirect scope 2 and scope 3 (upstream) emission[35] costs.

Abatement costs could in theory also be further split according to scope 1, 2 and 3 emissions. Due to methodical and data availability constraints, however, abatement costs are only introduced for direct scope emissions, i.e. the abatement costs of a sector to reduce its direct scope 1 emissions such as emissions from gas consumption. Note that the abatement costs can, at maximum, be equal to the product of the abatement volume and the CO2 Price as sectors can purchase carbon certificates instead of abating emissions if it is economically sound. For example, if abating emissions is more expensive than simply purchasing carbon certificates, a sector will always prefer to purchase carbon certificates:

Profit = revenue – fix costs

– [(scope 1 emissions x CO2 Price + scope 2 emissions x CO2 Price + scope 3 upstream emissions x CO2 Price) + (scope 1 abatement x CO2 price) + all other variable costs]

$$\pi_t = R_t - C_t^F - \begin{bmatrix} E_t^1 \times P_t^E + E_t^2 \times P_t^E + E_t^3 \times P_t^E) \\ + (A_t^1 \times P_t^E) \\ + C_t^O \end{bmatrix}$$

[35] Note that only upstream scope 3 emission costs are covered by the methodology. Any downstream scope 3 emissions cannot be covered due to methodical and data availability constraints.

$$with\ A_t^1 = E_{t-1}^1 - E_t^1$$

When calculating abatement costs, it is necessary to know how much a sector needs to reduce between two periods (here between 2015 and 2030). This information is retrieved from climate scenarios using data from the IEA.

As the profit function is largely dependent on sector specifics, it is important to consider sector characteristics, which can directly mitigate or aggravate the impacts of carbon risks on the revenues or costs of a sector. These are explained in chapter 2.2.1. To account for these sector characteristics, it is necessary to further extend the function above[36]:

*Profit = revenue x (1 - **revenues at risk**) – fix costs*

*– [(scope 1 emissions x CO2 Price x (1- **own-pass-through ability**) + scope 2 emissions x CO2 Price x (**supplier pass-through ability**) + scope 3 upstream emissions x CO2 Price x (**supplier pass-through ability**)) + (scope 1 abatement x CO2 price x (1 - **abatement capability**) + scope 2 abatement x CO2 price) + all other variable costs]*

$$\pi_t = R_t \times \boldsymbol{\gamma} - C_t^F - \begin{bmatrix} E_t^1 \times P_t^E \times \left(1-\boldsymbol{\alpha}^{\boldsymbol{E1}}\right) + E_t^2 \times P_t^E \times \boldsymbol{\beta}^{\boldsymbol{E2}} + E_t^3 \times P_t^E \times \boldsymbol{\beta}^{\boldsymbol{E3}}) \\ + ((A_t^1) \times P_t^E \times (1 - \boldsymbol{\partial}^{\boldsymbol{E1}})) \\ + C_t^O \end{bmatrix}$$

As we are interested in estimating how today's profit changes from now (t=2015) to the future (t+1=2030), we need to develop a sector profit function for 2030 (using 2015 values as a starting point). Therefore, we need to introduce information on economic change, emission change etc. from 2015 to 2030. This information is retrieved from climate scenarios using data from the IEA.

$$\pi_{t+1} = R_{t+1} \times \boldsymbol{\gamma} - C_{t+1}^F - \begin{bmatrix} E_{t+1}^1 \times P_{t+1}^E \times \left(1-\boldsymbol{\alpha}^{\boldsymbol{E1}}\right) + E_{t+1}^2 \times P_{t+1}^E \times \boldsymbol{\beta}^{\boldsymbol{E2}} + E_{t+1}^3 \times P_{t+1}^E \times \boldsymbol{\beta}^{\boldsymbol{E3}}) \\ + (A_{t+1}^1 \times P_{t+1}^E \times (1 - \boldsymbol{\partial}^{\boldsymbol{E1}})) \\ + \times C_{t+1}^O \end{bmatrix}$$

$$with\ R_{t+1} = \left(1 + \Delta_{IEA}^{Q}\right) \times R_t;$$

$$with\ C_{t+1}^F = C_t^F$$

$$with\ E_{t+1}^1 = (1 + \Delta_{IEA}^{E1}) \times E_t^1;$$

$$with\ E_{t+1}^2 = (1 + \Delta_{IEA}^{E2}) \times E_t^2;$$

$$with\ E_{t+1}^3 = \left(1 + \Delta_{IEA}^{E3}\right) \times E_t^3;$$

$$with\ P_{t+1}^1 = \text{given by IEA}$$

$$with\ A_{t+1} = \left(1 + \Delta_{IEA}^{Q}\right) \times E_t^1 - (1 + \Delta_{IEA}^{E1}) \times E_t^1\ ;$$

$$with\ C_{t+1}^O = \left(1 + \Delta_{IEA}^{Q}\right) \times C_t^O;$$

The final sector profit function in 2030 is thus represented by the following formula[37]:

[36] For further explanations on each sector characteristic please go to chapter 2.1.

[37] Note that the blue variables indicate economic variables, the orange variables emission variables and the grey variables sector characteristics.

$$
\begin{aligned}
&\pi_{t+1} \\
&= (1+\Delta^{Q}_{IEA}) \times R_t \times \gamma - C^F_t \\
&- \left[\begin{array}{c} (1+\Delta^{E1}_{IEA}) \times E^1_t \times P^E_{t+1} \times (1-\alpha^{E1}) + (1+\Delta^{E2}_{IEA}) \times E^2_t \times P^E_{t+1} \times \beta^{E2} + (1+\Delta^{E3}_{IEA}) \times E^3_t \times P^E_{t+1} \times \beta^{E3}) \\ + (((1+\Delta^{Q}_{IEA}) \times E^1_t - (1+\Delta^{E1}_{IEA}) \times E^1_t) \times P^E_{t+1} \times (1-\partial^{E1})) \\ + \times (1+\Delta^{Q}_{IEA}) \times C^O_t \end{array} \right]
\end{aligned}
$$

Note that the CO2 price is externally given and retrieved from climate scenarios using data from the IEA.

