Logic Model for Environmental, Social, and Governance (ESG)
Impact Pathways and Assessments

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“One should be light like a bird, and not like a feather.”

Paul Valery

Summary

The goal of this dissertation is to facilitate the assessment of impacts from sustainable measures and projects with an emphasis on impact reporting for Green, Social or Sustainability Bonds in the Sustainable Finance market. It does so by providing analysts with the means to develop, depict, formulate, and assess a causal hypothesis between an intervention and its subsequent effects in an impact-chain, represented by desired environmental (E), social (S) or governance (G) changes. This is achieved by developing a methodology for so-called ESG Logic Models or ESG-LM, that combine heuristic Theories-of-Change with propositional logic and Bayesian Reasoning.

Three research questions are investigated and responded to. Research Question 1 asks how such Theories-of-Change can be developed for any type of ESG-related issue and how the different process steps in a causal chain can be classified, hierarchised, and prioritised regarding their efficacy towards overarching sustainability goals and their plausibility. Research Question 2 studies (a) the means by which the analyst or any other interested third party might be warranted in believing the causal claims from an ESG-LM, and (b) how an ESG-LM can be improved if this credence is low. Research Question 3 then looks at the reporting of impacts themselves regarding indicator selection, indicator assessment and indicator quantification as well as the provision of information on the contributions and attributions by different actors.

The dissertation draws on a variety of theories and adapts existing methods to achieve that. It operationalises concepts from empirical Sustainable Finance research and already existing impact assessment methodologies. It adapts scholarly and practitioner approaches for theory-based evaluation and applies a qualitative social science perspective towards theory-building and evaluation, while some of the assessment tools in the dissertation are grounded in Logic, Set Theory and Bayesian Epistemology. Examples for such tools include rules for the Attribution by actors, heuristics for the abduction of plausible outcome pathways, or a four-stage Argument and Decision-Tree to assess the credibility of ESG-LM claims (based on Bayes Theorem).

My assessment of the entire methodology is positive overall, as it provides solutions to each of the three research areas. Limitations of the approach, and thus opportunities for further research, are the additional expertise and time required by analysts compared to the existing, and somewhat more pragmatic, solutions in the current market. However, this is outweighed in my opinion by the ability of the framework to strongly mitigate *impact washing* by actors in the financial markets as well as biases by analysts. Its overall methodology also provides opportunities for new research angles in the area of sustainability indicators and assessments.

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CONTENTS

1 Goals and Methodology 1

1.1 INTRODUCTION 1

1.2 GOALS OF THE STUDY 3

1.2.1 Interdisciplinary of the study........ 4

1.2.2 Premises and research questions 5

1.3 TASKS AND STRUCTURE OF THE STUDY 7

1.4 ON DEFINITIONS, TERMINOLOGY, AND EMPHASIS 8

1.5 DESK RESEARCH: ESG IMPACTS IN SF 8

1.5.1 Definitions in the context of ESG impacts........ 8

1.5.2 Relevant regulatory frameworks for ESG dimensions 10

1.5.3 Sustainable investments and funding 13

1.5.4 ESG impact assessment........ 22

1.6 PREMISES OF STUDY IN LIGHT OF DESK RESEARCH 28

1.7 DESK RESEARCH: IMPACT LOGICS 30

1.7.1 Scholarly methods 31

1.7.2 Practitioners' approaches........ 33

1.8 PREVIOUS AND CURRENT RESEARCH BY THE AUTHOR 34

1.9 THEORETICAL FRAMEWORK 36

1.9.1 Ontology (nature of causation) 36

1.9.2 Epistemology (knowledge of causation)........ 37

1.9.3 Epistemic purposes of the ESG-LM 38

1.9.4 Epistemic categorisation of the ESG-LM method 39

1.9.5 Theory-building of the ESG-LM........ 41

1.9.6 The role of the impact report in the ESG-LM framework........ 44

1.9.7 Measuring for impact reports in the ESG-LM 44

1.9.8 Epistemic justification of ESG-LM results 46

2 Development of Model Logic........ 48

2.1 FRAMEWORK OF THE ESG-LM........ 48

2.1.1 Building blocks of the model 48

2.1.2 Generic entities 49

2.1.3 Intervention entities........ 51

2.1.4 Outcome entities........ 53

2.1.5 Target conflict entities........ 55

2.1.6 Evaluation and measurement entities 57

2.2 HEURISTICS FOR TOC DEVELOPMENT 66

2.2.1 IBE for comparing working hypotheses ... *67*
2.2.2 Heuristic PrT of CMs ... *68*
2.3 CRITERIA-BASED EVALUATION OF ESG-LM ... 73
2.3.1 Goal Certainty ... *73*
2.3.2 Sufficiency ... *74*
2.3.3 Measurability ... *75*
2.3.4 Scaling and scoring of system attributes ... *76*
2.4 LANGUAGE OF THE ESG-LM ... 78
2.5 POC ... 80
3 PT for Climate Change Mitigation ... 82
3.1 CHARACTERISTICS OF THE EU TAXONOMY FRAMEWORK ... 82
3.2 DEVELOPMENT OF THE PT ... 83
3.3 CHARACTERISTICS OF PT ... 91
3.3.1 Potential indicators ... *92*
3.3.2 Generic target conflicts ... *93*
3.4 EVALUATION OF PROTOTYPE ... 94
3.5 ESG-LM OF PT ... 96
3.6 EMPLOYING THE PT ... 98
4 Impact Measurement ... 99
4.1 IMPACT ASSESSMENT METHODS ... 99
4.2 RULES OF ATTRIBUTION IN ESG-LMS ... 101
4.3 RULES OF ADDITIONALITY ... 103
5 Epistemic Justification for The ESG-LM ... 105
5.1 DEFINITION OF JUSTIFIED BELIEF ... 106
5.2 CAUSAL INFERENCE IN THE ESG-LM ... 108
5.3 ESG-LM HYPOTHESES FROM PROPOSITIONAL LOGIC ... 110
5.4 BR FOR ESG-LM HYPOTHESES ... 112
5.4.1 The five core rational constraints of Bayesian Epistemology ... *112*
5.4.2 Bays Theorem ... *113*
5.4.3 Additional objective rational constraints ... *114*
5.4.4 The integration of ranged credences and probability canons ... *115*
5.4.5 Bayesian Reasoning in ESG-LMs ... *117*
5.5 ADDITIONAL TOOLS FOR EPISTEMIC JUSTIFICATION ... 121
5.5.1 Bayesian Analysis (BA) ... *121*
5.5.2 Counterfactual Reasoning (CR) in ESG-LMs ... *122*
5.5.3 Causal-Diagrams from ToCs in ESG-LMs ... *124*
5.6 LIMITATIONS AND COMPARISON OF THE TOOLS ... 126
6 Operationalisation and Case Studies ... 128

6.1 OVERVIEW OF PROCESS STEPS (OPERATIONALISATION) ... 128
6.1.1 Initial ToC model ... 128
6.1.2 Data collection ... 128
6.1.3 Explication of hypotheses and epistemic justification ... 129
6.1.4 Rework of ToC and potential indicators ... 129
6.1.5 Impact assessment and interpretation of results ... 130
6.2 CASE STUDY A: NRW.BANK GB (WIND ENERGY) ... 131
6.2.1 ESG-LM and project data ... 131
6.2.2 Hypotheses and epistemic justification ... 133
6.2.3 Rework of ToC and potential indicators ... 138
6.2.4 Impact measurement and interpretation ... 139
6.2.5 Lessons learned ... 142
6.3 CASE STUDY B: GB-BW (BIOTOPE MAPPING) ... 143
6.3.1 ESG-LM and project data ... 143
6.3.2 Hypotheses and epistemic justification ... 145
6.3.3 Rework of ToC and potential indicators ... 150
6.3.4 Impact measurement and interpretation ... 152
6.3.5 Lessons learned ... 153
6.4 CASE STUDY C: NRW.BANK SB (CHILD-CARE FACILITIES) ... 154
6.4.1 ESG-LM and project data ... 154
6.4.2 Hypotheses and epistemic justification ... 156
6.4.3 Rework of ToC and potential indicators ... 162
6.4.4 Impact assessment and interpretation ... 164
6.4.5 Lessons learned ... 166
7 Synthesis ... 167
7.1 RESPONSE TO RESEARCH QUESTIONS ... 167
7.2 OTHER APPLICATIONS OF THE ESG-LM ... 169
7.3 ESG-LM METHODOLOGY FOR ACADEMIC RESEARCH ... 170
7.4 CONCLUSION ... 171
References ... 172
Annex ... 198
A-1 Definitions of terms ... 198
A-2 PoC: Development and Evaluation ... 200
A-3 Generic ESG-LM for PT ... 210
A-4 Theoretical Framework of the ESG-LM ... 212
A-5 Bayesian Decision-Tree for ESG-LM Impact Assessments ... 214
A-6 PrT heuristic from similar cases for “Case Study B” ... 216
A-7 Example of Rules of Attribution and Additionality ... 216

A-8 Spot-check of locatable Activities for Case Study C ... 218

List of Tables

Table 1-1: premises of the study ... 5
Table 1-2: research questions of the study ... 6
Table 1-3: matching of market strategies to SF types ... 16
Table 1-4: critique and review of TBE according to Coryn et al., (2011) and others ... 32
Table 1-5: ESG-LM characteristics from different perspectives ... 40
Table 2-1: asset classes of the logic model according to NACE ... 50
Table 2-2: potential intentions in the ESG-LM in line with the EUT ... 51
Table 2-3: examples of Long-Term Outcomes in the logic model ... 54
Table 2-4: attributes and expressions of indicators in ESG-LMs ... 57
Table 2-5: toolbox for formulating a ToC from entities in an outcome pathway ... 79
Table 3-1: definition and logic of descriptors for purposes of Inputs ... 84
Table 3-2: list of potential indicators for the ESG-LM of the PT ... 92
Table 3-3: identified Generic Rebounds for the PT ... 93
Table 3-4: evaluation of Goal Certainty from Outputs to Intermediate Outcomes ... 94
Table 3-5: evaluation of Goal Certainty from Intermediate Outcomes to Long-Term Outcomes ... 95
Table 5-1: Canon of Probability for informal BR in ESG-LM ... 117
Table 5-2: stage I to IV arguments for ESG-LMs (with increasing reliability) ... 119
Table 6-1: BR for H_1 in Case Study A ... 133
Table 6-2: BR for H_2 in case study A ... 136
Table 6-3: potential indicators for Case Study A ... 139
Table 6-4: share of displacement and GHG intensities for German energy sources (electricity) ... 141
Table 6-5: impact assessment of Case Sudy A (Q_R: Quality Q of the indicator and Robustness R of the indicator value) ... 141
Table 6-6: BR for H_1 in Case Study B ... 146
Table 6-7: BR for H_2 in Case Study B ... 148
Table 6-8: potential indicators for Case Study B ... 151
Table 6-9: calculation of increase in biotope areas since beginning of fourth mapping period ... 152

Table 6-10: impact assessment of Case Study B (Q_R: Quality Q of the indicator and Robustness R of the indicator value) 152
Table 6-11: description of primary data for Case Study C 156
Table 6-12: BR for H_1 in Case Study C 157
Table 6-13: BR for H_2 in Case Study C 160
Table 6-14: potential indicators for Case Study C 164
Table 6-15: Impact Assessment of Case Study C (Q_R: Quality Q of the indicator and Robustness R of the indicator value) 165
Table 7-1: research questions of the study 167

Annex Table a: definitions used throughout this study 198
Annex Table b: suggested intentions for PoC 200
Annex Table c: list of potential output-indicators for PoC 204
Annex Table d: identified generic target conflicts for PoC 204
Annex Table e: Goal Certainty evaluation of PoC (Note: AND indicates a conjunct of two independent conditions) 205
Annex Table f: investigation of evidence for additional child-care places in Case Study C 218

List of Figures

Figure 1-1: typology of substantial contribution in the EUT 12
Figure 1-2: sustainable investment strategies 15
Figure 1-3: categoriszation of impact logics 25
Figure 2-1: building blocks of the ESG-LM 49
Figure 2-2: set and subsets of plausible causal explanations in ESG-LMs 60
Figure 2-3: set-theoretic display of consequential Outcomes 64
Figure 2-4: set-theoretic display of a forward projection for consequential Financing 64
Figure 2-5: set-theoretic display of a forward projection for favourable Financing 66
Figure 2-6: guide to IBE heuristic 68
Figure 2-7: guide to heuristic PrT from similar cases 70
Figure 2-8: guide to heuristic PrT from evidence 72
Figure 2-9: criteria, control questions, and formular to assess the quality of any ESG-LM 78
Figure 3-1: example of an Outcome Model from the energy sector (inputs 4.1 - 4.9) 85
Figure 3-2: example of a Sector Model for the transport sector (inputs 6.1-6.17) 86
Figure 3-3: Aggregated Outcome Model of EUT for climate change mitigation 88

Figure 3-4: Simplified Logic Model for climate change mitigation in the EUT 90
Figure 3-5: ESG-LM for PT after evaluation 97
Figure 4-1: examples of heuristic attribution for constructing residential buildings 103
Figure 5-1: example of propositional logic for a disjunct of two Outputs 111
Figure 5-2: example of graphical propositional logic from the ESG-LM PT 111
Figure 5-3: low and high Empirical Importance from necessary or sufficient conditions 123
Figure 5-4: example of new confounders from controlling variables 125
Figure 6-1: initial ToC for wind farm loans by NRW.BANK (Case Study A) 132
Figure 6-2: ESG-LM (second iteration of ToC) for wind farm loans by NRW.BANK (Case Study A) 139
Figure 6-3: initial ToC for biotope mapping by state of BW (Case Study B) 145
Figure 6-4: ESG-LM (second iteration of ToC) for biotope mapping by state of BW (Case Study B) 151
Figure 6-5: initial ToC for child-care centres in NRW (Case Study C) 155
Figure 6-6: ESG-LM (second iteration of ToC) for constructing day care centres (Case Study C) 163

Annex Figure a: ESG-LM for the PoC 202
Annex Figure b: revision of ESG-LM for PoC after evaluation 207
Annex Figure c: ESG-LM for Climate Change Mitigation according to EU Taxonomy 210
Annex Figure d: overview of theories, methods, definitions, and tools of the dissertation 212
Annex Figure e: quick-guide for making Bayesian arguments for an ESG-LM 214
Annex Figure f: example of a PT heuristic for Biotope Mapping 216
Annex Figure g: Rules of Attribution example for “renovating multi-family home” 217

List of Abbreviations and Acronyms

ABB	**Abbreviation**
AI	Artificial Intelligence
APA	American Psychological Association
BR	Bayesian Reasoning
BT	Bayes Theorem
BW	Baden-Württemberg
CA	Contribution Analysis
CD	Causal Diagrams
CM	Causal Mechanism
CoA	Counterfactual Analysis
CPO	Causal-Process-Observations
CR	Counterfactual Reasoning
DE	Development Evaluation
DJ	Deontological Justification
DNSH	Do-No-Significant-Harm
DPO	Dataset Observations
EJ	Exajoule
ESG	Environmental, Social, Governance
ESG-LM	ESG Logic Model
EU	European Union
EUR	Euro
EUT	EU Taxonomy Regulation
GAR	Green Asset Ratio
GB	Green Bond
GBP	Green Bond Principles
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IBE	Inference-to-the-best-Explanation
INUS	**I**nsufficient but **N**on-redundant component of conditions that are **U**nnecessary but **S**ufficient for an outcome
IOM	Input-/Output Model
ISO	International Standard Organisation
ITS	Intelligent Transport System
IWR	Internationales Wirtschaftsforum Regenerative Energien
JRC	Joint Research Centre
KfW	Kreditanstalt für Wiederaufbau
LAK	Länderarbeitskreis
LCA	Lifecycle Assessment(s)
LCC	Lifecycle Costing
LCI	Lifecyle Inventory
LPR	Landschaftspflegerichtlinie (landscape maintenance directive)
NB-SB	Social Bond Pool of NRW.BANK
NGO	Non-Government Organisation
NRW	Nordrhein-Westfalen
PoC	Proof of Concept
PrT	Process-Tracing
PSI	Project Social Index
PT	Prototype

ABB	Abbreviation
RQ	Research Question
SB	Social Bond
SBP	Social Bond Principles
SDGs	Sustainable Development Goals
SF	Sustainable Finance
SLJ	Sufficient Likelihood Justification
SME	Small and Medium enterprises
SPO	Second-Party Opinion
SUIN	**S**ufficient but **U**nnecessary part of a factor that is **I**nsufficient but **N**ecessary for an outcome
TBE	Theory-Based Evaluation
TSCs	Technical Sceening Criteria
ToC	Theories of Change
UN	United Nations
USD	US Dollar

List of Mathematical Symbols

Symbol	Meaning (Subject)
$a \in A$	*a* is an element of set *A* (Set Theory)
$A \subseteq B$	*A* is a subset of *B* (Set Theory)
$A \nsubseteq B$	*A* is not a subset of *B* (Set Theory)
$A \cup B$	*A* union *B* (Set Theory)
$A \cap B$	*A* intersect *B* (Set Theory)
A^c	the complement of A (Set Theory)
$B - A$	the difference of B minus A (Set Theory)
$\neg p$	Not *p* (Logic)
$p \wedge q$	*p* and *q* (Logic)
$p \vee q$	*p* or *q* (Logic)
$p \rightarrow q$	if *p* then *q* (Logic)

1 GOALS AND METHODOLOGY

1.1 Introduction

The market for Sustainable Finance (SF) has grown immensely since the first introduction of a Green Bond in 2008 by the World Bank. Today, around USD 40 trillion globally are associated with sustainable financing or investing (European Commission, 2023a) which takes Environmental, Social and Governance (ESG) factors into account. Despite this growth, and strong policies supporting the development of this market, only a fraction of these assets actually seem to drive sustainable development (Busch et al., 2022; Kölbel et al., 2020; Krahnen et al., 2021; Migliorelli, 2021). An increased demand in sustainable assets should also decrease capital costs for sustainable companies and increase capital costs for unsustainable companies. So far, neither could be achieved on a scale that mirrors the size of the market.

There are several reasons for that. Most available SF assets, or financial products such as loans, relate to companies as a whole and only a small fraction is dedicated to capital with double materiality or impact generation (Busch et al., 2021; Schoenmaker & Schramade, 2018; Weber & Feltmate, 2016). Most sustainable capital only circumvents unsustainable sectors or steers towards companies that are already deemed sustainable by rating agencies. Such companies therefore have no incentive to use this capital in a dedicated sustainable manner.

Regulators have long understood this problem. In Europe, several initiatives and regulations have been implemented to facilitate sustainable capital markets, and to address the gap between the size of the market and the achievement of overarching goals. Among the most important of such policies are the Corporate Sustainability Reporting Directive (CSRD), the Sustainable Finance Disclosure Regulation, and the EU Taxonomy (EUT) Regulation.