6.2 Data needs for modelling of operator carbon risks

To set up a sectoral profit function, a lot of input data from different data sources is needed. The following data table provides an overview of the most important data required.

Table 6-1: Data inputs needed to model operator carbon risk

	Name		Description /calculation	Data source
Economics	Economic change (%)	Δ^{Q}_{IEA}	Economic change is the % change in output according to the IEA scenario.	IEA ETP
	Revenue	R_t	Revenue is not disaggregated into P and Q but given as one parameter in statistics.	Eurostat/ Destatis
	Fix costs	C^F_t	Fix costs are calculated by multiplying the fix cost share from statistics with the total revenue.	Destatis
	Other variable costs	C^O_t	Other variable costs are equal to the difference of total costs and fix costs.	Destatis
Emissions	Scope 1 emissions	E^1_t	Scope 1 emissions are equal to the direct GHG Emissions from statistics.	Destatis, EUTL
	Scope 2 emissions	E^2_t	Scope 2 emissions are based on the electricity and heat energy consumption from statistics.	Destatis
	Upstream scope 3 emissions	E^3_t	Upstream scope 3 emissions are based on the purchased inputs from Input-Output tables and the scope 1 emissions of the respective input supplier.	Destatis
	Scope 1 emission change (%)	Δ^{E1}_{IEA}	Scope 1 emission change is the change in direct GHG emissions in line with the IEA 2°C climate scenario	IEA ETP
	Scope 2 emission change (%)	Δ^{E2}_{IEA}	Scope 2 emission change is the change in indirect GHG emissions from electricity and heat in line with the IEA 2°C climate scenario	IEA ETP
	Upstream scope 3 emission change (%)	Δ^{E3}_{IEA}	Upstream scope 3 emission change is based on the purchased inputs ((Input-Output tables) and the scope 1 emission change of input supplier.	IEA ETP / Destatis
Sector characteris-	Revenues at risk (%)	γ	Revenue share at risk is the share of revenue that a sector generates in sectors with a high carbon risk. It is based on Input-Output tables.	Navigant/ Destatis
	Own pass-through ability (%)	α^{E1}	Own pass-through ability is approximated by the share of sector free EU ETS allowances. A sector that gets few free allowances due to low	Navigant

			carbon leakage risk is more able to pass-through increasing emission costs.	
	Supplier pass through (%)	β^{Ey}	Supplier pass-through ability is based on the purchased inputs (Input-Output tables), the scope 1 emissions of input suppliers and the pass-through ability of input supplier.	Destatis/ Navigant
	Abatement capability (%)	∂^{E1}	Abatement capability gives an indication in how far a sector can reduce emissions cheaper than the CO2 Price. It is based on MACC[38] curves.	Literature on MACC/ Navigant expert judgement

Source: Own representation, Navigant – A Guidehouse Company.

6.3 Further explanations on the IEA 2°C climate scenario

6.3.1 Analytical approach

Energy Technology Perspectives 2016 (ETP 2016) applies a combination of back casting and forecasting over three scenarios from now to 2050. The analysis and modelling aim to identify the most economical way for society to reach the desired outcome, but for a variety of reasons the scenario results do not necessarily reflect the least-cost ideal. Many subtleties cannot be captured in a cost-optimisation framework: political preferences, feasible ramp-up rates, capital constraints and public acceptance. For the end-use sectors (buildings, transport and industry), doing a pure least-cost analysis is difficult and not always suitable. Long-term projections inevitably contain significant uncertainties, and many of the assumptions underlying the analysis will likely turn out to be inaccurate. Another important caveat to the analysis is that it does not account for secondary effects resulting from climate change, such as adaptation costs. By combining differing modelling approaches that reflect the realities of the given sectors, together with extensive expert consultation, ETP obtains robust results and in-depth insights.

6.3.2 ETP model

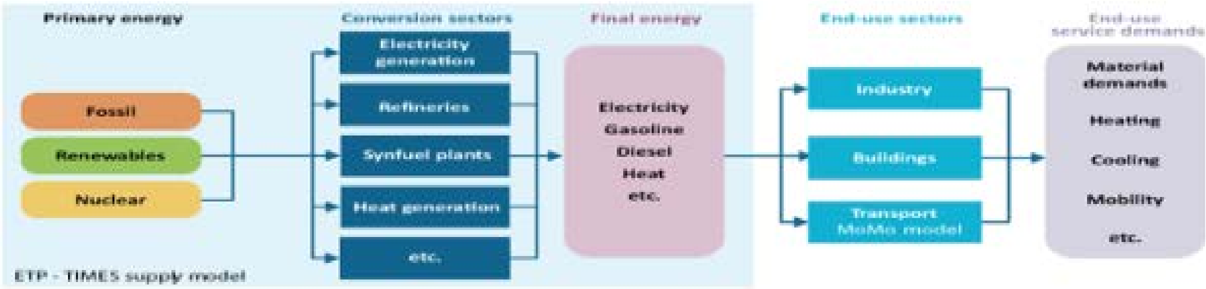
The ETP model, which is the primary analytical tool used in ETP 2016, supports integration and manipulation of data from four soft-linked models:

- energy conversion
- industry
- transport
- buildings (residential and commercial/services).

It is possible to explore outcomes that reflect variables in energy supply (using the energy conversion model) and in the three sectors that have the largest demand, and hence the largest emissions (using models for industry, transport and buildings). The following schematic illustrates the interplay of these elements in the processes by which primary energy is converted to the final energy that is useful to these demand-side sectors.

[38] i.e. marginal abatement cost curves.

Figure 6-1: Schematic illustration of the ETP model



Source: IEA ETP.

Notes: TIMES = The Integrated MARKAL-EFOM System; MoMo = Mobility Model.

6.3.3 Scenarios

In the ETP model, the IEA analysis how clean energy technologies and policies (e.g. CO2 prices) need to develop to restrict global warming to a certain temperature increase. The scenarios associated to a certain temperature increase are often referred to as climate scenarios.

The IEA analyses the following three climate scenarios on an annual basis:

- The 2°C Scenario (2DS) is the main focus of Energy Technology Perspectives. The 2DS lays out an energy system deployment pathway and an emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2°C. The 2DS limits the total remaining cumulative energy-related CO2 emissions between 2015 and 2100 to 1 000 GtCO2. The 2DS reduces CO2 emissions (including emissions from fuel combustion and process and feedstock emissions in industry) by almost 60% by 2050 (compared with 2013), with carbon emissions being projected to decline after 2050 until carbon neutrality is reached.
- The 4°C Scenario (4DS) takes into account recent pledges by countries to limit emissions and improve energy efficiency, which help limit the long-term temperature increase to 4°C. In many respects the 4DS is already an ambitious scenario, requiring significant changes in policy and technologies. Moreover, capping the long-term temperature increase at 4°C requires significant additional cuts in emissions in the period after 2050.
- The 6°C Scenario (6DS) is largely an extension of current trends. Primary energy demand and CO2 emissions would grow by about 60% from 2013 to 2050, with about 1 700 GtCO2 of cumulative emissions. In the absence of efforts to stabilise the atmospheric concentration of GHGs, the average global temperature rise above pre-industrial levels is projected to reach almost 5.5°C in the long term and almost 4°C by the end of this century.

Note that a new climate scenario with a temperature increase being equal to the agreements in the Paris Climate Agreement, i.e. well below 2°C and to pursue efforts to limit it to 1.5°C, is currently developed by the IEA.

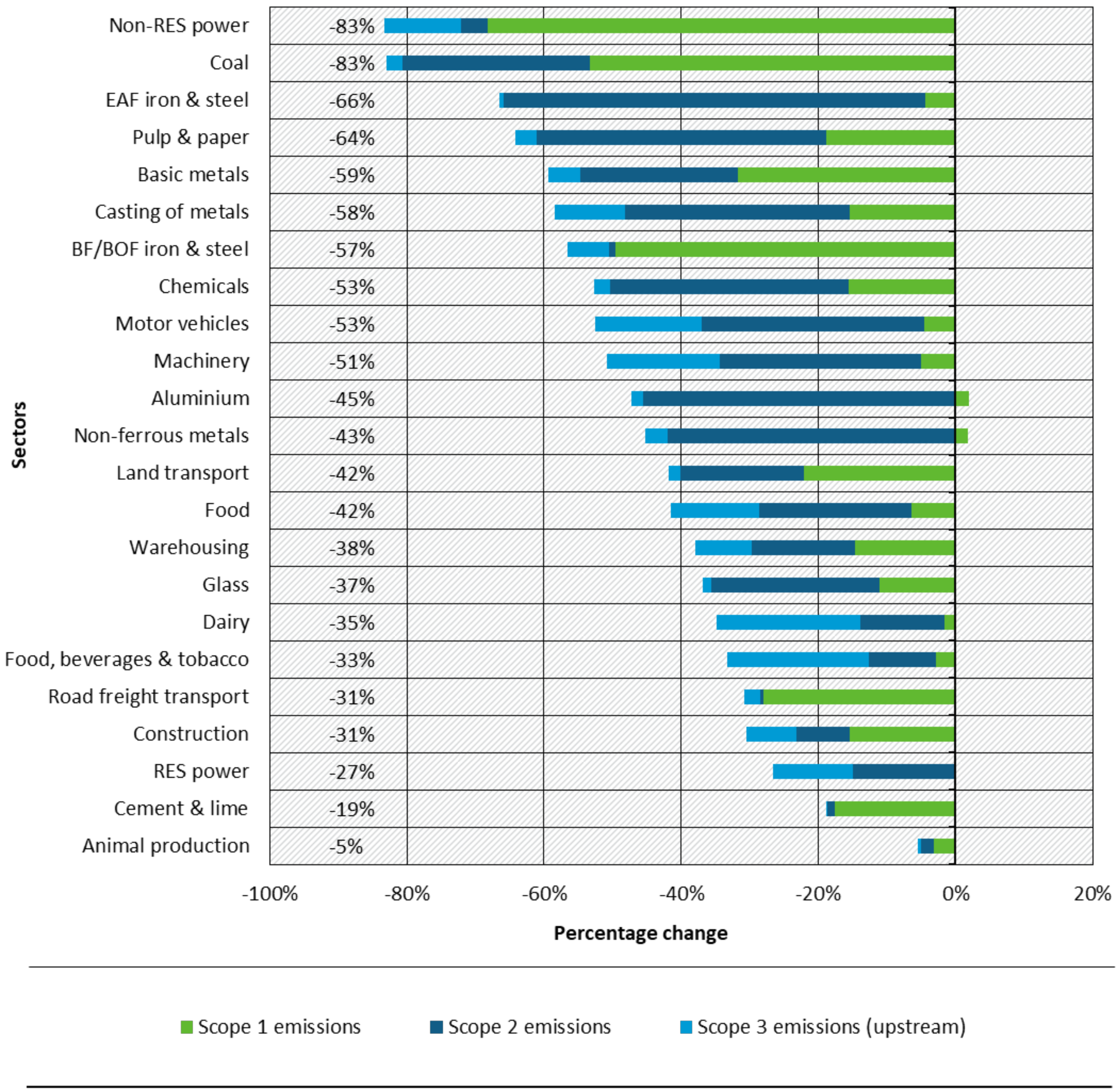
It is also important to note that the scenarios do not disaggregate the EU in all its individual member states but treat the EU as if it was one country.