While this strategy might be successful in the long run by forcing companies and financial institutions to report on their progress towards sustainability goals, it does not currently facilitate a transformation of the bulk of the economy. The EUT for example covers only a portion of the economy and is binary in nature. An activity is either sustainable or not, regardless of the actual transformation potential and regardless of whether capital is used for new assets compared to investments into existing assets (Schuetze & Stede, 2020). Consequently, a company that is currently unsustainable, but already has taken steps to reduce large parts of its negative impacts, might still not be eligible for a taxonomy alignment if financed by a European bank. A company that already achieves taxonomy alignment on the other hand, has no further incentive to tackle the rest of its challenges, unless the sustainability criteria are tightened. This, in turn, would it make even more difficult for unsustainable companies to finance their transformation, as the gap between unsustainable and sustainable practices would increase further.

ESG ratings or ESG scores are non-regulatory responses to some of the challenges in the market. These semi-quantitative datasets, purchasable from service providers, represent the ESG risks and sometimes the ESG impacts of companies. Fund managers can use ESG scores to select only sustainable companies for their portfolio. They also represent valuable data for actors that only want to invest in sustainable companies or to shareholders that actively engage in the policies of companies they invest in. However, there are several issues with the current market for ESG ratings.

Both companies and investors complain that ESG rating agencies do not gather their data in an accurate or reliable manner (European Commission, 2023b). There is lack of transparency regarding the methods used to derive the scores and more importantly, it is often unclear what ESG scores actually measure. The companies that are rated find it difficult to understand how they are rated, or how to improve their score. Professional actors in the market therefore usually need additional tools and data to assess the sustainability performance of their assets. ESG scores can also differ greatly for the same companies. Although this is somewhat expected given that ESG rating agencies use different methods and weights and have a different understanding of sustainability targets, this divergence raises reliability concerns (and can, in fact, constitute a reputational risk for providers that heavily rely on them). This reliability of ESG scores is also affected by biases (European Commission, 2023a). The geographical bias for example tends to benefit companies that are under stricter reporting requirements in their respective regions. The company size bias on the other hand tends to result in better scores for larger companies, because only these entities have the means and resources for their own departments specialised on ESG reporting.

Regulations and independent verification agencies might, as planned by the EU Commission, mitigate these issues. Nonetheless, such solutions will not change the fact that ESG-informed financing, as well as similar labelling schemes, limit their scope to the overall performance of companies (the *firm-level*). This helps to find companies that are best-in-class, or at least above average compared to their peers, but does not cover all the measures companies can undertake to contribute to sustainability goals. SF must become Finance for Sustainability to induce the much-needed acceleration of a sustainable transformation (Migliorelli, 2021). This means that at least some fraction of the capital that is intended to facilitate this transformation must come with tangible results or, more broadly speaking, desired impacts (Teubler & Söndgen, 2020). This is especially important in the context of public grants and joint financing between public and private financial institutions. Reducing capital costs for specific sustainable investments often requires both the earmarking of the financing and some process of monitoring, predicting, and managing contributions to goals.

The Green Bond market might — despite its other problems (European Commission, 2021b) — provide a part of the solution. Refinancing here is directly linked to specific green projects and measures by countries, organisations, and companies. There is also a process in place to ascertain whether the projects are eligible for contributions to overarching goals and how capital was spent in pursuit of these goals (frameworks by the issuers and second-party opinions (SPO) for corroboration). More importantly though, many issuers commit themselves to use the proceeds to finance additional sustainable projects and to report on the impacts of projects bundled in the bonds (usually conducted by independent service providers). Methods for these impact assessments have matured over time and best practices have evolved. Regarding the most common impact category of greenhouse gas (GHG) emissions avoidance, impact methods are well-grounded in Lifecycle Analysis (LCA) methodology and causal relationships are at least partially understood.

It took several years for the market to evolve to this point though. It is not clear whether the more novel products such as Sustainability or Social Bonds can be assessed with the same reliability. The current impact methods for climate change mitigation could draw on a broad corpus of scientific findings and several decades in LCA experience. Nothing similar is available for benefits and multiple-impacts in broader sustainability dimensions such as health or preservation of ecosystems. Impact assessment methods for such bonds are still in their infancy and there is no common understanding about which effects can be reported, and how (Boiardi, 2020; Jackson, 2013; Park, 2018; Quatrini, 2021). Current practices often focus on so-called key performance indicators (KPIs), that is, sets of indicators that analysts are encouraged to report, but with little guidance on how the effects are to be estimated. The goal certainty for such KPIs differs widely though. On the one hand, there are KPIs focusing on the intervention side, such as the number of loan recipients or number of projects funded. These values are easily collected directly and are therefore robust, but they also fail to convey to investors how projects contribute to societal goals. On the other hand, there are KPIs focusing on the societal benefits (e.g., improved access to affordable housing; income wealth ratio). These values are more difficult to estimate, as they require additional data outside of the projects and usually more complex models. And while they do assess societal contributions, they cannot explain on their own how and to what degree the projects were responsible for the effect.

1.2 Goals of the study

The dissertation tries to tackle some of these challenges by developing a so-called ESG Logic Model for Impact Assessments (ESG-LM).

The main goal of the study is to facilitate robust and reliable impact assessments by professional analysts in the market for Green, Sustainable or Social Bonds. The ESG-LM intends to demonstrate how financing contributes to interventions and how these interventions trigger desired societal change with the help of Theories of Change (ToC).

The second goal of the study is to facilitate the assessment of claims by issuers regarding their contribution to overarching sustainability goals. The ESG-LM and its tools are intended to provide guidance on whether rational actors are warranted in believing these claims and to what degree.

The third goal is to develop the ESG-LM in such a way that it can serve additional purposes. It should be applicable to similar products in the SF market such as impact investing or blended finance. It should also allow practitioners to develop their own ToCs that can be directly integrated into impact assessments.

The fourth and final goal is to stimulate interdisciplinary discussion among academic researchers in the area of impact assessments and evaluations. Although the tool is clearly intended as an example that *borrows* and *applies* methods from disciplines such as philosophy and qualitative research, it could encourage researchers to integrate some of the interdisciplinary insights into their own methodologies.

1.2.1 Interdisciplinary of the study

Assessments of sustainable impacts in the financial market are fairly new. In this context, even the meaning of the term ‘impact’ is still discussed by academics and practitioners. It is therefore not surprising that there are currently no academic disciplines where such impact assessment methods are developed for financed projects or measures. The impact reporting of Green Bonds can be traced back to LCAs and these are typically conducted by professionals with an engineering background. The underlying models are often also developed by scholars in the natural sciences such as physics, chemistry or biology. Progress in related methodologies such as Lifecycle Costing (LCC) or social Life Cycle Assessments have also increasingly involved professionals with backgrounds in economics and the social sciences. Impact assessment methodologies are therefore interdisciplinary but their development is also driven by practitioners in companies.

The model in this study is embedded in engineering practices. It applies heuristics to approximate quantitative results from available background knowledge, rather than developing new theories. This process requires the operationalisation of known relationships and the use of plausible assumptions because robust empirical data is scarce. It is also mechanistic in nature since it focuses on the physical materialisation of ESG projects rather than the intentions and resources of actors or the interdependence of policies with societies.

However, the model and its implementation rely on other disciplines as well. The formal logic as well as its epistemology are drawn from philosophy. These are the basis for a consistent and coherent theoretical framework. They also inform the iterative process of improving a particular model over time and increasing the credence of actors in the credibility of its claims. The model also employs methods from qualitative research in the social sciences. The case-based mindset and the application of Bayesian methods guide the operationalisation of the model and link it to scholarly insights on the actualisation of desired societal benefits.

My own educational background is in environmental engineering (specialised on renewable energy systems), and I have 12 years of research experience in the identification, modelling, and assessment of indicators for sustainability dimensions. My main clients are companies, banks, and sovereign issuers and my projects often investigate the sustainability performance of companies and products or the impacts of projects in bonds. I publish and review journal articles in these areas and have participated in several white papers on the issues.

1.2.2 Premises and research questions

The following table lists the premises for the research questions. The reflection on the desk research in Section 1.6 will investigate if these premises are justified.

Table 1-1: premises of the study

No	**Premises**
P1	Non-financial and non-government businesses or business-like entities (NGOs, households) are the main actors in interventions that result in desired sustainable changes on a societal or global level, because they implement physical outputs or help to realise them in others.
P2	Other actors like state agencies, investors, or financial intermediaries can help to realise these interventions by financing the necessary activities.
P2a	Earmarked investments (including financing measures) for individual goals can contribute to sustainability goals if the change process is explicated.
P2b	Unless the investment is earmarked, only active (governing) investors and agencies can induce change directly.
P2c	Other investments can only contribute to the overall sustainability performance of an actor in a general manner and not in relation to a particular desired societal outcome.
P3	The attribution of investments to overarching sustainability goals can be quantified, but this monetary transaction is only additional if it leads to additional desired outcomes or if these outcomes would not have been realised otherwise.

Source: own compilation

P1 is my main premise. It states that sustainable development is tied to the materialisation of activities and that the majority of these activities are caused by businesses, households, and non-government organisations. Even in cases where financial intermediaries or governmental organisation are the cause of interventions, it is presumed that they rely on these actors to materialise the effects.

P2 prescribes the supporting role of financial intermediaries in realising sustainable development. P2a highlights that earmarked financing, that is, capital tied to activities by the main actors, can be associated with a direct contribution. For non-earmarked financing, additional activities by these supporting actors are required for a direct contribution. It follows from P2a and P2b that generic financing without those efforts cannot be related to a particular change process, as it only contributes to the overall performance of main actors in regard to sustainability dimensions.

The final premise P3 refers to the fact that financial needs match up with investment costs. The amount of capital that is requested, compared to the overall costs of an activity, can represent the share of its contribution to desired changes. However, it is not assumed to be additional, unless it can be traced back to desired outcomes that would not have been achieved without financing by a specific actor.

Based on the problem description as well as the goals of the study and these premises, I derive the following research questions.

Table 1-2: research questions of the study

No	Research questions (RQ)
RQ1	**Contribution logic:** can ESG-relevant measures be classified, hierarchised, and prioritised in a consistent logic that results in adequate and plausible alignment of interventions with desired sustainability impacts?
RQ2	**Epistemic justification for contribution:** how can third parties be warranted in believing the claims of such a logic regarding the causal link between interventions and outcomes as well as the contribution of actors towards the desired changes?
RQ3	**Contribution assessment methodology:** can the developed logic be used to identify and estimate reliable indicators that demonstrate sustainability benefits on a societal level which can be traced back to the intervention?

Source: own compilation

RQ1 investigates whether it is possible to align the ESG targets of actors with their activities so that desired changes towards sustainability goals can be traced back to their intervention in the system. Such a contribution logic is successful if its categorisation and hierarchisation of process steps is plausible and each step is part of a set of necessary or sufficient conditions for at least one subsequent part of the sequence.

RQ2 investigates whether the contribution logic from RQ1 can be reviewed in such a way that it allows the credibility of its claims to be assessed. This epistemic justification is successful if interested rational third parties either agree to the reasoning or have sufficient information and an applicable assessment method to argue why they do not agree.

RQ3 investigates what an ideal set of indicators would look like if RQ1 and RQ2 could be demonstrated successfully. This contribution assessment methodology should also convey to the reader how the actual identified indicators fared against this ideal set regarding their quality and robustness.

These research questions are investigated with the help of the theoretical framework (Section 1.9, all RQs), during the model development (Chapters 2 and 3, RQ 1), with the help of the impact measurement tools (Chapter 4, RQ 3) and a Bayesian model for credence updates (Chapter 5, RQ 2). They are tested with the help of case studies (Chapter 6) and discussed in the synthesis (Chapter 7).

1.3 Tasks and structure of the study

This dissertation is divided into seven chapters.

Chapter 1 describes the goals, premises, and research questions of the study. It includes desk research and depicts the theoretical framework.

Chapter 2 is dedicated to the development of the ESG Logic Model (ESG-LM). It describes evaluation criteria for the quality of ESG-LMs and defines the components of the model. It also tests the ToC logic of the ESG-LM with the help of a Proof of Concept (PoC).

Chapter 3 demonstrates a prototype (PT) for the objective of climate change mitigation according to the EU Taxonomy (EUT). This prototype is evaluated and later used in Case Study A (directly) and Case Study B (adaptation) in Chapter 6.

Chapter 4 describes data collection and impact estimation concepts as well as tools for the ESG-LM. It also defines and operationalises the Attribution and Additionality of actors.

Chapter 5 develops and discusses tools for epistemic justification. These tools are intended to assess the credibility of the claims on the basis of a formalised process of hypothesis formulation.

Chapter 6 explicates the operationalisation of ESG-LMs and tests the methodology for three case studies. Case Study A applies the prototype to a common research question in impact reporting (climate change mitigation in Green Bonds). Study B adapts the prototype for a different EU environmental objective (*Protection and Restoration of Biodiversity and Ecosystems*). And Study C investigates the use of a different framework (Sustainable Development Goals (SDGs)) for the development of an ESG-LM regarding quality education.

Chapter 7 is the synthesis. It discusses the response to the research questions from Chapter 1. It also investigates potential applications of the model for other types of impacts assessments as well as its potential feasibility for broader academic research and empirical studies.

1.4 On definitions, terminology, and emphasis

The concepts described and adapted throughout this interdisciplinary work require the definition of terms that are sometimes understood differently in different disciplines. My own definitions are also necessary to understand the core concepts of the model itself. I have added a list of definitions and their sources to the Annex of the study so that readers can have a quick glance when such terms re-appear.

I use **bold lettering** within main paragraphs to indicate when such terms are followed by a definition or if I want to highlight parts of a citation. *Italics* are sometimes used when these terms are discussed themselves or if words are used in a more colloquial manner. Italics are also used if titles of documents or organisations are included. Terms in sources or citations within main paragraphs are marked by "sentences between quotation marks" either directly followed by the source in brackets or indicated by the source at the end of the sentence. Citations between main paragraphs are

> "indicated by an indented paragraph in smaller lettering and between quotations marks also followed by a" (Source, with or without emphasis).

Sources are cited according to APA-style (7th edition) and using Author (Year) within paragraphs. If sources have no clear list of authors, the abbreviation of the organisation that claims the source is used (either the organisation responsible for the content or the publisher).

The entities of the model are capitalised, so that they can be distinguished from the use of the same words in the conventional sense (e.g., Output versus output). Other terms capitalised are stand-alone terms such as Green Bonds or indicate a specific definition of a term in the context of the study (e.g., Financing in the ESG-LM).

1.5 Desk research: ESG impacts in SF

The following sections summarise literature findings for sustainable investing, sustainable funding, and sustainable lending.

1.5.1 Definitions in the context of ESG impacts

The premises of this study focus on businesses or business-like entities directly interacting with their surrounding system as they implement or realise real physical interventions. However, the research questions, application (impact assessments), and even wording (e.g, ESG) of the model are directly related to entities financing the change in a sustainable manner. To this end, I first define the term **Sustainable Finance (SF)** in a broad manner:

> All financing (investing and lending) can have impacts on social and environmental systems. These financial services are considered *SF* if they interact with the surrounding systems in a way that either avoids negative impacts to these

> dimensions and or results in desired changes in line with global and societal sustainability goals.

Other definitions are more narrowly defined. A recent paper on the “meaning” of SF by Migliorelli (2021) for example defines the term as follows: “finance to support sectors or activities that contribute to the achievement of, or the improvement in, at least one of the relevant sustainability dimensions” (Migliorelli, 2021, p. 2).

Here the emphasis is on a direct support for the economy that in turn contributes to sustainability goals. I distinguish the general term from this definition by referring to it as **Finance for Sustainability** (as suggested by the author).

Although this is clearly the preferred and strongest link in a cause-effect chain, it excludes other interactions (such as shareholder engagement) as well as the avoidance of negative impacts. Migliorelli’s definition is more closely aligned with the direct financing of sustainable industries such as those defined by the EUT as “own contribution” or “enabling economic activities” (European Commission, 2020b). It is not directly applicable to financial products with weaker sustainability links but a larger market share such as Green Bonds for re-financing.

Financing is another term that is used throughout this work when the ESG-LM incorporates the contributions of financial actors towards desired societal changes. The issue with this activity is that many different and causally distinct mechanisms can be involved. This is the reason why Financing must be defined in the broadest sense possible, so it entails different investment mechanisms but also public funding and sustainable lending. It also must be understood in the context of the model:

> The term *Financing* relates to all financial mechanisms that result in capital provision for actors in the economy used for the realisation of tangible Outputs. This specifically includes direct or indirect lending, non-refundable grants, and ex post allocations of previously financed economic activities and projects in Bonds.

Another term often referenced in SF literature and publications is ESG score or ESG rating. This term is not clearly defined and can therefore change its meaning depending on the context. This is also recognised in a recent policy proposal by the European Commission towards the regulation of ESG ratings, ESG scores, and providers of such values. In its impact assessment (European Commission, 2023a), the Commission recognises that there is currently a lack of transparency on what the objectives of ESG ratings and scores are. I adhere to the Commission’s definition of **ESG rating** in the current proposal:

> “*ESG rating* means an opinion, a score or a combination of both, regarding an entity, a financial instrument, a financial product, or an undertaking’s ESG profile or characteristics or exposure to ESG risks or the impact on people, society and the

> environment, that are based on an established methodology and defined ranking system of rating categories and that are provided to third parties, irrespective of whether such ESG rating is explicitly labelled as rating or ESG score." (European Commission, 2023b Art 3.1)

This definition includes all types of entities and distinguishes between exposure to risks and "impact on people, societal and the environmental" (ibid). The latter is not specified further in the regulation, however, and the term **impact** itself is used ambiguously throughout SF literature. I define impact in the broadest sense by grounding it on Migliorelli's "activities that contribute to the achievement of, or the improvement in, at least one of the relevant sustainability dimensions" (Migliorelli, 2021, p. 2) and relating these sustainability dimensions to overarching societal goals:

> *Impacts* are contributions to the achievement of overarching societal goals for sustainable development.

This definition is in line with the logic applied in the model and is applicable to both the EU environmental targets (referenced in the EUT) and the SDGs (used in Case Study C for projects in a social bond).