6.4 Impact of carbon risks on economic sectors in Germany under the 1.5 °C climate scenario of the IEA

6.4.1 Emission change

Figure 6-2 shows the change in Scope 1, Scope 2 and upstream Scope 3 emissions of the year 2015 compared to 2030 in the context of the 1.5 °C IEA climate scenario (B2DS). The sectors with the most significant emission reductions are the non-renewable power sector (-83%), the coal sector (-83%), the EAF iron & steel Route (-66%) and the pulp & paper sector (-64%).

Figure 6-2: Change in emissions (scope 1, scope 2 & upstream scope 3 emissions) under the IEA 1.5°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

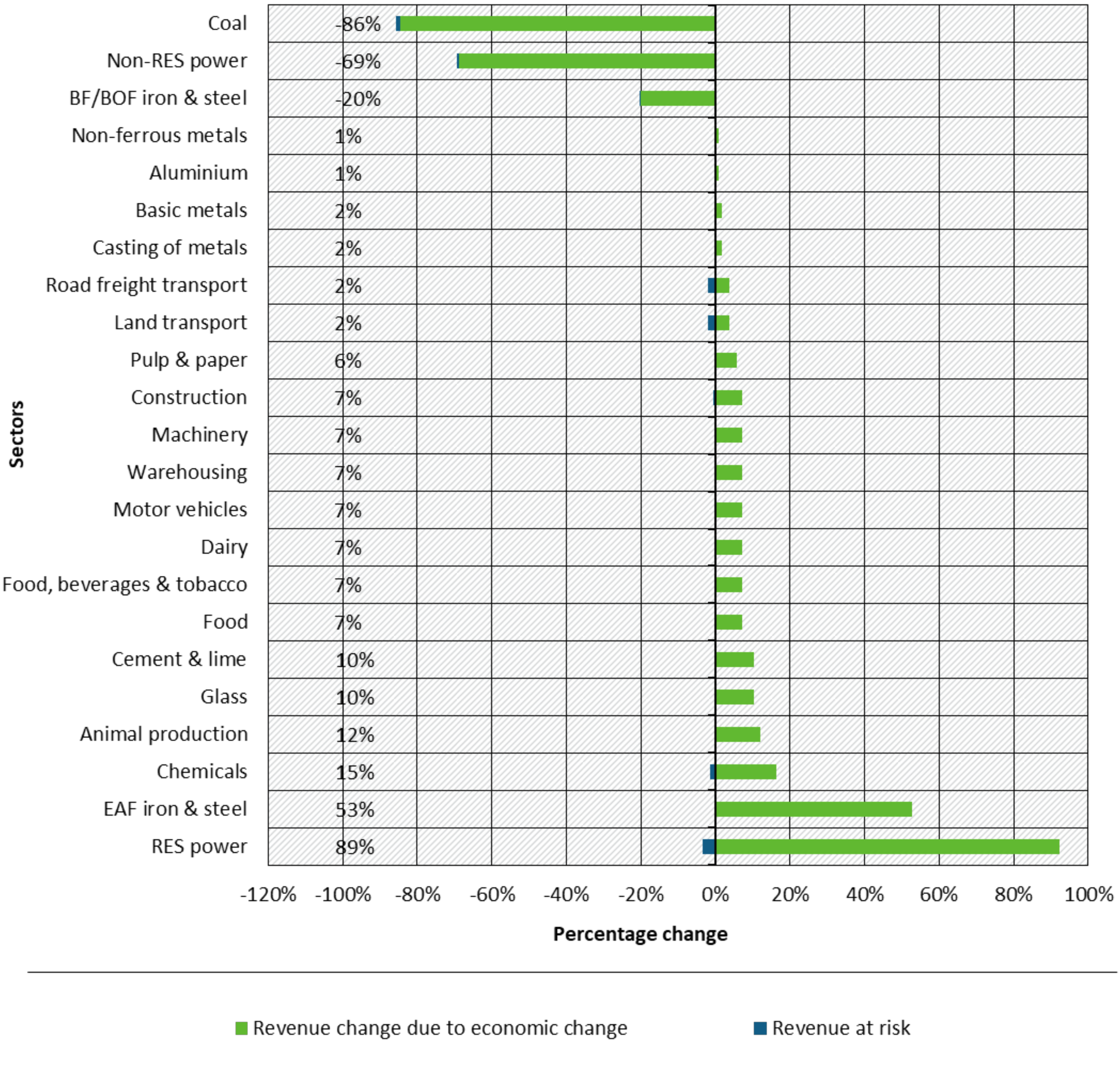
6.4.2 Profit change

The stranded asset indicator profit development is analyzed below. First, the variables determining the profit - sales and cost development - are illustrated and described for each sector. Finally, the resulting change in profit per sector is examined.

6.4.2.1 Revenue change

Figure 6-3 shows the revenues development within the framework of the 1.5 °C IEA climate scenario (B2DS). The sectors with the most significant reductions in turnover are the coal sector (-86%), the non-renewable power sector (-69%) and the BOF iron & steel route (-20%).

Figure 6-3: Change in revenue under the IEA 1.5°C climate scenario comparing 2015 with 2030

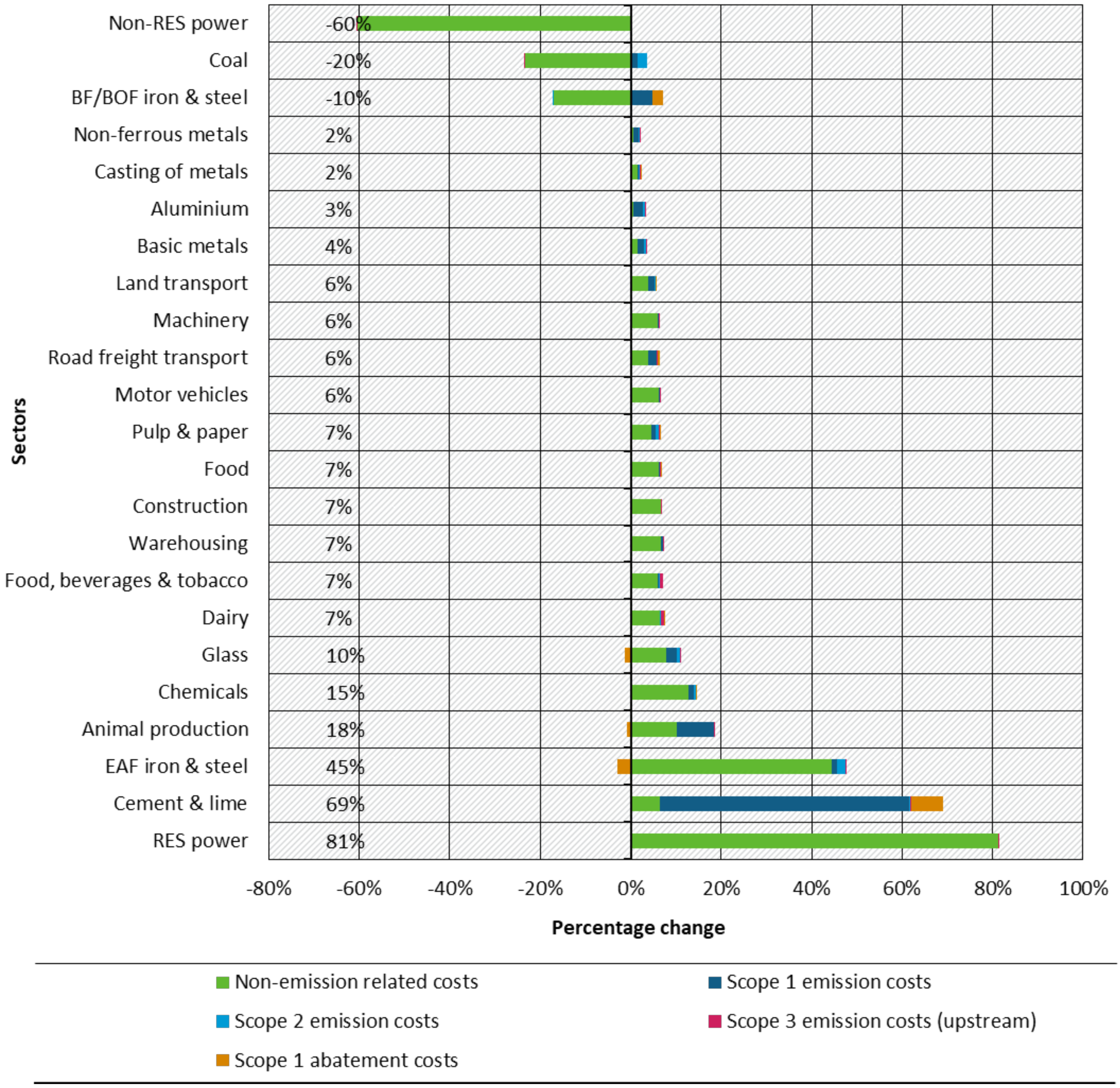


Source: Own representation, Navigant – A Guidehouse Company.

6.4.2.2 Cost change

Figure 6-4 shows the cost development within the 1.5 °C climate scenario of the IEA (B2DS). The sectors with the most significant cost reductions are the non-renewable electricity power sector (-60 %), the coal sector (-20 %) and the BOF iron & steel route (-20 %). The sectors with the most significant cost increases are the EAF iron & steel route (45%), the cement & lime sector (69%) and the renewable power sector (81%).

Figure 6-4: Change in costs under the IEA 1.5°C climate scenario comparing 2015 with 2030