Two other terms that are commonly used in ESG and SF literature are additionality and materiality. Since additionality is a crucial concept in the overall model in this dissertation, it is addressed throughout this work in separate sections. Materiality (or double materiality) on the other hand can already be defined here. It refers to the (mostly physical) realisation of positive or negative impacts on sustainability dimensions. A lean and simple definition of **materiality** that matches the challenges addressed in this dissertation can be found in Busch et al., (2021) and also in Section 1.5.3.1:

> "We define *materiality* as the measurement of tangible real-world parameters in the social and/or environmental realm. This measurement pertains to significant improvements based on sustainability performance indicators, such as greenhouse gas (GHG) emissions or gender representation on corporate boards of directors." (Busch et al., 2021, p. 33)

1.5.2 Relevant regulatory frameworks for ESG dimensions

The EUT is my frame of reference for the development of the prototype of the ESG-LM in Chapter 3. Regulation (EU) 2020/852 on the"establishment of a framework to facilitate sustainable investment (EU Taxonomy)" is intended to be a "technically robust classification system at Union level to establish clarity on which activities qualify as *green* or *sustainable*" (European Commission, 2020b). The EUT frames what sustainable investments and economic activities are and how they should be reported. This is an outcome of the General Union Environment Action Programme 2020 by the EU (European Parliament & Council of the

European Union, 2013) that defines its overarching environmental goals. It was an objective of the European Green Deal (European Commission & Secretariat-General, 2021) and a recommendation of the high level expert group on SF (European Commission et al., 2018).

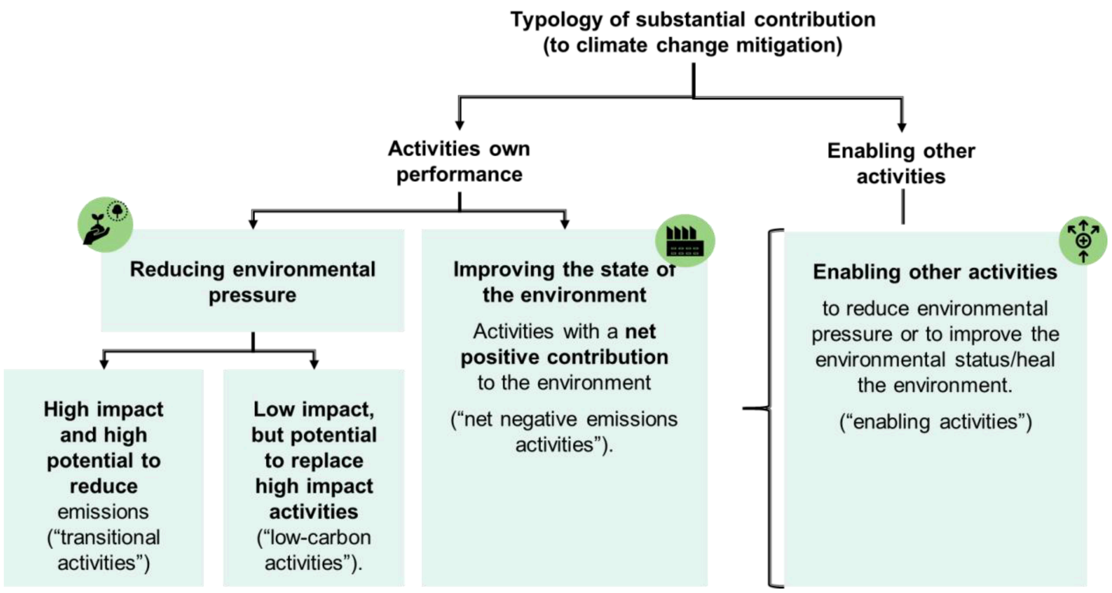
There are currently (as of September 2023) two Climate Delegated Acts and four Environmental Delegated Acts. They contain the so-called technical screening criteria (TSCs) which define the conditions under which taxonomy-eligible economic activities achieve a substantial contribution without violating the Do-No-Significant-Harm (DNHS) criteria of any of the remaining five goals. The framework itself is binary and shows progress only by increasing the *Green Asset Ratio* of the reporting entities. Any economic activity considered by the Taxonomy can either be taxonomy-aligned or not. The TSCs often cite existing regulations or refer to national targets but can also be quantifiable thresholds that need to be achieved by a company.

The main advantages of the framework for this dissertation are its compliance with European policies and statistics, the inclusion of multiple environmental and social goals as well as its consideration of enabling activities along the value chain. The detailed rule set is, in my opinion, also more easily translated into ESG pathways for companies than the more normative objectives of the European Green Deal or the national targets of the SDGs.

The drawbacks of the taxonomy, for the purpose of developing and investigating sustainable progress, are its legal complexity and its inconsistency. The taxonomy is a compromise between scientific findings, auditability, data availability, and the opinions of different stakeholders like lawmakers, financial institutions, companies, and NGOs. This results in a classification system of different levels of achievability, interdependency, and accountability for different actors in the economy. There are also gaps where important sectors are not accounted for specifically or even not accounted for at all.

The European Commission is aware of these problems and accompanies the roll-out with different tools for implementation. One of the first such documents was provided by the JRC (European Commission. Joint Research Centre., 2021). Its goal is to explain how a substantial contribution to a goal can be achieved and how the ambition levels of the TSCs relate to their feasibility as part of the framework. The authors also provide a hierarchy of pathways towards substantial contribution by expanding on the taxonomy's definition of *own performance* and *enabling activities* (see Figure 1-1).

Figure 1-1: typology of substantial contribution in the EUT



Source: European Commission. Joint Research Centre., (2021, p.9)

Another important regulation in the context of ESG dimensions is the recently established CSRD (European Parliament & European Council, 2022). The CSRD requires the collection and reporting of sustainability-relevant information by large companies. It is also intended to facilitate such reporting by small and medium sized companies. A first set of reporting templates covering ten ESG dimensions has recently been published by EFRAG (EFRAG, 2023). In the context of ESG impact assessments, the CSRD is relevant because it will be an important source of ESG data in the future.

Two additional regulations (or proposals) in the European ESG context relate to the transparency and integrity of ESG rating agencies (European Commission, 2023b, 2023a) as well as requirements for Green Bonds aligned with the EUT (European Commission, 2021a). Whereas the European commission recognises the relevance of ESG scores and the Green Bond market for activating private capital for a sustainable transformation, it is also concerned with the issue of *green washing* or *impact washing*. These and similar regulations (such as the *Green Claims Directive*) therefore aim to regulate the market in a way such that investors and asset managers have reliable ESG information to make informed decisions.

The SDGs (United Nations, 2015; United Nations Statistics Division, 2018) are the third regulatory framework that relates to ESG dimensions. Since their introduction, and the explication of its targets in the form of national indicators, it has seen integration into national policies, academic research, and the sustainability strategies of companies. Although the targets themselves are national and quantified on a territorial level, many stakeholders have undertaken the task of translating the underlying goals for their purpose. For example, it has become a common practice in the SF market to map investment or indicator categories to the SDGs or to sell products that are *SDG-aligned*. The relevance of the SDGs for the study at hand is twofold. Firstly, many frameworks, standards, and reporting templates for sustainable Bonds use the SDGs. It is therefore an established practice any impact assessment framework should be able to accommodate. Secondly, it also provides a broader framework on societal goals usually not covered by established impact reporting practices. This is, of course, relevant if the achievement of such goals is to be assessed. Moreover, many of the SDG goals can constitute potential target conflicts even if contributions to other goals are achieved. An impact assessment could for example find concrete health benefits towards *Good Health & Well-being* (SDG 3) but also indicate that these benefits are reduced for women and girls (target conflict with *Gender Equality*).

1.5.3 Sustainable investments and funding

1.5.3.1 Typology of SF strategies

I start by briefly introducing core concepts of SF strategies, as they provide a framework for different types of ESG-aligned versus impact-aligned capital provisions. Non-sustainable and sustainable business practices and investment strategies lie on a continuum rather than a scale and this is true for both the asset managers and their assets. The stakeholders involved have different functions and intentions. Externalities can also translate into different risks which in turn leads to different values and management thereof. A company can very well forego profit in order to achieve a specific overarching goal in line with the company's *mission* but might be unwilling to do so for a different goal. On the investor side, there might also be actors that are willing to pay more for products that they perceive to be aligned with non-financial impacts (Barber et al., 2021).

Most typologies in this regard start with a focus on internalities: actors aim to maximise their profits (within the rules of society). This translates into maximising shareholder value (optimum between financial return and risks) for financial markets. The endpoint (or ideal) from a societal standpoint focuses entirely on externalities. In the finance industry, this translates into maximising the value of common goods (Schoenmaker & Schramade, 2018), but similar distinctions can be made for banking (Jeucken & Bouma, 1999) as well as general business practices (Dyllick & Muff, 2016).

In the field of SF, Schoenmaker & Schramade, (2018) consider three tiers for the gradual shift from finance-as-usual on a short-term horizon (starting point) towards benefits for society in the long-term (end point). They operationalise the strategies by looking at the value that is maximised or optimised. As baseline, financial-as-usual only maximises profits for shareholders. The next step in the continuum, SF 1.0 then increases shareholder value by avoiding excessive environmental or social risks (e.g., by divesting from *sin stocks*). SF 2.0 describes a strategy where those external risks are additionally internalised. This is typically achieved by monetising social and environmental impacts and integrating these costs or values into the optimisation process. This corresponds to stakeholder rather than shareholder value on a medium-term horizon. The endpoint in this typology, SF 3.0, applies a long-term horizon, as the goal is to improve the value of common goods. Social or environmental improvements are subject to financial viability but not to profit maximisation or optimisation. Financial instruments that are part of SF 3.0 strategies are for example “Impact Investing”, “Green Bonds”, “Impact Lending”" and “Microinsurance” (ibid.).

Current SF 3.0 strategies as well as similar approaches[1] for sustainable investing seem to be successful in regard to an increase in asset volume over the recent years, but they are also increasingly scrutinised for their lack of reliability (Hays & McCabe, 2021). One reason for that is that the terms and categorisations used are not well-defined or regulated. Actors that do not demonstrate a materialisation of impacts mislead their clients by using terms that suggest that they do. This weakness of the SF classifications is sometimes described as *purpose washing* or *impact washing* and are a real concern for scholars and practitioners alike (Findlay & Moran, 2019).

Another reason for the observed discrepancy (SF 2.0 or SF 3.0 products lacking materiality) is the categorisation itself. Busch et al., (2021) recently suggested a different typology that distinguishes between “ESG-screened Investments”, “ESG-managed Investments” and “Impact-related Investments”. Only the last category is considered to represent strategies that “provide and require proof of social and/or environmental materiality” (ibid., p.32) . This category is then further differentiated into “impact-aligned” and “impact-generating” investments. Impact-aligned actors address social and environmental challenges by providing evidence for already realised improvements, whereas impact-generating investments actively contribute to further social and environmental solutions.

Impact-generating investments are thus in line with the goals of this study, because they seek to facilitate impact assessments on the level of concrete measures and investment decisions. They can be defined as follows:

> For an investment to be *impact-generating*, there must be an apparent causal effect on an outcome that can be attributed to the underlying investment made” (Busch et al., 2021, p. 33)

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[1] The taxonomy in Hays & McCabe, (2021) for example, focusing on the distinction between ESG risk/turn metrics compared to “impact generation”, has been developed to address similar concerns.

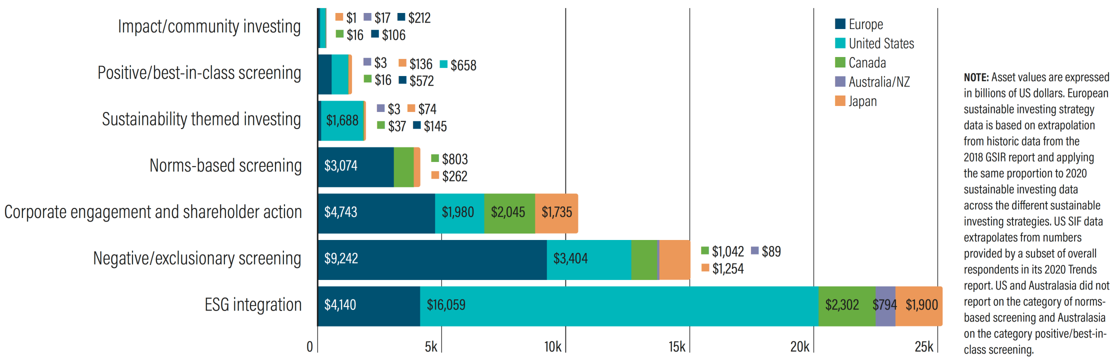
1.5.3.2 SF assets

The Global Sustainable Investment Alliance (GSIA) publishes its GSIA Review every two years. It is one of the most common sources of data on the SF market, which is why I use its classification for investigating the relevance of sustainability criteria in the world of finance.

In its 2020 report, global sustainable investment is estimated at USD 35.3 trillion in five major markets (GSIA, 2021). Between 2016 (USD 22.9 trillion) and 2020, this market increased by over 55% in four years. In terms of investments under management, 35.9% are deemed sustainable management assets. Europe is the only region with a decline in professionally managed sustainable assets (from USD 14.1 trillion to USD 12.0 trillion). The authors accredit this fact to changes in European legislation as part of the *European Sustainable Finance Action Plan* rather than changes in the market. They note that “not all products or strategies considered in the past would meet these new regulatory definitions” (GSIA, 2021, p. 9). It becomes clear from this statement alone that different criteria are used to attribute sustainability characteristics and strategies to financial interactions. It is thus crucial to distinguish between different sustainable investment strategies in the market.

The following Figure 1-2 shows the results, with “ESG integration” and “Negative/exclusionary screening” being the most common strategies. Although there is double-counting involved (managers may apply more than one strategy to a pool of assets), some strategies are clearly less favoured. Four out of seven strategies manage a combined asset pool of less than USD 8 trillion (out of USD 58.5 trillion).

Figure 1-2: sustainable investment strategies



Source: GSIA, (2021)

The ambition and importance of each of these strategies can be better understood when they are matched to the types of SF strategies proposed by Schoenmaker & Schramade, (2018). Not all of these strategies fully line up, but all strategies can be matched to the values that each type focuses on (refined shareholder value, stakeholder value, common good value). The following Table 1-3 matches the definitions in GSIA, (2021) with these values in Schoenmaker & Schramade, (2018).

Table 1-3: matching of market strategies to SF types

Strategy	Definition by GSIA	Matching to SF 1.0-3.0	
Norm-based screening	screening of investments against minimum standards	avoiding sin stocks	SF 1.0
Negative screening	exclusion of certain sectors, companies, countries	avoiding sin stocks	SF 1.0
ESG integration	explicit inclusion of ESG factors into financial analysis	internalisation of externalities	SF 2.0
Corporate engagement	employing shareholder power to influence corporate behaviour by ESG guidelines *	internalisation of externalities	SF 2.0
Positive screening	investment into assets with positive ESG performance relative to peers	internalisation of externalities	SF 2.0
Sustainability themed investing	investing into assets specifically contributing to sustainable solutions	contributing to sustainable development	SF 3.0
Impact investing	investing to achieve positive, measured, and reported social and environmental impacts	contributing to sustainable development	SF 3.0
* Shareholders may focus on other values but GSIA's definition is most closely matched with some form of ESG integration into the optimisation of financial performance (SF 2.0).			

Source: own compilation with matching based on Schoenmaker & Schramade, (2018)

Compared to their market size, the two strategies with the most ambitious sustainability strategy (SF 3.0) make up less than 4% of assets managed. This is not necessarily a surprise since both strategies prioritise non-financial values over financial performance (whether these also materialise is a separate question). By comparison, the most favoured strategy, "ESG integration", is not only the most relevant strategy in all five regions but has also seen consistent growth between 2018 and 2020 (GSIA, 2021, p. 30). This is facilitated by a wide range of commercial service providers that evaluate companies on their ESG value.

1.5.3.3 Financial performance of sustainable investments

It is unclear whether companies and assets that are deemed to be sustainable have a better or worse financial performance than conventional economic activities. Given the need for additional capital to achieve global and national sustainability targets[2], the answer to this question is especially important to both public and private investors. While early studies suggest

[2] For Europe alone, additional investments of 175 to 290 billion Euro are needed every year over the upcoming decade (European Commission, 2019).

that there is at least no indication for the underperformance of sustainable investing, recent literature is a lot more critical in regard to any potential benefits for the shareholders.

In one of the most-cited and discussed studies, Friede et al., (2015) investigate the relationship between ESG criteria and corporate financial performance (CFP). The authors find that there is a positive correlation between ESG criteria and CFP. A recent meta-study (Bush et al., 2020), considered to be an expansion of Friede et al., (2015) and published as a white-paper, finds that beneficial CFPs in the context of ESG dimensions might be region-specific. The authors conclude for example that ESG approaches appear to be positively correlated with CFP in emerging markets. And a more recent study on the transmission channels between ESG characteristics of a company and its valuation (Giese et al., 2019) concluded that positive ESG score changes lead to better financial performance over time.

In opposition, Halbritter & Dorfleitner, (2015) did not find any significant return differences between high and low ESG ratings. The authors consider the return difference *alpha*[3] from three strategies: high portfolio ESG, low portfolio ESG, and high-low strategy. They state that "ESG ratings show a significantly lower influence on the financial performance than previous studies indicate" (Halbritter & Dorfleitner, 2015, p. 25). Even a best-in-class approach did not result in a significant better financial performance. The authors attribute that to the fact that there is an outperformance in older studies (up to 2007) that later declined. A more recent study by Taliento et al., (2019) focused on larger companies in Europe by looking at the relationship between financial materiality, ESG information, and non-financial sustainability disclosures. The authors state "that the ESG dimension is moderately yet significantly impactful not so much because of the absolute height of their individual scores [...], but because of their respective *positioning*, i.e., in consideration of their *spread* over or *distance* from the industry sector average-normal score" (Taliento et al., 2019, p. 19). Summarising the overall results, the authors conclude that for large companies in particular, an "extra-ESG advantage" translates into a "competitive advantage" for better financial return. This effect is attributed to recognition and support of market players, while the additional costs are, according to the authors, "recovered by incremental incomes from revenues and sales" (Taliento et al., 2019, p. 20).

Some authors also suggest that a higher financial performance for SF products is merely a result of climate-concern shocks. Using the PST equilibrium model, Pastor et al., (2022) suggest that *greeniums* should indeed lead to lower expected returns for investors and that higher realised returns are a result of increased preferences for green assets and higher profits for green firms.

[3] "A measure of the active return on an investment. An investments' alpha is the excess return relative to the beta-adjusted market return" (Bush et al., 2020, p. 20).

These and other studies (e.g., Krahnen et al., (2021)) highlight the ambiguity of results on the financial performance of sustainable investments and companies. The differences in perspectives, selected data sets, and evaluation methods, as well as rating systems seem to contribute to the difficulties.

1.5.3.4 Earmarking: sustainable funding & lending

Over the past years, the amount of scholarly literature on the subject of *sustainable investments* has continuously grown and now also incorporates research questions regarding its material impacts rather than just insights into its demand or profitability (Kumar et al., 2022). These impacts are usually understood as changes to the overall sustainability performance of companies. Even in the context of Bonds, where projects are usually restricted to specific purposes, this focus on company-level metrics is prevalent in the mostly empirical literature.