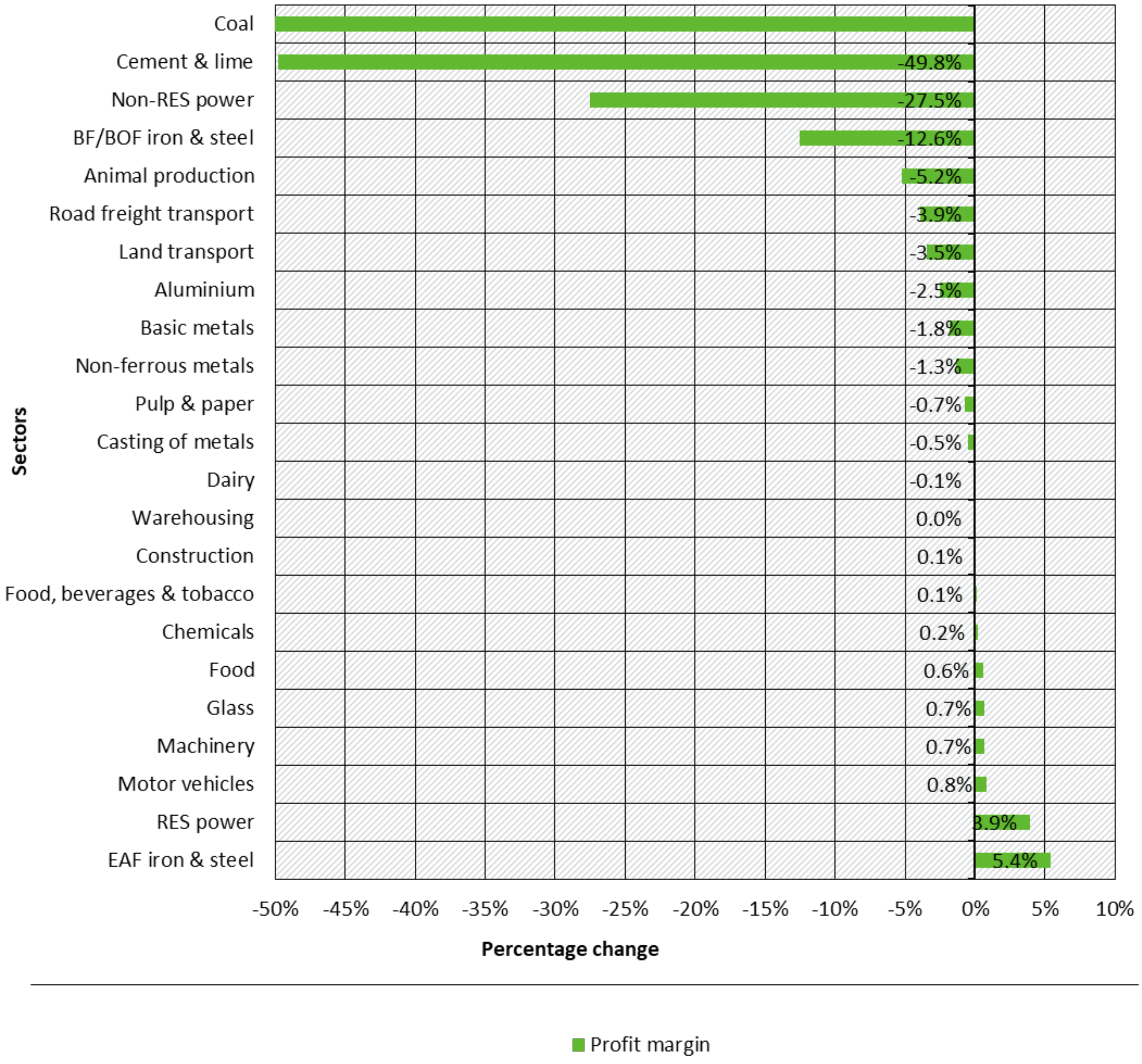


Source: Own representation, Navigant – A Guidehouse Company.

6.4.2.3 Profit margin change

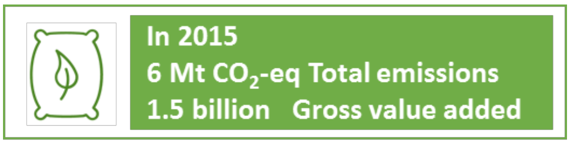
Figure 6-5 shows the change in profit margins (in percentage points) within the 1.5 °C climate scenario of the IEA (B2DS). The sectors with the most significant declines in profit margins are the coal sector, the cement & lime sector (-49.8 %) and the non-renewable power supply sector (-27.5 %).

Figure 6-5: Change in profit margin in percentage points under the IEA 1.5°C climate scenario comparing 2015 with 2030



Source: Own representation, Navigant – A Guidehouse Company.

6.5 Excursus on fertilizer industry



Fertilizer.[39] Due to unavailability of data, the fertilizer sector, which is a subsector of the chemicals sector, was not included in any of the analysis above. However, as it is also a sector that is likely to face high carbon risks, we at least would like to give some brief insights into this sector. The fertilizer industry is emitting a significant amount of emissions, i.e. nearly 6 Mt CO_2-eq in 2015. The most important driver of the emissions in this sector is the ammonia (NH_3) production, with an average emissions of 1.95 t CO2/t NH_3 in a European plant. The total energy use of European

[39] The fertilizer production sector was not included because of a lack of available and reliable data.

production plants is on average 35 GJ/t NH_3. For existing plants, the biggest lever in reducing emissions is to reduce the energy use by energy efficiency measures. The energy saving potential for European plants is estimated at 3 GJ/t NH_3 until 2030.[40] Replacing all existing plants by state-of-the-art production plants would reduce the average energy use even further, down to 27 GJ/t NH_3.

The theoretical minimum energy use required for the ammonia production is 18 GJ/t NH_3 (based on the current hydrogen manufacturing process, i.e. steam reforming from hydrocarbons). This cannot be further reduced given current production process & conditions. In the future, however, green hydrogen[41] could be a lever to further decarbonize the remaining energy use. One alternative would be green hydrogen production via electrolysis, which today is not yet cost competitive to conventional production processes. However, green hydrogen via electrolysis gains momentum as the electricity costs development of renewables is further decreasing.[42]

6.6 Existing regulatory initiatives

Some countries have initiated an agenda for sustainability within financial policy and regulation, including the identification of climate-related transition risks as well as actions to redistribute the trillions required to transition towards a low-carbon and sustainable economy. However, initiatives remain at an early stage. In the following table, we provide in a non-exhaustive list of the enterprises led at the regulatory level.