This is surprising as there is a long tradition of earmarked funding by institutional actors (Bahn-Walkowiak et al., 2012; Baumann, 2021) or intermediaries in the context of sustainable development policies (Reinsberg, 2017) and earmarked lending (e.g. in form of promotional loans) by public banking institutions (Mazzucato & Penna, 2015). Although the term earmarking is usually discussed in the context of donations for international organisations such as the UN, it can also be considered in the context of loans tied for example to a programme or target (such as housing loans). For a working definition of **earmarking**, I adapt a definition from Weinlich et al., (2020, p. 26) by replacing *donors* with *capital providers* and including *financial instruments*:

> Earmarking means that [capital providers] restrict resources or [financial instruments] to specific purposes, usually in terms of geographic and thematic scope.

One could expect that this tailoring of funds to specific purposes leads to a better alignment of funding intentions with specific material impacts. This does not seem to be currently the case though. For Weinlich et al., (2020), who thoroughly investigated earmarking in the multilateral development systems, the question of "development impact" cannot be easily ascertained. Establishing "clear causal relations, from funding practices to development impact" can currently only be looked at from 'development effectiveness', that is "[...] efficiency, coordination and ownership by the host government" (Weinlich et al., 2020, p. 107).

This notion of a lack of information and focus on efficient capital allocation is also mirrored by Clark et al., (2018). The authors investigated the barriers of *unlocking* private capital for sustainable development. They highlight the need for "improved monitoring, evaluation, reporting and overall enhanced information flows [that] will facilitate deciphering additionality and distinguishing benefits resulting from efficient allocation of capital to environmental and sustainable development projects" (Clark et al., 2018, p. 342). One of their recommendations for closing financing gaps is thus to ”develop a strong evidence base for sustainable development projects” (Clark et al., 2018, p. 344).

In the case of sustainable lending, Mazzucato & Penna, (2015) investigate the active “mission-oriented” role of investment banks in developing new tools that address short-termism and financialisaton in the context of “technological missions” and “grand societal challenges”. The authors explore the activities of two state investment banks (KfW in Germany and BNDS in Brazil) for this purpose. They argue that such banks need a strong mandate that is not guided by market failure but by societal challenges. They advocate for new indicators “that help show whether these institutions are making things happen that otherwise would not” (Mazzucato & Penna, 2015). This advice seems to have resonated since then, as KfW has implemented a ToC that incorporates such indicators (KfW Sustainable Finance, 2021).

I conclude that there is currently no common practice in place for earmarked funding or lending that quantifies material impacts from capital provision. There also seem to be few incentives or initiatives to do so in the future. At the same time, the lack of such information is discussed and understood as a problem from the societal perspective.

1.5.3.5 Additionality of SF strategies

Discussing the research on additionality in SF requires a terminology first. A successful SF strategy provides, from a societal perspective, more than financial returns. Any type of SF strategy or product ideally contributes to the sustainable development itself or makes it possible in the first place. This criterium is usually referred to as *additionality* and can be distinguished into different types including financial, investment, development, or project additionality. There are definitions tailored to different purposes and a wide range of methods and tests for the evaluation of additionality. However, all definitions refer to effects that otherwise would not have occurred. For the purpose of my research (causality of interventions towards desired societal changes), I use the definition of non-circular additionality by Gillenwater, (2012) and adapt it to the language of my model:

> (1) An outcome is additional if it is different from what would happen without an input.
>
> (2) An input is additional if it is different from what would happen without an intervention.

The first refers to what can be called development or ESG additionality, while the latter is more in line with financial additionality. Most literature on additionality of SF or finance for sustainable development focuses on the second type (sustainable investments that would not have happened otherwise or investments that fill the gap in capital despite lower returns). Additionality is an important criterion when comparing different SF strategies or products such as Green Bonds. A SF asset without financial or ESG additionality is irrelevant for sustainable development (and needs no strategy). It might even, in the worst case, distract capital and investors from assets that do in fact lead to additional non-financial value. Migliorelli, (2021) for example associates this risk of "rebranding without additionality" with a "lessening of investors' confidence in the market and consequent sub-optimal resource allocation to *sustainable* sectors" as well as "dilution of policy action [...] to reach sustainability-related policy objectives" (Migliorelli, 2021, p. 15). There is a wide range of literature on the additionality of SF in general and on the additionality of policies and financing for sustainable development in particular. It is also an important field of research in the area of GHG compensation certificates.

A recent OECD working paper (Andersen et al., 2021) investigates financial and development additionality in the area of blended-finance operations. They provide a broad overview of studies that discuss additionality in the context of Development Finance Institutes from *ex ante* and *ex post* evaluations as well as for (public) subsidies, guarantees, equity finance and venture capital. As an example for the "additionality of subsidies" found in Andersen et al., (2021), Zúñiga-Vicente et al., (2014) investigate the impact of public R&D subsidies on private R&D investments. The authors conclude that the empirical evidence for additionality in this area "prevails", but that there is also evidence for the crowding-out of private investments (substitution effect). Factors that influence the additionality or crowding-out/crowding-in effects are (among others) the frequency of public subsidies to a firm, its financial constraints, the composition of R&D investments, the size of the subsidy and the size of the R&D project. Another example in Andersen et al., (2021) focuses on "credit guarantee schemes". Abraham & Schmukler, (2017) investigate in their literature review (i) whether state interventions are necessary for credit guarantees to persist and (ii) whether such public guarantees have a positive impact on the access to capital for financially constrained firms. Again, the results are ambiguous and the (financial and/or economic) additionality depends on the design, evaluation and monitoring applied. The authors conclude that the "empirical evidence has not been helpful in settling this debate. In some cases, the use of public schemes has been beneficial, whereas in other cases, they have imposed costs with their net effect being unclear" (Abraham & Schmukler, 2017, p. 4). The third area of investigation in Andersen et al., (2021) looks at additionality in the context of "equity finance and venture capital". Colombo et al., (2016) argue that the goal of public venture capital is to a have positive crowding-in effect on private capital as well as positive spill-over effects on the local economy. The latter is often expressed as indirect objectives for job creation and job empowerment. According to the authors and the studies they cite, such desired effects on job growth are negligible. As to the question of crowding-in versus crowding-out, results from the literature are mixed with both examples for good as well as bad performance.

There are also studies that focus on the additionality of SF products, one of which provides a good overview of the assumptions and biases involved. Krahnen et al., (2021) investigate how financial policies and instruments may lead to actual (desired) impacts rather than "wishful thinking". They present three hypotheses that actors in the market falsely associate with SF according to the authors:

1 Investors believe that sustainable investments are attributed to sustainable projects (attributability).
2 Investors assume that their money *adds* to the green investments of companies (additionality).
3 Investors assume that higher green investment shares lead to negative effects for brown portfolios (segregation or substitutability).

Although only one of these hypotheses is labelled "additional", all of these statements can be considered questions of additionality one way or another (more in line with development, economic or project additionality).

The authors argue against the first assumption (1) that "managerial decisions about production techniques and the firm's investment in machinery and equipment hardly ever depend on a particular funding source" and that "ESG-compliant spending, as with any other investment of the firm, is funded by the totality of the cash flow generated by the firm" (Krahnen et al., 2021, p. 4,5). On the second notion of additionality, the authors concede that this type of additionality can occur with a net increase to the funds available, but that there must be a difference between the actual and potential counterfactual investments (in line with the most basic definition of financial additionality). The third notion is the most thorough investigated in the paper and focuses on the pricing of sustainable securities. The authors first consider the mechanism of "greenium", where investors are willing to accept lower returns, thus lowering the cost of capital for the firms providing these securities (and increasing the costs of capital for *brown* firms). However, this type of mechanism only "swaps" green for brown investments in the overall market if the supply of green investment financial instruments falls short of the demand for them. The authors then also look at the empirical data regarding the overperformance of green assets in the market that seem to contradict this mechanism. Citing the findings by Pastor et al., (2022), they argue that there is a hindsight bias in relation to climate concerns that "systematically selected *ex post* winners, namely, those stocks that were positively surprised by the climate-concern shock" (Krahnen et al., 2021, p. 6). Instead of focusing on these passive investment strategies for sustainable development, Krahnen et al., (2021) finally conclude that an active or "activist" investment strategy with the intention of triggering change, might "induce higher ESG values".

Looking at these findings on additionality of sustainable development policies, interventions, and strategies, all authors emphasise the relevance of properly designed evaluation methods. There seems to be a consensus that there is currently not sufficient evidence for additionality from sustainable investment strategies. Actual positive causation can occur but is difficult to evaluate. Busch et al., (2021) summarise this point in the following statement:

> "As such, additionality assumes that the investor is willing to or is convinced to invest at non-market conditions and that the investor generally accepts poorer financial performance (Barber et al., 2021), i.e., an inferior risk-return ratio. That is indeed the case with several investors, particularly in the microfinance field. However, in most investment cases, additionality remains a problematic criterion. Where investments are an intermediary service and made in an open and competitive market, additionality is hard to prove."
> (Busch et al., 2021, p. 33)

1.5.3.6 Material impacts of SF

The material impacts of sustainable investments or SF products have not been thoroughly investigated. Moreover, the studies that do, usually focus on issues of climate change. At first glance, there even seems to be a negative *reversed* relationship, since companies with high carbon footprints exhibit a better financial performance than companies with low-carbon footprints (Busch et al., 2022). However, a direct positive correlation between green financial products and green companies has also been indicated by the emerging literature.

Flammer, (2020) for example finds "that following the issuance of green bonds, companies (i) reduce their CO_2 emissions and (ii) achieve a higher environmental rating" (Flammer, 2020, p. 97), if and only if, these bonds are certified by independent third parties. The author finds that environmental ratings went up by 7.3% and CO_2 emissions were reduced by 21.6 tonnes of CO_2 per USD 1m of assets. Although a full causal relationship could not be ascertained with this type of study (as in 100% attribution from Green Bonds), it indicates a positive empirical relationship between Green Bond issuers and green companies.

Fatica & Panzica, (2021) corroborate these findings only for non-refinancing issuers. They also find that external reviews correlate with larger GHG reductions. However, the authors argue against a causal relationship between Green Bond issuances and environmental performance, since the funds raised with Bonds are very small compared to the overall investments of these companies. Instead, the positive relationship seems to be merely an indication of a stronger commitment of these companies towards climate-friendly behaviour.

1.5.4 ESG impact assessment

1.5.4.1 ESG impact assessments standards

In the market for sustainable bonds, the *International Capital Market Association* (ICMA) standard is used by most of the participants. The *ICMA* provides standards and guidelines for green, social, sustainability, and sustainability-linked bonds as well as a *Climate Transition Finance Handbook*. The *Green Bond Principles* and *Social Bond Principles* as well as the *Sustainability Bond Guidelines* are a popular standard for the emission, management, and evaluation of this type of products. They aim to outline best practices when issuing Bonds serving social or environmental purposes and promote transparency and disclosure. The model described in the study at hand focuses on the key recommendations regarding reporting by the issuer (usually in the form of a framework) and reporting by external reviewers (usually in the form of an impact report).

The framework lists all targets of a Bond, argues for the selection of certain projects or portfolios, and describes how the emission is monitored and verified. The eligibility of investments is usually confirmed by an SPO provider. It is also common to map these investments to overarching sustainability goals, that represent Impacts or Long-Term Outcomes in the logic model at hand (e.g., with help of the mapping tables in ICMA, (2021b)). Bond frameworks according to ICMA are therefore a good starting point to develop the narratives in a ToC logic and to define Inputs and Activities.

Although the *Harmonised Framework for Impact Reporting* (ICMA, 2021a) currently focuses on the accounting of environmental impacts, its core principles can also be applied to social or sustainability impacts that are usually more difficult to quantify. A recent, more specialised framework by ICMA on impact reporting for social bonds acknowledges and addresses these issues (ICMA, 2022). According to this framework, indicators can be used to measure outputs, outcomes, and impacts. Outputs in this methodology are tangible results from activities, whereas outcomes are defined as changes or leanings as “a result of the output”. Impacts are defined “as the attribution of an organisation’s activities to broader and longer-term outcomes” (ibid.). Although the exact definitions differ from the definition and uses of these terms in this dissertation, they are in many regards very similar to the definitions for the ESG-LM. ICMA (i) ties the activities of actors to their direct, tangible outputs, (ii) it considers outcomes to be in a causal relationship with outputs and (iii) emphasises the question of attributions and contributions by actors to desired societal changes.

A more *hands-on* methodology for impact reporting can be found in the *Position Paper on Green Bonds Impact Reporting* by Nordic Public Sector Issuers (NPSI, 2020). It targets different actors, but sustainability analysts in particular. I cite this methodology because it represents a *best-practice* for impact reporting of Green Bonds in my opinion. Its reporting principles discuss important assessment recommendations such as “reporting on a project-by-project” basis, “reporting based on share-financed”, “distinguish between financing and re-financing” or more broadly, “maximize transparency and useability” (ibid.). It also deals with questions of causality, although mostly in an implicit manner.

1.5.4.2 ESG impact assessment methods

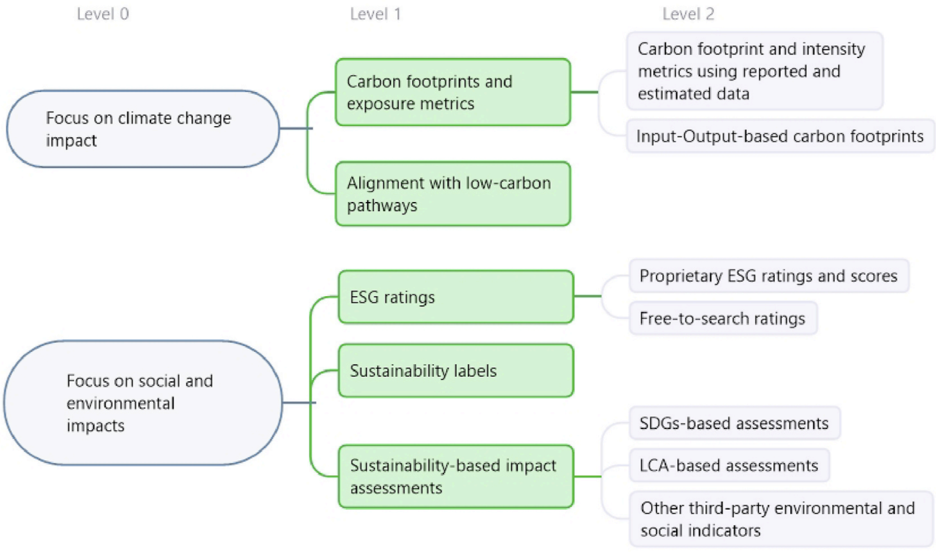
Looking at the literature on “impact measurement”, there is a strong emphasis on impact-metrics and impact measurement principles rather than assessment methods. Boiardi, (2020) for example provides an extensive literature review on “principles and guidance”, “frameworks”, “standards, certifications and ratings” and “metrics and indicators to measure impact”. The author cites numerous standards from different groups, but not many of these methodologies actually provide guidance on how to assess or measure impacts of sustainable investments (the topic of this OECD paper). Here, the emphasis is on monetisation and weighting approaches, that is, methods or standards used to monetise and aggregate units of impact. It is up to the user of such methods to either collect primary data or to come up with a method themselves to estimate these units of impact. I therefore classify such methods and frameworks as tools for decision-making and indicator selection rather than as assessment methodologies. However, and despite this focus on metrics rather than assessment methods, some of the suggested indicator sets take causality into account. The IRIS+ core-metric system for example clearly distinguishes between “outcomes” for different target groups, categorises data for different types of scale or duration, and incorporates contrafactual thinking for evaluating the contribution of actors (GIIN & IRIS+, 2019). Applying this framework and combining it with a robust method for monitoring and impact estimation thus conveys some relevant information to the reader on how an actor contributed to overarching goals.

However, a recent literature review by Quatrini, (2021) argues that many of the currently available decision-support tools in the SF market are lacking in guiding a sustainable transition and directing Sustainable Finance towards “doing good”. According to the review of around 100 sources, DTSs are criticised by scientists, investors, and regulators for their lack of credibility, insufficient scope, and their focus on *ex post* effects. In order to address this issue, the authors recommend (among other suggestions) that people “measure more accurately and comprehensively all relevant material risks, dependencies, liabilities, and trade-offs in the short, medium and long-term” (Quatrini, 2021, p. 13).

This notion is seconded by Liang et al., (2021) in their book article on *Impact assessment and measurement with Sustainable Development Goals*. The authors argue that “current impact assessment and management practices are inadequate to guide SDG investments” (Liang et al., 2021, p. 3). They highlight the differences between “ESG measurement”, which is output- and input-focused, and impact measurement, which is about “effects” and “outcomes”. Impact measurement methods are not only applicable to both public and private entities (with ESG measurement mostly restricted to the former), but also allow one to distinguish between absolute and marginal impacts. Absolute impacts explicate how an organisation’s activities create impact for different stakeholders, whereas marginal impacts are derived with the help of an alternative reference scenario.

In the context of the ESG-LM, it is therefore useful to start with an overview of the existing assessment methods. A recent review by Popescu et al., (2021) lists and evaluates numerous methods and frameworks for sustainability assessments of investments. The authors cover a wide field of tools, distinguishing two method families with a focus on climate change impacts and five method families with a more holistic view of environmental and social impacts (see Figure 1-3).

Figure 1-3: categoriszation of impact logics



Note: Level 0 splits the tools based on their focus – either climate or environmental and social focus. Level 1 defines five categories, based on methodological differences. Level 2 further distinguishes methods based on more in-depth methodological differences

Source: Popescu et al., (2021)

Only a few method families shown here, or discussed by similar studies (Boiardi, 2020; Thomä et al., 2018), refer to actual activities that can be addressed and operationalised in terms of causal inferences. Instead, a portfolio or firm-level perspective is chosen that measures, or more often qualifies, the sustainable state of companies as a whole or as part of an industry. ESG ratings as well as sustainability labels do not report actual impacts though (Popescu et al., 2021). They are frameworks for risk mitigation of exposures rather than tools for the impact maximisation of investments (Boiardi, 2020).

Based on the intended functions of the logic model, I classify the following four method families that can be used to quantify indicators for the different levels of the ESG-LM and are also explicitly applicable to interventions on a project, measure, or investment basis:

1. Monitoring
2. Empirical Studies
3. LCA
4. Input-/Output Models (IOM)

Out of this list, I will only discuss LCA-based and IOM-based methods in the next sections. Monitoring provides direct results or is used as a data basis for other assessment methods. Empirical assessments require their own, usually separate, study design. It is also more likely that a classical empirical investigation would collect the data of several financial actors to increase the sample size and to respond to academic inquiries rather than the needs of a particular actor in the SF market.