Table 6-2: Examples of Regulatory Initiatives

Countries	Initiatives
Europe	The Green European Foundation, founded by the European Parliament, has requested an analysis on the potential carbon bubble impacts on the EU financial system (Green European Foundation 2014). The European Bank for Reconstruction and Development (EBRD) launched the Investment Climate and Governance Initiative (ICGI) in 2014 to help governments, corporations, and investors improve transparency, good governance, and healthy competition on climate issues (EBRD 2014). The ICGI is designed to increase the impact of EBRD policy reform dialogue initiatives on areas of economic governance that directly affect the private sector. The Directive 2014/95/EU requires companies over 500 employees to report annually information on 'policies, risks and outcomes as regards environmental matters, social and employee aspects, respect for human rights, anti-corruption and bribery issues, and diversity in their board of directors' (European Parliament & Council of the European Union 2014). In September 2015, the European Commission formally defined the Capital Market Union (CMU) Action Plan for 'creating more opportunities for investors; connecting finance to the wider economy; fostering a stronger and more resilient financial system; and deepening integration and increasing competition' (2 Degrees Investing Initiative & UNEP Inquiry 2016). The European Commission launched, in December 2015, a public consultation on 'long-term and sustainable investments', to sustain European competitiveness and meet the EU's policy objectives on enhancing 'environmentally and socially sustainable wealth creation'.

[40] Ecofys (2015). Fertilizers and Climate Change - Looking to 2050.

[41] Production methods of green hydrogen are (a) Water electrolysis powered by renewable energy sources (b) Biological water splitting, (c) Fermentation, (d) Thermochemical conversion of biomass and wastes, (e) Photoelectrochemical water splitting or (f) Solar thermal water splitting.

[42] Ecofys (2017). Green hydrogen - Can low-cost renewable electricity bring us closer to a carbon neutral fuel?

	On December 2016, the new 'Institutions for Occupational Retirement Provision Directive' (IORP II) was passed at the EU level to improve the management of carbon risks (Official Journal of the European Union 2016). Major public financial institutions (e.g. the European Investment Bank (EIB)) are leading in screening out high-carbon investments (2 Degrees Investing Initiative & UNEP Inquiry 2016). The European Systemic Risk Board released an assessment (ESRB 2016) of the impacts of a transition to a low-carbon economy on systemic risk, in response to a request from the ECB. The European Commission has defined a High Level Expert Group (HLEG), which submitted its preliminary report (EU High-Level Expert Group on Sustainable Finance 2017) suggesting, in particular: the classification of sustainable assets; a European standard and label for green bonds and other 'green' products; accounting standards for energy efficiency; an enhanced fiduciary duty and disclosure incorporating sustainability; and the re-positioning of European supervisory agencies on sustainability.
France	The French public investor FRR has initiated a project (Fonds de Réserve des Retraites 2009) to define investment strategies with a broader environmental focus (climate, fossil fuel resources, biodiversity, and water). The Law on Energy Transition (Article 173) was enforced in August 2015 and compels financial and non-financial companies to report their exposure to climate risks, as well as financial institutions to disclose their climate-friendly and financed emissions (Ministere de la Transition Ecologique et Solidaire 2015). In particular, banks and credit institutions must perform regular stress tests.
G20	A Green Finance Study Group was set up under the Chinese G20 Presidency in 2016 and is co-chaired by China and the United Kingdom, with support from the UN Environment Programme (UNEP Inquiry 2016). It is designed to research and report on the challenges of reaching a climate-friendly economic and financial system. The G20 Green Finance Synthesis Report (G20 Green Finance Study Group 2017) summarizes the work done in this regard. The Financial Stability Board (FSB) of the G20 launched a Task Force on Climate-related Financial Disclosure (TCFD 2017), led by Mark Carney and Michael Bloomberg, aiming at improving reporting on the financial impacts of climate risk (including from climate policy) to avoid abrupt market corrections.
Germany	In 2001, the German Council for Sustainable Development ('Nachhaltigkeitsrat') has been created to advise the government on 'its sustainable development policy' (German Council for Sustainable Development 2001). The Insurance Supervision Act of 2002 mandates German funds to disclose to beneficiaries whether, and if so, how, they account for ethical, social, and ecological interests in their investment strategies (2 Degrees Investing Initiative & UNEP Inquiry 2016). On 14 November 2016, the government approved the German Climate Action Plan 2050 ('Klimaschutzplan 2050') outlining measures to support the 'Energiewende' (Amelang et al. 2016).

	Four federal states are planning to divest from assets with a detrimental climate impact (Energy Transition & The Global Energiewende 2016).
Sweden	The Minister for Financial Markets, Per Bolund, has claimed the support of financial markets in climate change mitigation (Government Offices of Sweden 2015). In February 2016, the Swedish Financial Supervisory Authority reported to the government on the impacts of climate change on financial stability (Swedish Financial Supervisory Authority 2016).
United Kingdom	In 2012, the UK established the world's first Green Investment Bank (UNEP Inquiry 2016). Following an invitation from the Department for Environment, Food and Rural Affairs under the 2008 UK Climate Change Act, the Prudential Regulation Authority released long-term oriented climate stress-test results of the UK insurance sector (Prudential Regulation Authority 2015), encompassing physical, transition, and liability risks (from parties impacted by climate change). This report was part of an adaptation report, which informed, among others, the UK Climate Change Risk Assessment Report released in 2017. The UK government supported the City of London Corporation in the creation of the Green Finance Initiative (Green Finance Initiative 2016).
United Nations	The UNEP Finance Initiative was created to act as a platform associating the United Nations and the financial sector globally. Through its network, the publication of research reports, the organization of conferences and training seminars, UNEP-FI contributes to promoting the adoption by financial institutions of the 'UNEP-FI Statements'. This work has included efforts on the development of a sustainable financial system (http://www.unepfi.org/about/unep-fi-statement/). The United Nations and Carbon Disclosure Project (CDP) facilitated the creation of the Portfolio Decarbonization Coalition to catalyze document, and display to governments ahead of COP21, current and future decarbonization leadership worldwide, including among investors (UNEP-FI 2015).