1.5.4.3 LCA

LCAs are the most common method for measuring potential harm to environmental objectives by products and services. LCA methods consider these objectives in the form of areas of protection (e.g., protection of ecosystems) and the underlying environmental mechanism (e.g., global warming potential). The methodology is based on international standards, most importantly EN-ISO 14040 and EN-ISO 14041-14043 (DIN EN-ISO 14040, 2021; DIN EN-ISO 14044, 2021). A full LCA consists of four phases and covers all lifecycle phases from cradle to grave. Conventional LCA results can be differentiated into midpoint indicators and endpoint indicators (see Bare et al., (2000) for a more detailed discussion on the implications of midpoint and endpoint approaches in LCA). Whereas midpoint indicators are more closely related to the environmental mechanism of a single environmental problem, endpoints show impacts on a higher aggregated area of protection. Although there are endpoint indicators that do not come from a midpoint calculation (e.g., human health effects), many endpoint indicators require the interpretation, normalisation, and weighting of midpoint effects.

This cause-effect link of midpoints to endpoints is in line with the definition of outcomes and impacts in theory-based impact evaluation methods, albeit with a negative rather than a positive connotation. LCA is also investigated as a tool to inform decision-making for policy interventions and assessments (Gava et al., 2020; Jeswani et al., 2010; Sevigné-Itoiz et al., 2021). Nonetheless, a full LCA analysis is seldom used to quantify the impacts of policy interventions or sustainable investments (see Gibon et al., (2020) and Lauesen, (2019) for examples on the latter). This is not surprising, as LCA requires extensive data on the investigated physical systems, scientific reasoning, and documentation as well as expert knowledge on the use of assumptions, uncertainty analysis, cut-offs and rules for allocation and attribution. However, LCA studies (or LCA tools) often provide the data basis for the evaluation of companies, projects, or investments into products and services. To that end, there are frameworks that simplify the LCA approach or regulate the calculation rules with the help of standards.

The GHG protocol, for example, defines the minimum data requirement for Scope 3 emissions (GHG emissions in the value chain) of purchased products as: “all upstream (cradle-to-gate) emissions of purchased goods and services” (World Business Council for Sustainable

Development & World Resource Institute, 2011, p. 34). The usage of the term *cradle-to-gate* here clearly refers to LCA terminology, where the lifecylcle of all upstream emissions from the *cradle* of raw-material extraction to the final product at the *gate* of the manufacturer is accounted for. This type of *cradle-to-gate* results (or *GHG intensity*) can be calculated with the help of impact assessments methods and data bases for lifecycle inventories (LCIs). Such factors are commonly used in impact reporting to derive potential GHG savings from building refurbishments or from replaced GHG emissions by renewable energy production. LCA-based approaches in impact reporting of Green Bonds for example usually rely on some baseline (the frame of reference for difference-making) as well as bottom-up calculations of the required changes in physical properties. They are also not restricted to GHG emissions and could very well also be used to provide midpoint indicators for other environmental stressors (as shown for the impact assessment of Green Bonds by Gibon et al., (2020), p. 7).

1.5.4.4 IOMs

LCA and related methods like LCC apply a bottom-up approach from micro- to meso-economic systems. They can be highly detailed and comprise information on specific production recipes, material inventories, material sourcing, and energy flows. However, they often lack a holistic perspective of the entirety of a society. Even the use of generic LCI databases cannot account for the fact that the social and environmental effects of producing goods are interlinked with and dependant on their local economies.

Input-/Output tables provide this kind of information and are the basis of IOMs and multi-regional Input-/Output Models (MRIO) (Bunsen & Finkbeiner, 2022). The starting point is usually a table or matrix with descriptive data on the monetary flows between sectors, industries, or product categories within as well as between countries. Such a dataset is usually annualised and already includes further economic information on, for example, expenditure by households or value added. An IOM is able to adjust the interlinkages between industries in a coherent manner so that, for example, a reduction of demand in one industry in one country leads to consistent changes for all industries that are connected to this demand. Such a model can be equipped with so-called satellites, that is, data extensions for other areas of interest (usually indicated by the prefix *environmental-extended* MRIO). Typical applications of that approach are satellites reporting on energy supply and demand as well as the related CO_2 emissions from combustion.

IOM related impact assessment methods have the advantage of being internally consistent, as the overall monetary inputs and outputs usually remain in balance throughout the process. They are also highly applicable for assessments of markets since they already imply some form of standardised sector or industry classification. For example, it is very easy to derive the average characteristics of a sector by normalising some explicated effect in reference to a known statistical value. This *law of averages* is also a disadvantage though, as the high level of aggregation in IOM makes it difficult to assess the effects of specific measures or even the performance in sub-industries. I myself used the results of such a model to derive average intensity factors to estimate the carbon footprint of loans by a German bank with the help of proxies (Teubler et al., 2021). While we were able to differentiate a bit beyond the given industry level using a hybrid approach (e.g., on organic versus conventional farming), this solution had limits regarding the asset classes that can be modelled.

One example for such a model is the *Framework for Integrated Sustainability Assessment* presented by Rodríguez-Serrano et al., (2017). The authors link an extended MRIO framework with social risk data from the *Social Hotspots Database*. Their model allows the use of project specific data as inputs (e.g., investment costs) and the calculation of economic, environmental, and social effects from these inputs (e.g., employment generation, water consumption, or the Project Social Index of labour rights). A later case study then tested the approach for a solar thermal electricity project in Mexico (Rodríguez-Serrano et al., 2017), although the approach seems to have not been used since.

Another example of applying IOM methods is a recent study by Popescu et al., (2023). The authors applied a hybrid approach (IOLCA), incorporating LCA data into an IOM, and investigated the carbon emissions from a sample of 1,340 sustainable and conventional funds with 11,275 unique holdings. The authors find that a "fund can significantly reduce its carbon footprint [...] by investing in stocks with higher valuation and lower level of emissions" (Popescu et al., 2023, p. 8). The authors highlight in their method section that, while IOM databases are considered reliable in general, their supply chains rely on industry averages and might therefore not match the supply chain of a given company.

1.6 Premises of study in light of desk research

The literature review in the previous sections is intended to provide an overview of the current SF market as well as its regulatory framework (at least in Europe) and to introduce methods that can potentially be used to alleviate the issues with the assessment of its material impacts. It is also intended to provide background knowledge for the premises that were initially adopted for the formulation of the research questions (see Table 1-1).

P1 states that non-financial and non-government businesses, organisations, and households are the main actors in any intervention that results in desired changes in the system. The literature review determined that while there are actors that actively trigger changes with the help of engagement strategies, capital allocation alone is not a reliable tool to improve the sustainability performance of companies (Kölbel et al., 2020). It also corroborated the assumption that current decision tools are more concerned with ESG risks and financial returns than material impact generation (Braak-Forstinger & Selian, 2020; Popescu et al., 2021; Quatrini, 2021). Moreover, many of the material claims of the SF market seem to stem from a misunderstanding of what the causal mechanisms (CM) of most of its products are and what decision tools measure (Krahnen et al., 2021). ESG ratings and sustainability labels in particular are frameworks of risk mitigation rather than impact measurement (Boiardi, 2020). I thus conclude that P1 holds true in the current market environment.

P2 builds on P1 by categorising the potential contributions of sustainable financing towards desired changes. It asserts that such financing is (a) either earmarked to a purpose or (b) accompanied by governing activities such as engagement by investors. It excludes all other types of contributions to direct impact generation and restricts such contributions to (c) potential improvement of the overall performance of main actors. The latter (P2c) is clearly corroborated by the literature at least for the Bond market (Dorfleitner et al., 2022; Flammer, 2020). The positive influence of active investors on the sustainability performance of companies (P2b) has not been specifically investigated in my desk research, but it seems to be a consensus in the literature (e.g., Chen et al., (2020); Dyck et al., (2019); Quatrini, (2021)).

Regarding P2a, several studies highlight the risk that non-directed or "sustainable-labelled" (Migliorelli, 2021) capital often dissipates in the balance sheets of the companies without generating impacts (Krahnen et al., 2021; Migliorelli, 2021). However, it seems to be the weakest of my premises in light of the literature, since many authors argue that this lack of attributed impacts is mainly caused by insufficient frameworks, insufficient data availability, and unregulated financial markets and policies (Braak-Forstinger & Selian, 2020; Popescu et al., 2021; Quatrini, 2021). Even in the case of actual earmarked Financing, there are currently no clear demands for new or alternative material impact assessment methods. Nonetheless, the lack of relevant information for causation is noted by many authors and at least some of the suggested metrics indicate tangible results from concrete interventions rather than merely reporting on the overall performance of actors (Clark et al., 2018; KfW Sustainable Finance, 2021; Mazzucato & Penna, 2015; Weinlich et al., 2020). There are also studies and guidelines (Boiardi, 2020; Gibon et al., 2020; NPSI, 2020) that demand and discuss metric-driven accounting of impacts on the level of outputs and outcomes. Moreover, there is evidence that the issuance of Green Bonds, which are often earmarked, is positively correlated with environmental performance (Fatica & Panzica, 2021; Flammer, 2020). Thus, I tentatively suggest that the potential benefits of assessing material impacts from earmarked sustainable Financing has not been sufficiently investigated yet.

The last premise, P3, states that attributions from earmarked investments can be quantified (as advocated by standards such as ICMA, (2021c) or NPSI, (2020)), but that the additionality of these investments relies on robust counterfactual assessment. The literature indeed suggests that measuring impacts and contributing them to actors is possible — at least on the level of contributions by companies. However, the desk research also showed that such frameworks and decision tools mainly focus on pre-defined indicator sets that are deemed to establish the causal relationship implicitly by consensus or indirectly by classification of metrics (e.g., GIIN & IRIS+, (2019)). Each of the investigated frameworks for impact-metrics as well as methods for impact assessment lacked a recipe that shows how given data is translated in such a way that it provides evidence for attribution. On the question of additionality, Andersen et al., (2021) provided an extensive review of the existing academic literature and frameworks by practitioners on this issue. They argue that financial additionality requires an understanding of the causal relationships between interventions and their additional effects. The authors recommend that practitioners consider the lessons learned from earlier studies and advocate for ToC as an analytical tool for evaluation. In addition, there is at least evidence that some investors are willing to pay more for impact-aligned or impact-generating products (Barber et al., 2021) which could also translate into some form of additionality. I thus conclude that P3 is warranted and is a viable starting point for my study.

1.7 Desk research: impact logics

Impact logics are frameworks that focus on *how* and *why* sustainable development materialises (desired outcomes of interventions in the ESG-LM). These methods can be distinguished from impact measurement that focus on *what* materialises. However, this is not an exhaustive distinction as some impact logics allow for quantifications and some impact measurements also have a clearly defined underlying impact logic (e.g., the counterfactual of intervention costs versus opportunity costs).

The landscape of ESG impact measurement and management frameworks is very diverse. It is inconsistent regarding the meaning of terms and purpose of methods. However, many standards or frameworks use some form of impact logic that can often be traced back to theory-based evaluation (TBE) approaches often described as Theories-of-Change. As these approaches provide the academic basis for the ESG-LM in the work at hand, I briefly discuss different types and applications for these methods.

A good way to distinguish the different method families is to look at how and why they are used. The original idea of TBE is connected to the so-called *programme theory* which goes back to the 1970s[4]. It has considerably evolved and branched since then, but is mainly used to describe the causational mechanisms of policy programmes from an academic point of view. There is a clear emphasis on causation, the role and capacities of different actors, and the use of

[4] ToC in general can also be traced back to earlier scholars like Paolo Freires' works on education in the 1960s or Peter Druckners' works on management in the 1950s.

empirical data to test claims. For that purpose, TBEs are "means to understand when and how programs work" (Weiss, 1997).

By opposition, current TBE practices are also often applied to a management or practitioner perspective[5]. They are developed for and used by companies, financial intermediaries, and social institutions or their organisational bodies. They provide impact logics for strategies and standards. Although they are helpful in shifting the focus of actors from activities towards outcomes and goals, they often only describe how these outcomes *might be* achieved and what metrics or key-performance indicators are helpful in measuring the actual or potential effects.

1.7.1 Scholarly methods

This distinction was recognized early-on in the literature. Carol Weiss, one of the most notable theorists in the field, already separates the two basic types in 1997 (Weiss, 1997). She calls the first, more academic approach for a social science theory "Programmatic Theory", for which Carol Weiss and Patricia Rogers provide the following definition in 2007: "Programmatic theory […] deals with the mechanisms that intervene between the delivery of program services and the occurrence of outcomes of interest. […] The mechanism of change is not the program activities per se but the response that the activities generate" (Rogers & Weiss, 2007, p. 73). By comparison, "Implementation Theory" describes how a programme develops. It therefore maps an assumption on the effects of activities to stimulate tangible results like failure or success.

Rogers and Weiss later discuss, among other things, the question of using programme theory for purposes of evaluation (2007). The authors assert that many programme theories at this point were only used to investigate the question of *whether* something happened, and not *why*. Three potential responses to this challenge were suggested. First, some programme theories could only be used to improve the programmes themselves ("to improve, not to prove"). Secondly, programme theories could be used to design better experimental designs in combination with more conventional methods. And thirdly, a Popperian approach could be applied that aims to develop testable hypotheses.

There was and is also an ongoing discussion on the complexity of programmes that TBEs are able to address. Rogers, (2008) attributes the complexity of different types of aspects of interventions to three types of problems (simple, complicated, complex) and therefore to three distinct forms of logic models. In this framework, "simple logic models" mostly deal with single organisations, single causal strands, apply a universal mechanism, and have proportional and linear impacts and pre-identified outcomes. By comparison, "complicated logic models"

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[5] A good example of this kind of application is the Development Effectiveness Rating (DERa) by KfW DEG (see https://www.deginvest.de/DEG-Documents-in-English/About-us/What-is-our-impact/Policy-brief_EN.pdf)

can encompass multiple agencies and multiple simultaneous causal strands and can have different CMs.

Since then, numerous classifications for theory-driven types of evaluation have been suggested. A more recent review of academic theory-driven evaluation practices by Coryn et al., (2011) discusses these types and also provides its own methodology based on five core principles: (a) theory formulation, (b) theory-guided question formulation, (c) theory-guided evaluation design, planning, and execution, (d) theory-guided construct measurement, and (e) causal description and causal explanation. The authors also address the claims by critics and advocates of the method family. The following Table 1-4 summarises the critique, the responses of advocates, and the results (if any) of the review by Coryn et al., (2011).

Table 1-4: critique and review of TBE according to Coryn et al., (2011) and others

Critique	Review
(a) The role of evaluators is to determine *whether* programmes work and not *how* (Scriven, 1998)	many cases where programme theory was unnecessary; other cases where a plausible theory was essential for planning, designing, and execution of programmes
(b) Well-articulated, validated programme theories are not feasible and need resources that could be used more efficiently elsewhere (D. Stufflebeam, 2001)	no dependable confirmation that evaluations with the help of TBE are more or less proper, useful, feasible, or accurate than other forms of evaluation
c) TBEs create a conflict-of-interest where evaluators evaluate programme theory they themselves developed (D. L. Stufflebeam & Shinkfield, 2007)	small minority of cases where social scientists used TBE to test theoretical proposition; however, these studies were not conducted with the intent to serve any stakeholder evaluation needs

Source: own compilation (Sources directly referenced in table)

There are numerous studies that apply the more scholarly approach to ToCs, especially in the areas of health (Bonell et al., 2020; Breuer et al., 2015), education (Armitage et al., 2019; Kearney et al., 2022), or on issues of sustainable transformation (Dinesh et al., 2021; Rice et al., 2020).

Moreover, there is also a growing number of research projects that apply ToCs for the purpose of (ESG) modelling. A recent paper by Zell-Ziegler & Thema, (2022) for example investigates how a classical impact-chain model (more associated with practitioners' approaches described in the following section) can be used to inform the modelling of inputs and outputs for impact quantifications. The authors apply a ToC inspired logic to identify "success factors", "barriers" and "risks" for a desired outcome-pathway, but also to select modelling parameters and variables antecedent or within the system under investigation.

1.7.2 Practitioners' approaches

Despite the ongoing debates on the feasibility of the method, many practitioners and academics have further advanced the core idea and applied it to other contexts. Jackson, (2013) is the first (to my knowledge) that acknowledges the already ongoing practice of using ToC as an implicit tool in the finance industry and suggests using them explicitly too. The author argues "that making the theory of change explicit enables all parties to better understand and strengthen the processes of change and to maximize their results, as well as to test the extent to which results and processes actually align with the expected theory of the intervention" (Jackson, 2013, p. 96).

The author sees three ways in which so-called "development evaluation" (DE) methods (ToC and programme theory are concepts of DE in this regard), might improve impact measurement in the impact investing industry (ibid, p.99). Firstly, DE provide a more comprehensive frame for understanding the evaluation function. Secondly, DE comes with a set of data collection and analysis methods useful for the industry. Thirdly, DE explains how "tangible, positive changes" for the "ultimate beneficiaries" can be attributed to investments (ibid, paraphrased from p.99). However, Jackson, (2013) also emphasises the role of ToC as "more of a framework and not a sufficient tool in and of itself to collect data on and understand the multiple levels and dimensions" (Jackson, 2013, p. 103). After discussing several additional assessment tools (e.g., interviews with industry leaders, organisational assessment tools), the author advocates using a wide range of methods for measuring the impacts of investments. He also suggests using qualitative tools for a better understanding of the cause-effect relationships. A recent OECD paper (Habbel et al., 2021) highlights the potential of TBE methods for analysing blended finance interventions as well. The authors explicitly advocate for negative ToCs intended to "uncover the dynamics underlying unintended negative results" (Habbel et al., 2021, p. 28).

More concerned with ToCs in praxis, the authors of the *Inspirational Guide for Development CSOs* (Fagligt Fokus, 2015) describe the application of ToCs on an organisational level as well as for programmes and projects. To their understanding, ToC "forces us to make our implicit rationale — our assumptions — explicit" with the focus "on what we think will change, not on what we plan to do". Regarding ToC design, there is a clear emphasis on the iterative process of continuously testing the original assumptions in order to improve a theory. Although the guide is primarily concerned with ToCs for programme design, *ex post* evaluation on the basis of ToCs is discussed as well. The authors distinguish attributions from contributions by drawing a so-called accountability line. Attributions in this framework can be traced back to one actor alone (the organisation doing the intervention), while contributions acknowledge that other actors are necessary for achieving the desired objectives.

Many more conventional organisations have since adapted ToCs to their purpose and there are numerous standards and guides for their implementation (e.g., Fagligt Fokus, (2015); Taplin &

Clark, (2012)). Some practitioners also explicitly distinguish logic models (LMs) from ToCs. Analytics in Action, (2019) for example define LMs as descriptive ("**what** you expect to happen") and ToCs as explanatory ("**why** it will happen"). They also ascertain that LMs are usually developed after a programme has been developed and ToCs before an intervention starts.

In Germany, the federal promotional bank[6] KfW has recently introduced their impact management scheme based on a ToC (KfW Sustainable Finance, 2021). Implementing an impact pathway clearly inspired by a linear programme theory model, the bank characterises its services as inputs, the actions of its customers as activities, and their measurable results as outputs. Quantitative and qualitative "cross-impact" indicators are then established to account for outcomes, that in turn contribute to the SDGs.

1.8 Previous and current research by the author

This dissertation is embedded in my previous and ongoing research in the area of SF. This research can be categorised into research projects and method papers as well as white papers and articles. My work on impact reporting for Bonds started in 2016 for Green Bonds issued by NRW.BANK. The most recent method paper on this subject was published in April 2023 (Teubler, Buschbeck, et al., 2023), while all previous impact reports have been uploaded to the issuer's website[7]. These reports document a transition from quantification methods strongly influenced by LCA methodology towards alignment with industry practices, the ICMA standards, and the available academic literature. Impact reporting for the Sustainability Bonds by the federal state of North-Rhine Westphalia (NRW) started in 2017[8] and represented one of the first impact methodologies in the market concerned with other environmental issues and benefits to society from social programmes. The initial reports and methodological considerations focused on GHG emission reductions and presenting available data on social issues. The first methodology for "social impact-indicators" was introduced in the impact report for the *Sustainability Bond #6 of the State of North Rhine-Westphalia*. It introduced the categorisation of indicators in light of the the robustness of their quantification and the available evidence for success (Teubler et al., 2020).

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[6] Promotional banks are "are legal entities carrying out financial, development and promotional activities on a professional basis which are given a mandate by a Member State at central, regional or local level" (European Investment Bank, 2023).

[7] https://www.nrwbank.de/de/die-nrw-bank/investor-relations/green-bonds/

[8] https://nachhaltigkeit.nrw.de/en/sustainability-bonds-nrw/sustainability-bond-9-of-the-state-of-north-rhine-westphalia

This early attempt to assess social impacts influenced both this dissertation and later projects. The impact reporting for the Green Bond by the federal state of Baden-Württemberg (since 2021, ongoing) for example incorporates the evaluation perspective of the EUT in regard to the DNHS criteria and already qualifies its indicators regarding their position in a ToC inspired impact value chain (Teubler & Brauneis, 2022; Teubler & Schekira, 2023a). The social and economic assessment in the MEDITOMATO project that investigated the sustainability benefits of digital interventions for tomato production was also based on a ToC approach (Teubler, Hennes, et al., 2023).

The impact reports for the NRW.BANK Social Bonds[9] then included the first fully explicated ToC and discussed Additionality in the context of Bonds for sustainable development (Teubler, 2023b, 2023c). The methodology there was developed on the basis of this dissertation, but it also constituted a test-case for its ideas and tools.

I also assessed the credibility of causal strands in Social Bonds in a related journal article (Teubler & Schuster, 2022). It comprises of a full Bayesian Analysis (BA) for the NRW.BANK Social Bond regarding its claims for affordable housing and discusses the merits and drawbacks of the method. Further articles and white papers discuss the additionality of ESG financing and investments (Teubler, 2023a), criteria for public grants aligned with the EU taxonomy (Teubler & Söndgen, 2020), carbon accounting for loans (Teubler & Kühlert, 2020), and the tools for an evolution of promotional banks to banks for sustainable transformation (Teubler et al., 2022).

[9] https://www.nrwbank.de/en/about-us/investor-relations/social-bonds/

1.9 Theoretical framework

This chapter describes the theories, concepts, and related methodologies that are used and adapted throughout this work as well as the practical implications of their application. The framework is an onion-like set-up, in which ontology and epistemology are the outer layers that encompass both the actual ESG-LM (and its intrinsic mechanics) as well as questions of measurement and epistemic justification. This results in the framework shown in the Appendix (see A-4, which summarises the most important definitions, concepts, and literature sources.

The ESG-LM is a model for impact assessments that operationalises cause-effect relationships. Therefore, each of the methods developed and adapted must align to a common explanation and rule set for causes, effects, and the CMs between them. However, adopting these positions on the nature of causation (ontology) and empirical knowledge about causation (epistemology) does not require an absolute commitment of the author or users of the model to these positions. Instead, both ontological and epistemological positions are selected, so that they are compatible with each method applied and so that these methods are mutually compatible. This is in accordance with the way Beach & Pederson (2019) define their principle of methodological alignment:

> "Although we advocate a pluralist position on methodological issues in which one understands and accepts ontological and epistemological differences across methods, we do not argue an *anything goes* position. Instead, we argue for the principle of methodological alignment, in which **our methods match up** with the deeper ontological and epistemological assumptions that **we adopt** based on the type of inquiry in which we are engaging" (Beach & Pedersen, 2019, p. 14, emphasis mine)

1.9.1 Ontology (nature of causation)

I adopt a position of **soft ontological determinism**. Simply put, I assume that things happen for reason(s). This means in the context of the ESG-LM that outcomes are necessitated by one or more conditions (**multi-causality**). The determinism is soft, because it allows for agency (compatibilist determinism in line with Adcock, (2007)). Outcomes are therefore not inevitable when considering agents and their decisions.

The ESG-LM is also defined to propose and deal with **static asymmetric causal claims** (Goertz & Mahoney, 2012). It assumes that interventions (explicated as Inputs and Activities in the model) function as causes that help to realise desired Outputs and Outcomes ($X \rightarrow Y$ with all things being equal), but that the opposite is not necessarily the case. The ESG-LM is usually silent on the presence of Outcomes without these antecedents ($\neg X \rightarrow ?$). Outcomes could be reduced or prevented without these causes, but do not have to be. However, there is one exception to this convention. Counterfactuals, and therefore **symmetric causal claims**, are considered when questions of the Attribution and Additionality of financing are concerned (see

Section 2.1.6.3). This relates to outcomes that would be different without the capital but also to those that would not occur at all (~X → ~Y with all *other* things being equal).

An additional ontological specification relates to the processes that are triggered by the causes and produce (by actors and entities) the Outcomes. These CMs (**causal mechanisms)** are **heterogeneous**. The same set of causes lead to the same Outcomes across cases, but different CMs could have been responsible for it.

1.9.2 Epistemology (knowledge of causation)

Practitioners that evaluate causal explanations in cases (even if they deny causal relationships altogether) sometimes conflate ontological positions on determinism with the methods and data used to investigate whether these explanations are true. Ontological determinism describes a world in which the same set of conditions always leads to the same outcome but does not presuppose that we understand and know all these relationships.

It is therefore not surprising that many deterministic claims are tested or confirmed with the help of some interpretation of probability. I too adopt a position of **epistemic probabilism** for the ESG-LM in regard to the type of research questions it can answer. Instead of investigating whether propositions are true or false (extreme values 0 or 1), epistemic probabilism applies the concept of **non-extreme credence** in a proposition. Credence, in the sense that it is used in this study, describes the "degree of belief" an actor has in a proposition or cr(P). If non-belief is defined with a cr(P) = 0 and full-belief with a cr(P) = 1, cr(P) can achieve any value between 0 and 1. In philosophy, credence in probabilism is tied to the rationality of agents which are understood to "obey the probability calculus" (Hájek, 2008, p. 806). These rational constraints require Kolmogorov's axiomatisation of probability (ibid) as a type of minimum standard but can include additional conditions for what is considered rational (see Chapter 5 on epistemic justification). For the ESG-LM, this credence can be understood as the "degree of belief a reader of the impact assessment is warranted to have in particular results" (own definition). In line with the axioms, they are at least non-negative ($cr(P) \geq 0$ for any proposition, first axiom)), normal ($cr(T) = 1$ for any tautology, second axiom) and finite additive ($cr(P \vee Q) = cr(P) + cr(Q)$ for mutually exclusive propositions, third axiom). This means for example, that the credences of two propositions sum up to 1 if (i) no further propositions are possible, (ii) they are mutual exclusive and (iii) not a tautology.

With these requirements in place, I apply the **extensibility version of epistemic probabilism** for the epistemology of the ESG-LM:

> "One's assignment of credences ought to be probabilistically extensible in this sense: either it is already a probability measure, or it can be turned into a probability measure by assigning new credences to some more propositions without changing the existing credences." (Lin, 2022)

At this point of the outer layer of epistemology, no particular interpretation of probability is adopted. The epistemology of the ESG-LM is therefore open to different interpretations such as frequency, propensity, or subjective interpretations (see Hájek, (2019) for an in-depth discussion on the different interpretations).

1.9.3 Epistemic purposes of the ESG-LM

All the above also directly affects the types of practices and methods that are aligned with this epistemology, which I broadly conceptualise as epistemic purposes.

The entire process of developing an ESG-LM, testing, and updating it and then using it as a blueprint for an impact assessment, follows a line of logical reasoning. The first step of finding one or more plausible explanations on how a particular intervention contributes to an (often pre-defined) overarching goal can be compared to abductive reasoning. **Abduction** can be described as a process of causal inference from observed phenomena[10]. It is based on the intuition of the analyst, that is, her experiences and background knowledge. The early 20th century philosopher C.S. Peirce rediscovered (the roots go back to Aristotle) abductive reasoning as the starting point of scientific inquiry (Peirce & Ketner, 1992) and tied it complementarily to deduction and induction. The heuristic development of a ToC is very similar to finding a tentative, and defeasible, explanation from abduction. The second step of explicating the ToCs hypotheses as a starting point for epistemic justification is similar to deductive reasoning. **Deduction** leads to rule-based arguments (*if x then y*) such as a syllogism that argues for a conclusion from premises. If a deductive argument is sound and valid, and its premises are true (e.g., ESG-LM hypotheses), one can infer the truth of a proposition. The third and final step of Bayesian Reasoning (BR) is closely related to inductive reasoning. **Induction** generalises case-specific inferences based on evidence, so that the truth of a proposition becomes more or less probable. Induction is, in many ways, the counterpart to abduction as it is defeasible as well and can strengthen an abductive insight or trigger new lines of abductive arguments.

The ESG-LM is also most closely aligned with a **mechanism approach** to explanations in **middle-range theories** in sociology. The term middle-range theory is coined by Robert Merton in the 1960s and describes a set of social theories that are narrower than grand or unifying theories but are also distinguished from research into micro-sociological problems. According to Kaidesoja, (2019), Merton's original definitions were restricted to a static view of theories and the single function of empirical testing. It neglected other aspects of theorising such as concepts for identifying social phenomena. Kaidesoja suggests a multi-functional view of

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[10] Merziger, (1992) provides a more formal definition of abduction. She also shows how different formal models deal with the question of finding the *best* or most *simple* hypothesis.

middle-range theories instead, which I also adopt and which focuses on the phenomena and their mechanisms:

> "Social phenomena addressed in middle-range theories are typically the types of outcomes that are produced by the social processes that have a similar causal structure." (Kaidesoja, 2019, p. 10)

Thirdly, the ESG-LM is most closely related to **case-based**, case-oriented, or within-case evaluation (Goertz & Mahoney, 2012). While difference-based, cross-case, or population-oriented methods look at the differences between variables of inputs and outcomes across larger sets of cases, case-based investigations investigate and propose causal conditions and mechanisms in smaller set of cases. According to Mahoney, (2008), causation is thus either understood as a mean effect (difference-based) or as different configurations of necessary, sufficient, INUS, or SUIN causes (case-based). One of the main distinctions between these two perspectives is that outliers in single cases (X not confirming Y) in difference-based research are not considered a problem if the overall trend holds (increase in X leads to increase in Y across cases), while for case-based research such explanations are disconfirmed. That is, either the causal explanation is not true, or the case investigated does not belong to the same set of cases for which the explanation works. This means that case-based research often requires some form of *heavy-lifting* when cases are generalised (e.g., with the help of additional assumptions) or can only claim that a portion of the selected cases are consistent with the hypothesis and as such hint at additional required conditions. By contrast, difference-based research can be considered a *black-boxing* of causality (often phrased as "correlation is not causation"). To put it colloquially, case-based research deals better with *how-* and *why-questions*, whereas difference-based research is more concerned with *what-questions*. It might be surprising that I prefer case-based research for the ESG-LM, given that it is, at its core, about impact assessments (which, in SF research, are often investigated by looking at the difference-making variables of companies in ESG datasets). The reason for that is that the ESG-LM (i) investigates particular types of measures or projects and their physical realisation involving different actors; (ii) is a tool designated to find the best-available indicators under data-constraints in mostly *ex ante* evaluations and (iii) should also allow for a conditional control of the desired sustainability outcomes. However, I also propose a method that equips the ESG-LM with difference-making properties in the chapter on epistemic justification (Causal Diagrams; CD) that is more closely aligned with causal inferences in traditional population-oriented methods.

1.9.4 Epistemic categorisation of the ESG-LM method

The large variety of available principles, standards, frameworks, and methods applicable to ESG-related topics makes it necessary to define the ESG-LM in both the scientific and practitioner landscape. As shown by the literature review on impact logics (Section 1.7), merely characterising it as a *theory-based* approach or as a *ToC tool for impact assessment* might be misleading regarding the services it provides and the questions it is able to answer. However, I can use the concepts and terms described in the literature review to show what the ESG-LM is on a continuum and what it is *capable of doing*.

The following statements in Table 1-5 describe the characteristics of the ESG-LM method in regard to the scholarly definitions of TBE, the available practitioner approaches, as well as the research area of SF. Although some of the definitions are similar between these three areas, each helps to describe more clearly what the ESG-LM is intended for (and what it is not).

Table 1-5: ESG-LM characteristics from different perspectives

Perspective	**Characteristics of ESG-LM method**
Theory-based evaluation	• ESG-LM is an impact logic that draws on the academic programme theory but is an applied version of an explicit ToC for practitioners (own assertation). • ESG-LM is more (but not fully) consistent with implementation theory than programmatic theory. It is assumed that the desired results are forthcoming if the process is conducted as described (see Weiss (1997)). • ESG-LMs' evaluation purpose is Popperian in nature. It is not used to enhance experimental design or policies. Instead, it provides hypotheses that can be tested (see Rogers & Weiss (2007)). • ESG-LMs' implementation theories are mainly implicit stakeholder theories as they are built on existing ESG frameworks and not on fully articulated social-science theories or observations (see Coryn et al., (2011)). However, both approaches can play a role either implicitly (from the authors of the framework) or explicitly (as a means to provide evidence for causation). • ESG-LM helps to measure outcome constructs rather than process or context constructs (see Coryn et al., (2011)).
Practitioner Approaches	• ESG-LM provides a frame for understanding the evaluation function and tries to explain how positive changes can be attributed to interventions and investments (see Jackson, (2013)). • ESG-LM is intended to be compatible with qualitative tools for causal analysis but is itself restricted to providing an internal "mechanistic" logic (see Jackson, (2013)). • ESG-LM distinguishes between attributions (desired change traced back to single actors) and contributions (desired change as a result of activities by several actors) (see Fagligt Fokus, (2015)). • ESG-LM is more closely aligned with the concept of a logic model than a ToC ("what" over "why") but has an explanatory character as well (own assertation based on Analytics in Action, (2019)). • ESG-LM limits activities to actors that materialise change but allows for inputs by financing or funding organisations (see KfW Sustainable Finance, (2021)).
SF Strategies	• The interventions in ESG-LM best relate to Sustainable Finance 3.0 strategies for impact investing and impact lending as well as sustainable securities such as green bonds (see Schoenmaker & Schramade, (2018)). • An impact assessment based on the ESG-LM usually focuses on impact-generating rather that impact-aligned investments and financing (Busch et al., 2021) • ESG-LM includes control questions of causation and additionality in the intervention logic but cannot provide empirical evidence for these cause-effect relationships by itself (own assertation).

Source: own compilation based on sources indicated directly in the table

Based on these statements, I formulate the following **definition of the ESG-LM method**:

> (1) The ESG-LM is an *ex post* evaluation method open to *ex ante* predictions that explicates testable hypotheses for the presumed causality and measurability of outcome constructs on the basis of implicit stakeholder ToCs.
>
> (2) Its linear cause-effect logic addresses multiple agencies and multiple simultaneous causal strands and can have different CMs.
>
> (3) It is used to qualify and quantify indicators for the attribution and contribution of economic entities towards sustainability objectives, including the direct or indirect financing of such interventions (in line with a maximation of common good value).

1.9.5 Theory-building of the ESG-LM

The theory-building mechanism is based on ToC. The ESG-LM is of my own design but inspired by the literature. It is supplemented by the concepts of Process-Tracing (PrT) in Contribution Analysis (CA) by Mayne, (2012) for selecting intermediate outcomes (CM_S) as well as PrT by Beach & Pedersen, (2019) for the purpose of designing causal mechanisms (CM) on the level of the measures (CM_P). In addition, I also show how and argue why the additionality of financing is treated differently in this framework (in line with Counterfactual Analysis (CoA) by Mahony). Finally, I briefly describe how the goal of a conventional assessment, the impact report, fits into this overall ESG-LM framework.

1.9.5.1 The ToC Logic Model of the ESG-LM

The first ToCs go back to the concept of programme-based and TBE strategies, for which the term logic model was often used interchangeably (Weiss, 1997). A main distinction in this early, scholarly literature was also made between "implementation theory that specifies the activities and some intermediate outcomes, rather than a programmatic theory that specifies the mechanisms of change" (Rogers & Weiss, 2007, p. 64).

The more pragmatic approaches later adopted by organisations, or for business management practices, usually focus on implementation and arrange the different steps of inputs, outputs, outcomes etc. in a linear fashion (ibid). I used three of these approaches to inform my own development of a logic model for ESG financing, which postulates **causal narratives** with **two interconnected causal claims**: from Inputs (C_1) at t_0 via Activities (CM_P) at t_1 to Outputs at t_2 (O_1) on project level and from Outputs (C_2) via Intermediate Outcomes (CM_S) at t_3 to Long-Term Outcomes (O_2) at t_4 on the societal level that contribute to Impacts (overarching goals).

First, I adopted the linear **Impact Value Chain** suggested by the Social Impact Investment Taskforce, (2014) and incorporated **outcome hierarchies** to allow for different types of outcomes in line with Funnell & Rogers, (2011). Secondly, I also consider societies as a programme of change with "ultimate goals", "change activities" and "inputs from multiple actors" that facilitate the delivery of change activities as suggested by Corlet Walker et al., (2018) in *Measuring economic welfare beyond GDP*.