Source: Own representation, Oxford University.

6.7 Performance Assessment Matrix (PAM) Scoring

Table 6-3: PAM categories of assessment for tools used by and financial institutions to measure and integrate carbon and climate risks in an efficient manner

Category	Sub-category	Description
1) Supports Carbon Risk Management in Financial Institutions	1.1) Reveal risks for financial institutions	Does the instrument improve access to carbon risk data or analysis, or foreground carbon risk for financial institutions?
	1.2) Price signal for risks facing financial institutions	Does the instrument create a price for carbon risks in support of a below 2ºC scenario?
	1.3) Creation of alternative investments, hedges, or risk management products for financial institutions	Does the instrument support risk management through diversification, hedging, or insurance opportunities?
	1.4) Tools or capabilities to help financial institutions manage risk	Does the instrument facilitate the management of carbon risks?
2) Implementation	2.1) Simplicity and speed of implementation	Can the instrument be implemented in a simple and rapid manner?

Category	Sub-category	Description
Feasibility	2.2) Previous experience of implementation	Has the instrument already been implemented and is that experience relevant to implementation today?
	2.3) The cost of implementation and who bears the cost	How high are the costs of implementation and who bears these costs? Private sector, public sector, etc.?
	2.4) Consistent and supportive of international efforts	Does the instrument have potential to support harmonization and standardization?
	2.5) Fit with German economic, legal and financial system	How compatible is the instrument with the German economic context or legal framework?
	2.6) Political feasibility	How possible politically is the implementation of the instrument?
3) Impact on Climate Change	3.1) Ultimate impact on availability and cost of capital for 'brown' and 'green'	Does the instrument reduce (increase) the cost of capital for 'green' ('brown') or increase (reduce) the availability of capital/liquidity for 'green' ('brown')? To what extent does it do this?
	3.2) Support of systemic change and 'tipping' points	Does the instrument support systemic change or adoption of green practices through spillover effects?

Source: Own representation, Oxford University.

Those pre-defined assessment criteria will be employed to outline the strengths and weaknesses of each instrument. They will be applied to each instrument through a literature review and will be rated on a scale from 1 to 5, with 5 being the highest score.

6.8 Explanation and results of the quantitative assessment of carbon risk integration tools in the financial markets

The results in chapter 4.4.3 of the report are based on a quantitative evaluation in which weighted numerical values were replaced by high, medium and low. These are listed below.

Classification of sub-categories

1.) Supports Carbon Risk Management in Financial Institutions (50 %)

   >2 = High

   >1 und 2< = Medium

   ≤1 = Low

2. Implementation Feasibility (30 %)

   >1 = High

   >0.7 und 1≤ = Medium

   ≤0.6 = Low

3. Impact on Climate Change (20 %)

   ≥0.7 = High

   ≥0.5 und 0.6< = Medium

   ≤0.4 =Low

Table 6-4: Summary of Weighted Instrument Ratings[43]

Instruments	1) Supports Carbon Risk Management in Financial Institutions (50%) Subtotal I	2) Implementation Feasibility (30%) Subtotal II	3) Impact on Climate Change (20%) Subtotal III	Total PAM-Score	Final Rating
Fiduciary duties of institutional investors and asset managers	1,375	1,15	1	**3,525**	
Carbon Risk Scanning	1,75	1,25	0.6	**3,57**	
Financial Disclosure and Reporting	2,25	1,35	1	**4,60**	
Taxonomies, Labels and Standards	2,375	0,95	1	**4,325**	
Carbon Pricing (Taxation)	2,33	0,8	1	**4,13**	
Carbon Pricing (EU ETS)	1,625	1,1	0,8	**3,525**	
Incentives for investments/financial advisers and asset managers	1,25	0,95	0,6	**2,8**	
Capital Requirements	1,5	0,85	0,5	**2,85**	
Accounting Standards (IAS and IFRS)	2,125	0,95	0,7	**3,775**	
Indices and Ranking	2,125	1	0,7	**3,825**	
Credit and Sustainability Ratings	2,125	1,05	0,9	**4,175**	
Tax Credits	1,25	0,75	0,5	**2,5**	
Sustainability Mandates	1,5	0,8	0,6	**2,9**	
Green Investment Banks	1,625	1,35	0,8	**3,775**	
Central Bank Mandates	1,75	0,6	0,6	**2,95**	
Extend Legal Liability Regimes for Investors	1,17	0,65	0,4	**2,22**	
Priority Sector Lending	1	0,6	0,5	**2,1**	
Targeted Sectoral Investment Prohibitions	2	0,45	0,9	**3,35**	
Consumer and Regulator Capacity Building	1,5	1,35	0,8	**3,48**	

43 (Scores 0-2.49 = red [low potential]; 2.5-3.49 = orange [medium potential]; 3.5-5 = green [high potential])/ Blue = Priority instruments

Instruments	1) Supports Carbon Risk Management in Financial Institutions (50%) Subtotal I	2) Implementation Feasibility (30%) Subtotal II	3) Impact on Climate Change (20%) Subtotal III	Total PAM-Score	Final Rating
Codes of Conduct and Non-financial Guidance	1,15	1,15	0,8	**3,12**	
Engagement	1	0,55	0,4	**1,95**	

Source: Own Representation, Oxford University.

7 Literature

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