For theory-building, my starting point for any ESG-LM is an **implicit stakeholder theory**, which identifies and links interventions to overarching goals such as SDGs and is, according to Coryn et al., (2011), one option ("Core Principle" 1b) to formulate a plausible programme theory for evaluation. In the two cases explicated in the study at hand (PoC, Prototype), policy frameworks were used for this purpose, while my previous work usually developed ToCs from SDG-Mapping by the issuers of Bonds. Another aspect of theory-building are the constructs the ESG-LM aims to evaluate (ibid, "Core Principle" 4a and 4b). I evaluate **process constructs** on the level of the CMs for Activities and Intermediate outcomes, and **outcome constructs** on the level of Outputs and Long-Term Outcomes.

The characteristics of the ESG-LM can also be aligned with the categorisation and terminology in Rogers, (2008). The ESG-LM is **complicated** regarding multiple agencies, multiple simultaneous causal strands, and different CMs operating in different contexts. It is **simple** regarding a linear causality with proportional impact and its use of pre-identified outcomes.

The criteria-based evaluation of any ESG-LM regarding its adequacy (see Chapter 2.3) are my of my own design. However, they are inspired by conditional configurations and set theory in qualitative social research (Goertz & Mahoney, 2012), such that two of the three criteria (Goal Certainty, Sufficiency) require the identification of sufficient and necessary conditions as causes for effects.

1.9.5.2 Heuristics for ToC development in ESG-LMs

Heuristics are mental short-cuts that are useful for quick decision-making and ranking alternatives when the available information is insufficient for holistic assessments. I developed three such heuristics for the process of ToC development: Inference-to-the-Best-Explanation (IBE) for outcome pathways, PrT from similar cases and PrT from evidence. All three heuristics are compatible with Bayesian Epistemology (see my theoretical framework in Section 1.9.8 and Chapter 5). They can complement a formal BA and in the Case of PrT from evidence, precede a later assessment of the credibility of the claims.

For IBE, competing non-exhaustive hypotheses or explanations are compared. Dellsén, (2018) has shown that IBE heuristics cannot be used to estimate absolute credences of hypotheses but are still useful in comparing the explanatory power and antecedent plausibility of competing explanations for observations or theories.

For PrT heuristics, different potential CMs are compared to each other. I start by operationalising concepts such as **Hoop-Tests** and **Smoking-Gun-Tests** for ToCs from Befani & Mayne, (2014) as well as **Theoretical Certainty** and **Empirical Uniqueness** for theory-building from Beach & Pedersen, (2019). These concepts are then translated into two different heuristics. The **PrT from similar cases** ranks competing explanations for Intermediate Outcomes on the basis of literature or background knowledge in cases that are similar to the case to be developed. Whereas Hoop-Tests look for CMs that did occur, Smoking-Gun-Tests investigate (i) what type of evidence is expected to be present; (ii) whether this evidence could be observed and (iii) whether such observations also occurred if other CMs were present.

Similarly, but starting with the available evidence, **PrT from evidence** investigates potential CMs on the intervention level (Activities in the ESG-LM). After collecting, sorting, and qualifying the relevant information, such CMs can be postulated and compared to each other. Ideal CMs match to as many *empirical fingerprints* as possible, while also showing fingerprints that are unique to them (not expected or found under alternatives).

1.9.5.3 Counterfactual Analysis for Financing

The entire theoretical framework deals with asymmetric causal claims. It investigates whether the activities of certain actors lead to desired changes and not what happens if this activity is absent in the system. The act of financing these activities via loans or investments is usually necessary but not sufficient for that change. Any provision of capital that enables the main actors (who in turn provide the main cause for impacts) is thus a contributing factor and an act of finance for sustainability.

However, there are financial activities that do more because they either lead to additional desired effects (defined by me in Section 2.1.6.3 as **favourable financing**) or make the activities possible in the first place (**consequential financing**)[11]. All these cases describe acts of financing that are additional compared to an alternative (which I call **conventional financing**).

In order to operationalise these "what if"-conditions, or counterfactual worlds, I adopt the method of **Counterfactual Analysis** by Mahoney & Barrenechea, (2019). This **set-theoretic logic** allows me to convert conditional configurations of an actual causal relationship into their corresponding configuration in a counterfactual world. For example, a necessary condition observed in reality becomes a sufficient condition when investigating the absence of this cause. It thus transforms an asymmetric causal claim into a symmetric one and allows me to distinguish different types of financing as interventions in the model: **Contribution**, **Attribution**, and **Additionality** (see Section 2.1.6).

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[11] Examples for the first kind are loans with rates well below market conditions or grants that do not have to be re-paid. Examples of the latter could be investors that help to get a start-up off the ground or that steer companies towards sustainable practices via voting.

The authors also introduce additional concepts that I integrate into different aspects of the ESG-LM and its evaluation tools. The **minimal-rewrite rule** in Counterfactual Analysis aims at counterfactual changes that are as minimal as possible. Applied to the ToC in ESG-LM, this rule facilitates updates and iterations, if the original causal relationship is deemed implausible after a first evaluation. The set-theoretic idea of **empirical importance** on the other hand describes how some necessary conditions come close to being sufficient (the subset of outcomes is only slightly smaller than the set of its antecedents) and how sufficient conditions can be close to also being necessary (the superset of outcomes is only slighter larger than its antecedents). Any such relationship that can be established for a causal pathway in the ESG-LM, therefore entails a high empirical uniqueness in the Bayesian sense and is relevant for the process of epistemic justification.

1.9.6 The role of the impact report in the ESG-LM framework

The impact report is the result of an impact assessment conducted with the help of the ESG-LM. It summarises the underlying heuristic relationships between the actors and society (ToC). It shows the interested reader what the contribution of the financing actor is and what outcomes can be expected. It describes how and which indicators were quantified and provides information on their quality and robustness. It also discusses the validity of the claims and the question of additionality. Whereas the indicators themselves are often not evidence for the claims, all data and relevant information that led to the quantification or estimation of these indicators very well can be.

Examples of such impact reports, with or without integration of a full methodology, are referenced in my previous work (see Chapter 1.8). Best practices for the identification and documentation can be found in the impact reporting frameworks by International Capital Market Association (ICMA, 2021a).

1.9.7 Measuring for impact reports in the ESG-LM

Measurement refers, in this dissertation, to the process of identifying and quantifying indicators along the ToC of projects or financial products assessed with the ESG-LM. There is no theoretical framework on the permissibility of certain impact assessment methods. It is up to the analyst to determine which type of quantification methods or estimation models are applicable in light of the data and the goal of each impact report. This **openness in measurement methodology** is justified in that not every impact report relies on its own individual measurement methodology and that measured effects are not necessarily used or required to justify the credibility of ESG-LM claims (see next section).

Impact reporting for green assets is currently still in its infancy and current guidelines allow for many different options. This is even more true for the measurement of societal effects on the level of projects or interventions. It is therefore common in impact reporting standards to point to already established generic data sources (e.g., factors for GHG accounting by *United Nations Framework Convention on Climate Change*) or to refer to some other form of available proxy factorisation. Nonetheless, some methods are more commonly used than others. LCA or LCA-inspired methodologies often provide the basis for the accounting of environmental effects and LCA-derived GHG intensities are probably one of the most common external data points in impact reports. A good example of such an LCA-based methodology is provided by NPSI, (2020). Less common are the application of proxy-factors from regional or extended IOMs. Many impact reports also solely focus on direct reporting of available data, such as reporting the number of borrowers as the number of beneficiaries.

All of the above (and probably more) are suitable for impact reporting according to the developed ESG-LM scheme. However, there are additional requisites from the ESG-LM that also fall indirectly into the realm of measurements — all of which are developed and discussed in this dissertation (own development). The first requisite is mandatory and relates to **indicator quality** as well as **indicator robustness**. An impact report in accordance with the ESG-LM assigns each reported effect to its place in the ToC hierarchy (placed between entities in the ToC) and is thus attributed with a certain quality (from A to E). In addition, indicators should also be further qualified regarding their robustness ranging from 1 for directly monitored effects to 5 for non-verifiable information from third parties. These two characteristics ensure an alignment of the impact report with the underlying narrative and its claims.

The second requisite is optional but enhances the informational value for all actors involved. It defines the proportional **attribution** of actors, especially from financial institutions, to the desired and reported indicators. It also allows one to further define and justify the **additionality** of financing and investment. These three characteristics are partly based on industry standards such as PCAF (PCAF, 2022), partly derived from case-based evaluation practices such as Counterfactual Analysis (Mahoney & Barrenechea, 2019), and further discussed in my previous work.

Another aspect of the measuring process is the collection of data. I use the concept of **Causal-Process-Observations** (CPOs) and **Dataset Observations** (DPOs) in regard to relevant information gathered during the assessment. CPOs and DPOs were first introduced by Collier et al., (2004) and are discussed by Goertz & Mahoney, (2012) to make an distinction on the type of data qualitative researchers are interested in compared to quantitative researchers. CPOs are mostly expected in qualitative research, as they refer to additional data within cases. This could be for example additional primary data (columns in a dataset) provided by the issuer or its business partner for the assessment of a specific set of financed projects. Such variables are usually not available for all rows in a dataset, but they can, nonetheless, provide relevant information regarding the credibility of the claims. DSOs on the other hand are usually the focus of quantitative research, as they add cases with the same variables to the dataset. This could be for example additional data from the issuer on previous projects. Such data can then be used to estimate indicators that are more robust, because they relate to a larger sample of comparable cases. Both types therefore have their value during the process of an ESG-LM impact assessments (mainly DSOs) and during the process of its epistemic justification (mainly CPOs).

1.9.8 Epistemic justification of ESG-LM results

An impact report based on an ESG-LM is intended to convey to third parties how measures or projects by some stakeholder led to or will contribute to overarching sustainability goals. It uses a ToC to describe and illustrate the evolution from an intervention to desired outcomes. This process is heuristic because it is based on the understanding and knowledge of a analyst but is not generated by a tightly framed empirical investigation and methodology. Some of its propositions, or claims, might describe relationships that are already established in scientific literature, and some might be self-evident, while others should better be described as educated guesses. The analyst, as well as any other interested party, can therefore be more confident in some claims of the ESG-LM and less confident in others.

Epistemic justification is the term I use to describe the theoretical framework and the tools which the analyst in an ESG-LM should apply to describe confidence in each of its claims and to discuss the reasons for this assessment. The goal of epistemic justification is to guide the analyst through this assessment, but also to facilitate the scrutiny of the assessment by third parties. This can be best achieved if (i) the confidence of the analyst is graded; (ii) there are rules to grade this confidence, and (iii) the analyst shows and weights evidence for the assessment.

In terms of theories for epistemic justification, **Evidentialism** and **Reliabilism** seem like a good fit for these goals. Evidentialism bases justified belief on the availability of evidence and Reliabilism requires that justified belief in propositions is based on some process that is deemed reliable (see Chapter 5 for a thorough discussion). I use a theory by Juan Comesaña that combines both: **Fine-Grained Evidentialist Reliabilism** (Comesaña, 2010). This theory justifies belief by either undefeated experiences (not the case for ESG-LM) or a *sufficient* credence (degree of belief) of an agent in a proposition that is based on evidence.

This requires a set of formalised propositions to be tested by the analyst, which is achieved by translating the narratives of ESG-LMs into hypotheses. I use **propositional logic** (Kashef, 2023) for this process and separate each ESG-LM Outcome Pathway into at least two such propositions. Hypothesis 1 relies on the intervention (Input) triggering a CM on the level of projects (Activity) to get to a relevant tangible effect (Output). Hypothesis 2 then uses this Output as a possible cause that triggers another CM (Intermediate Outcome) in order to achieve a desired effect on the societal level (Long-Term Outcome). Both are always contingent on system-wide, commonly expected processes outside of the ESG-LM but can also rely on additional pre-conditions.

Several methods could be used to proportion the analyst's credence to the available evidence. Criteria for tool selection should be the availability of data (symmetric and asymmetric variables, sample size, CPOs, DPOs) and the availability of relevant literature findings. I discuss four such methods in detail and also briefly describe variations of these methods in Chapter 5 (BR, BA, Counterfactual Reasoning, CDs). Among those tools, I consider BR (**Bayesian Reasoning**) to be the best option. It can be quickly conducted, but proportions the credence of the analyst to the amount and quality of relevant information at their disposal.

BR is based on Bayes Theorem (BT). I developed a decision tree for arguments from BR in four stages, using existing ideas on the use of **ranged credences** (Titelbaum, 2022) and a **Canon of Probabilities** (Carrier, 2012). Ranged credences enable analysts to define upper and lower bounds of confidence in the credibility of claims and a *Canon-of-Probability* allows me to approximate a quantitative reference for this confidence (see Section 5.4.4). I also incorporate the ideas of **Theoretical Certainty**, **Empirical Certainty,** and **Empirical Uniqueness** that are used in (PrT) and are compatible with Bayesian Epistemology (Beach & Pedersen, 2019). I use these concepts to provide the analyst with a pathway of yes-/no-questions that enables them to argue for credence in the ESG-LM claims. Each step along the way comes with different levels of robustness depending on the available background knowledge and information.

2 DEVELOPMENT OF MODEL LOGIC

This chapter describes the entities of the ESG-LM, develops heuristics guiding the development of ESG-LMs, and provides a criteria-based evaluation process for generic ESG-LMs.

2.1 Framework of the ESG-LM

The logic model consists of eight different types of entities of which the first three can be called generic entities, three can be called intervention entities, and three are societal or system entities.

Generic entities are (i) actors; (ii) asset classes and (iii) types of Financing. Although any type of project can be roughly described just using these entities, they also define what type of impact pathways are possible in the first place.

Intervention entities are part of the ToC approach of the scheme. They describe how Inputs, and their resulting Activities (as CM) lead to tangible Outputs. This is where a company decides what measures are taken in the first place and what type of threshold need to be overcome (e.g., the retrofit level of a building). Intervention entities are also directly connected to any type of primary data provided by the Initiator of an impact assessment.

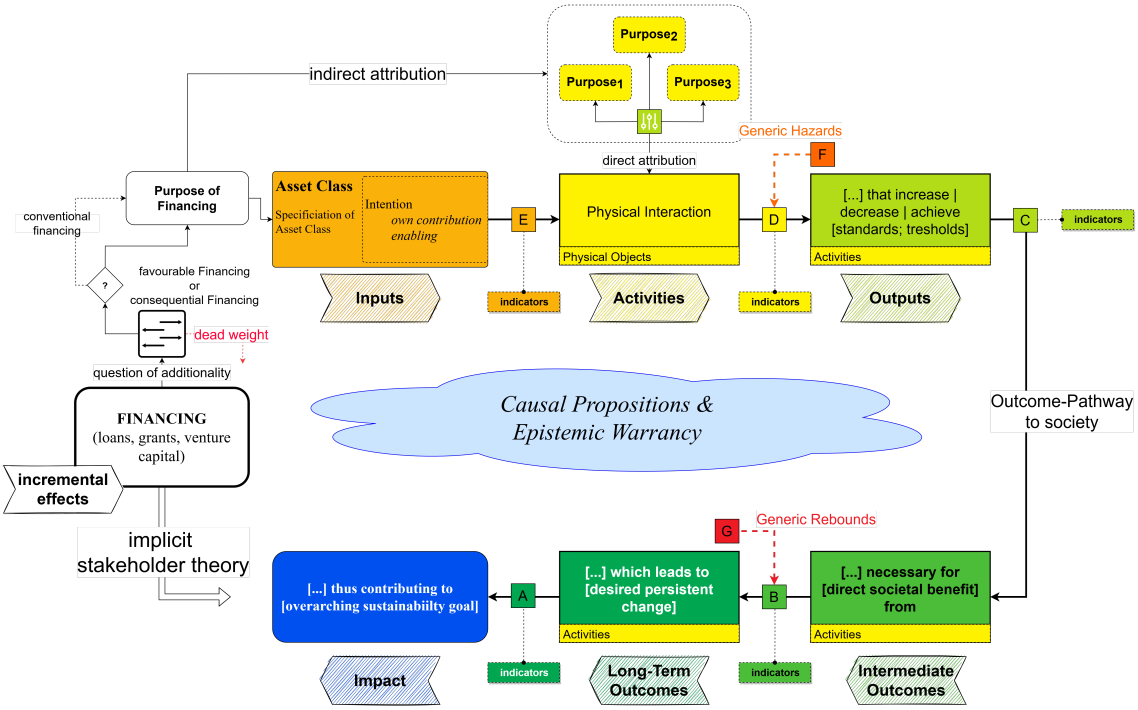
The system entities relate to the broader changes on a societal level. They are distinguished between Intermediate Outcomes, Long-Term Outcomes and Impacts. Whereas Impacts represent the overarching societal sustainability goals on a national or international level (such as the SDGs), Outcomes are desired improvements for targeted groups or regions. There are Intermediate Outcomes triggered as CM by Outputs of interventions and Long-Term Outcomes as a result of several smaller changes that are required to improve the situation permanently.

2.1.1 Building blocks of the model

The following Figure 2-1 shows the entities of the model and how they interact with each other. The main entities are the incremental effect of Financing which is connected to an intervention consisting of Inputs, Activities, and Outputs. This intervention then proceeds to trigger Intermediate Outcomes, that lead to Long-Term Outcomes necessary for a Contribution to an overarching sustainability goal (Impact). An *outcome pathway*, or causal strand, is any combination of interventions that trigger an Intermediate Outcome in this logic.

The ESG-LM is, by definition, an explication of an implicit stakeholder theory (usually a financial intermediary mapping capital to impacts). This is indicated by a second, incomplete, pathway between Financing and Impact.

Figure 2-1: building blocks of the ESG-LM



Source: own development

The following sections describe the entities of the model:

- Generic Entities: Actors, Asset Classes, Financing
- Intervention Entities: Inputs, Activities, Outputs with the additional attributes intentions, purposes, physical objects, physical interactions
- Outcome Entities: Intermediate Outcomes, Long-Term Outcomes, Impacts
- Target Conflict Entities: Hazards, Rebounds
- Indicator Attributes
- Rules of Attribution
- Rules of Additionality

2.1.2 Generic entities

Generic entities in the model provide a bird-view of the economic relationships and the actors involved. They are defined in such a way that they can be linked to empirical data classifications.

2.1.2.1 Actors

I call the institution responsible for potential incremental effects from financing the **Initiator**, although this term might be misleading if their contribution turns out to be inconsequential for the contribution during the assessment. By contrast, the actor that is directly causally linked to desired outputs is named the **Main Actor**. All other contributors are **Other Actors**.

The Initiator usually provides capital to Main Actors or Other Actors but can also be directly responsible for the materialisation of Outputs.

2.1.2.2 Asset Class

The Asset Class describes the economic sector (or core business) any intervention is assigned to. It is also used for operations that do not result in change, such as the day-to-day operations of a company. Although any type of sector classification would suffice for that purpose, the applicability of the model increases when a common classification is used.

The EUT for sustainable activities is currently the largest catalogue of ESG-related operations. However, there are several sectors that have not been added to the taxonomy yet. The ESG-LM will therefore use the EU taxonomy classification as well as the original NACE[12] codes which were mainly used for it (European Commission, 2006). The following table shows the resulting asset classes on the first level.

Table 2-1: asset classes of the logic model according to NACE

Asset category **(* indicates sectors that are partially or fully covered by the taxonomy regulation)**	**NACE Code**
Agriculture, Forestry, & Fishing*	A
Mining & Quarrying	B
Manufacturing*	C
Energy*	D
Water Supply, Sewerage, Waste Management, & Remediation Activities*	E
Construction*	F
Wholesale and Retail Trade; Repair of Motor Vehicles, and Motorcycles	G
Transportation & Storage*	H
Accommodation & Food Services	I
Information & Communication*	J
Financial & Insurance Activities*	K
Real Estate Activities*	L
Professional, Scientific & Technical Activities*	M
Administrative & Support Service Activities*	N
Public Administration & Defence; Compulsory Social Security	O
Education	P
Human Health & Social Work Activities*	Q
Arts, Entertainment, & Recreation*	R
Other Service Activities*	S
Activities of Households	T
Activities of Extraterritorial Organisations	U

Source: based on https://nacev2.com/en

[12] "NACE (Nomenclature of Economic Activities) is the European statistical classification of economic activities. NACE groups organizations according to their business activities" (NACEV2, 2023).

2.1.2.3 Financing

The ESG-LM is explicitly concerned with the contribution of stakeholders from the financial industry towards sustainability goals, such as banks financing companies, states providing grants, or venture capital for start-ups. This is indicated by an additional entity called **Financing**, that precedes the intervention itself and comprises of loans, equity capital, grants, and similar financial transactions.

2.1.3 Intervention entities

The ESG-LM is divided into two causal hypotheses. The first part of the outcome pathways is the intervention. It has a cause (Input) that triggers a CM (Activities) which results in a tangible effect (Output). The following sections describe each of these intervention entities.

2.1.3.1 Inputs

The logic model differs from other impact methods (especially ESG ratings) mainly in its focus on the intention of the stakeholders and their intervention. My definition for **Input** in the ESG-LM stems from Social Impact Investment Taskforce, (2014) and only specifies further what "resources" can be:

> *Inputs* are resources — such as capital, personnel, or physical assets — deployed in service of certain activities.

Inputs are described by the Asset Class as well as the intention of the actors responsible for the desired change. For ESG investments or measures, this intention can be roughly distinguished into either environmental, social, or governing goals (as in ESG). It also takes precedence over the industry or business an actor is a part of.

The intention characterises the interventions that the Initiator has regarding the overarching sustainability goal that the intervention is aimed at. Interventions aiming at climate change mitigation for example, might be *climate-efficient* if they facilitate greenhouse gas (GHG) emission reductions, *climate-friendly* if they replace GHG emissions, or *climate-positive* if they store or remove GHG emissions. Intentions that are not linked to interactions with the physical systems involved, can constitute a risk of sustainability washing, but do not have to be.

The following, non-comprehensive list of intentions is tailored towards the environmental objectives of the EU taxonomy. It is based on Article 10 to Article 15 of the EUT.

Table 2-2: potential intentions in the ESG-LM in line with the EUT

Environmental objective in taxonomy	**Possible purposes**
Climate change mitigation (Article 10)	climate-efficient | climate-friendly | climate-positive
Climate change adaptation (Article 11)	climate-resilient | climate-impact-reducing | climate-risk-reducing

Environmental objective in taxonomy	**Possible purposes**
Sustainable use and protection of water and marine reSources (Article 12)	water-efficient | water-protective | water-restorative
Transition to a circular economy (Article 13)	waste-preventive | waste-reductive | circularity-inducing
Pollution prevention and control (Article 14)	pollution-preventive | pollution-reducing | pollution-restorative
Protection and restoration of biodiversity and ecosystems (Article 15)	nature-conserving | nature-protecting | nature-enhancing

Source: own development

Intentions can also be divided into two types of Contribution: *own contribution* (the induced effect achieves a contribution on its own) and *enabling* (the induced effect enables additional actors to contribute to goals). Enabling activities are explicitly covered by Article 16 of the EUT.

2.1.3.2 Activities

My definition for **Activities** is based on Social Impact Investment Taskforce, (2014), but specified for Main Actors:

> *Activities* are tasks performed by Main Actors in support of specific objectives.

Activities can also be described as CM, as defined by Carman, (2010) in Corlet Walker et al., (2018): "The activities [...] that facilitate the transformation of the system inputs into outputs" (Corlet Walker et al., 2018, p. 6). They are described in the ESG-LM by the Input (as a derivate of Asset Class and Intention), the purpose of the Activity, and an additional attribute that specifies the affected objects. These physical objects are the part of the systems that contributes to Outputs (Main Actor of the Contribution).

Purposes are placeholders for earmarking but can be anything that actors do to contribute to outcomes (such as "purchasing", "producing", or "operating"). Purposes can also be used as means for Attribution, as they are linked to the actions of different Actors contributing to Outputs.

Activities in the ESG-LM are also attached to the interaction with real-world objects that are assumed to be the CM for the outcome pathway. They consist of a descriptive noun specifying the physical system and a verb specifying the physical activity. The definition of such objects should be as precise as possible because this description can already imply some of the impact of the intervention on the system[13]. For example, "purchasing battery-electric cars" allows for a more robust impact claim than "purchasing low-emission vehicles".

[13] See Ylikoski & Kuorikoski, (2010) for a discussion on how *Precision* in this sense affects the *Explanatory Power* of a theory.

2.1.3.3 Outputs

My definition of Outputs is adapted from its description in widely used impact value chain methodologies (Social Impact Investment Taskforce, 2014):

> *Outputs* are tangible desired results from Activities by the Main Actor.

They describe the minimum changes to the directly affected systems by the Main Actor. Outputs can refer to quantifiable values (such as the reduction of energy demand) but can also be limited to qualitative attributes that describe the achievements (such as energy standards for buildings). Outputs as entities in the ESG-LM are part of the causal hypothesis because they are the direct effects caused by Inputs and triggered (facilitated) by Activities. They are, at the same time, also understood as causes themselves that lead to societal changes further down the outcome pathway.

It is sometimes difficult to distinguish Outputs from output-metrics or output-indicators, which is why I define **Output-Indicators** separately by borrowing from Carman, (2010) and Wholey et al., (2010) in Corlet Walker et al., (2018):

> *Output-Indicators* are measures, estimations, or evidence of what has been produced or delivered by Activities.

I recommend expressing Outputs in the ESG-LM as adjective dependent clauses connected to the described activity. Examples of such changes are systems *that increase* or *that decrease* parameters or *that achieve* certain standards.

2.1.4 Outcome entities

The second part of an outcome pathway are Outputs as causes that trigger a CM on the societal level (Intermediate Outcomes) which then results in a persistent desired change of the system (Long-Term Outcome). These changes represent the actualised effects that contribute to the achievement of overarching sustainability goals (Impacts). The following sections describe each of these outcome entities.

2.1.4.1 Intermediate Outcomes

Outcomes are changes to organisations or groups that follow from the delivery of the Outputs in a ToC. Although some Outputs can lead to persistent, long-term changes in the system on their own, they usually represent one of many necessary or sufficient conditions. For example, reducing the energy costs of low-income households is important when the goal is to mitigate energy-poverty. However, only if these cost reductions are achieved in a such a way that they sufficiently reduce the overall monthly expenses and if this effect persists, can the number of people living in energy-poverty actually be reduced.

ToC literature suggests the term “pre-conditions” for this type of effect (Taplin & Clark, 2012). However, the ESG-LM intends to facilitate data sorting, data gathering, and impact assessments from the perspective of an Initiator. Conditions that are triggered by Outputs and which then deliver a CM towards a desired effect are thus a part of the intended outcome pathway towards impact generation.

Intermediate Outcomes therefore relate to any kind of system changes that are a direct and likely result from realising the intended Outputs. They can be measurable (e.g., GHG savings compared to the status quo), but also be qualitative and verifiable (e.g., scientific studies that corroborate the fact that the same outputs lead to positive outcomes in other cases). I define Intermediate Outcomes as follows:

> *Intermediate Outcomes* are direct and desired changes for individuals, groups, or regions that follow from the successful delivery of Outputs.

2.1.4.2 Long-Term Outcomes

Long-Term Outcomes represent continuous or persistent improvements for larger communities or regions. They cannot usually be traced back to the original intervention and its outputs alone but require several conditions to be met in order to be successful. A Long-Term Outcome can be defined as follows:

> *Long-Term Outcomes* are persistent desired changes on groups or regions that contribute to overarching goals.

Successful Long-Term Outcomes can be a blueprint for achieving national or even global sustainability goals. This is why, in the PoC (see Chapter 2.5), they are aligned with the *targets* that constitute each of the 17 SDG goals of Agenda 2030.

However, not all targets in the SDGs (or targets related to the EU environmental objectives used by the taxonomy) can be influenced by company or NGO interventions. In addition, many targets refer to societies or nations as a whole in opposition to progress on a smaller scale. The following table shows some examples of such Long-Term Outcomes that can be applied in the model.

Table 2-3: examples of Long-Term Outcomes in the logic model

SDG	Examples of Agenda 2030 targets as Outcomes
1 No Poverty	1.2 reduce proportion of people that are poor by national standards 1.4 equal rights to economic resources and access to basic services 1.5 reduce exposure to economic, social, and environmental shocks
4 Quality Education	4.2 ensuring access to early childhood development and care 4.3 equal access to affordable tertiary education 4.5 eliminate gender disparities in education
8 Decent Work & Economic Growth	8.4 improve resource efficiency in consumption and production 8.5 productive employment and decent work for all 8.6 reduce proportion of youth not in employment or education

Source: own development

2.1.4.3 Impacts

Impacts describe the overarching goals of an ESG-LM. They can be self-defined or refer to existing frameworks by policy makers. Although they can be purely normative (No Poverty), impacts in the ESG-LM usually refer to quantifiable targets that can be achieved over time (e.g., achieving GHG emission reductions until a given year). Any overarching sustainability goal on the societal level is eligible as an impact for an ESG-LM, if Long-Term Outcomes can be identified that directly contribute to their achievement. Ideally, such a contribution is well-established in literature.

I define **Impacts** in line with Corlet Walker et al., (2018):

> "*Impacts* are the ultimate, societal level changes that occur as a result of the sum of the processes that happen within the system" (Corlet Walker et al., 2018, p. 6, emphasis mine).

2.1.5 Target conflict entities

A ToC organises and explains positive change in societies (the *how* and *why* of impact evaluation according to Stern et al., (2012)). As such and in opposition to other causal logics (such as CDs by Pearl, (2009)), it is not intended to reveal all possible interactions and unintended side-effects. Instead, so-called pre-conditions outside of the organisation are defined that facilitate or enable the change in the first place. Nonetheless, there are examples in which the applicants of a ToC or variations of the basic method include information on potential negative consequences (such as *negative programme theory* by Funnell & Rogers, (2011)).

Sustainable financing instruments such as Green Bonds and sustainable development policy frameworks such as action plans by the EU Commission seldom address negative trade-offs explicitly. They are, depending on the type of framework,

- not addressed at all,
- excluded by underlying regulations and premises,
- or excluded by some form of (what I call) method of conjunction: results need to adhere to more than one criterion at once (e.g., affordable **and** sustainable housing).

A remarkable exception to that practice is the EUT. The affected organisations need to demonstrate not only a substantial contribution to one of the objectives, but they also need to show that none of the other targets or the societal safeguards are compromised. This can entail a reference to already existing regulations or other action plans, but it can also include explicit statements on additional quantitative or qualitative minimal requirements.

The ESG-LM handles negative effects in a similar manner. Two types of target conflict entities are distinguished: Hazards and Rebounds. Hazards indicate the risk of weaker or reduced outputs und thus represent non-realised or diminished effects of the causal hypothesis on the intervention side of the outcome pathway. Rebounds[14] indicate the risk of strongly reduced or even overcompensated outcomes in the system and represent non-realised or diminished effects on the impact side of the outcome pathway. Both entities are only considered potentials with Rebounds representing the more serious but also more manageable problem. It's up to the applicator of the model to identify these target conflicts and to decide what probability and damage thresholds should be considered here. It is a heuristic process that can, but does not have to be, accompanied by additional risk assessments or other methods of evaluation (for example via Bayesian Updating during the *ex post* evaluation of interventions such as that suggested by Befani & Mayne, (2014)). The identification and handling of specific target conflicts is therefore part of impact assessment on a case-by-case basis.

However, some Hazards and Rebounds can already be identified when looking at the logic of the entire system that surrounds the explicated outcome pathways in the ESG-LM. In fact, any explicit or implicit CM described has the risk of not being achieved or simply ascribing a causal process where there is none. Moreover, target conflicts can also be the result of negative trade-offs between Activities, Outputs, and Outcomes by the same actor or between Outputs and Outcomes of different actors in the system.

These risks are intended to be minimised with the methodology described here in the study (for example by looking at the degree of belief in a specific CM). The careful formulation of a testable hypothesis allows to identify empirical fingerprints that would show if such risks could be realised and the process itself is intended to be iterative in nature. Subsequent versions of the ToC improve the understanding and theorisation of the causal relationships within the model and with the system in such a way that these risks are mitigated.

Nonetheless, both specific and generic target conflicts should be explicated whenever possible. Whereas specific Hazards and Rebounds can only be discussed within the scope of a specific case or set of cases, Generic Hazards and Rebounds can often already be identified from looking at overall framework that is used to align interventions with desired changes. For that purpose, I define **Generic Hazards** and **Generic Rebounds** as follows:

> *Generic Hazards* are risks of reduced Outputs caused by actors with different intentions or competing for the same resources.
>
> *Generic Rebounds* are caused by insufficient or unintended interactions of the system with the explicated outcome pathways in the ESG-LM. They either represent

[14] Rebounds in this dissertation merely represent unintended side-effects. The term is therefore not used to indicate a particular definitition of rebounds found in literature.

(i) risks of partial compensation or overcompensation of desired outcomes or (ii) risks of negative contributions to other overarching goals.

2.1.6 Evaluation and measurement entities

The following sections describe how indicators are qualified and what Rules of Attribution and Additionality might be suitable to allocate contributions among actors.

2.1.6.1 Indicators and indicator attributes

Indicators[15] are the main metrics of any impact assessment. They quantify the contributions and or demonstrate achievements. They can also be further specified regarding their actualisation (actual results versus potential metrics) with actual results being further differentiated regarding their quality and robustness. The following Table 2-4 lists and defines all of these attributes.

Table 2-4: attributes and expressions of indicators in ESG-LMs

Type	Attribute	Expression	Definition
Actual Indicators	Quality	A: optimal	contribution to overarching goal
		B: best-in-class	contribution to persistent societal changes
		C: best-practice	contribution to short-term societal changes
		D: standard	contribution to effects on project level
		E: minimum	alignment with overarching goals
		F: hazard	risks of reduced contributions
		G: rebound	risks of reduced or negated Outcomes
	Robustness	1: very high	direct case-specific results from observational data | monitoring & evaluation | statistics | empirical experiments or evidenced relationships between type 1 data
		2: high	linear relationships of type 1 data with (mean) values from type 1 data from previous cases or entailing the case
		3: medium	linear relationships as in 1 or 2 but requiring additional assumptions
		4: low	estimates (proxies) on the basis of bottom-up models | top-down models | empirical studies in similar cases
		5: very low	results or relationships from third parties in similar cases

[15] The term indicator is sometimes used interchangeably with the term metric, but most disciplines distinguish the two concepts. I use a common definition by the Sustainable Development Solutions Network (SDSN): “An indicator is a meaningful, simple, and quantifiable metric used to assess progress toward meeting a target” (Barredo & SDSN, 2013).

Type	Attribute	Expression	Definition
Potential Indicators	best-needed		highest possible goal certainty an indicator can achieve without being sufficiently measurable itself
	best-available		highest possible goal certainty an indicator can achieve based on data or information that is available

Source: own development

Actualised indicators represent the key results of any impact assessment after an ESG-LM has been developed and found to be plausible. Conversely, **potential indicators** can be identified before investigating the available data, but after the initial ESG-LM has been developed. They represent an *ideal set of metrics* that we would like to have, if either all data is available and complete (best-available) or if such data could be gathered in the future (best-needed). They can be used to evaluate the *Measurability* of the ESG-LM as a whole (see Section 2.3.3) and to compare the actual set of indicators with their potential counterparts. Such a comparison conveys to the reader how the actual assessment fares against an ideal model, but can also be used to identify future data needs or to outline future methodological solutions.

For actualised indicators, their **quality** describes the degree to which they measure or estimate contributions — if the underlying causal inferences are reliable (assessed during the epistemic justification). An indicator that measures the causal link between Long-Term Outcomes and Impacts is *optimal*, as it measures *a contribution to the overarching goal*. I assign the letter A to it in line with the categorisation of energy efficiency classes of products in Europe that many readers might be familiar with. Indicators that measure the causal link between short-term societal benefits (Intermediate Outcomes) and desired outcomes (Long-Term Outcomes) are consequentially awarded the quality B. If such an indicator is found, it can be considered a *best-in-class* indicator as it constitutes a *contribution to persistent societal changes*. Indicators that provide evidence for a causal connection between interventions and their surrounding systems (link between Outputs and Outcomes) show a *contribution to short-term societal changes*. They are assigned with quality C and can be considered *best-practice* indicators. Indicators between Activities and Outputs merely indicate *a contribution to desired effects on the project level*. They conform to a *standard* indicator and are assigned the letter D. Consequently, indicators pointing to these Activities are no measurement of a substantial contribution at all. However, they provide at least evidence that the intervention is *aligned with a specific overarching goal*. This is considered a *minimum* requirement for any assessment and is assigned the letter E. Hazards (F) and Rebounds (G) are usually not quantified, although they sometimes can be described by probability functions. They point the assessor, or any third party, to the most important target conflicts in the outcome pathway. Ideally, such risks are ruled out by avoiding them during ESG-LM development. If this is not possible due to a lack of knowledge, methodology, or data, Hazards can be considered *risks of reduced contributions* and Rebounds *risks of reduced or negated Outcomes*.

Regarding the **robustness** of results, it is not possible to display uncertainties in a quantified manner across all possible types of impact reporting methodologies. However, even if users of an ESG-LM apply methods of uncertainty assessments (which I encourage), such information would be less useful to third parties than a standardised set of robustness levels that enables comparisons between different types of indicator values, outcome pathways, or ESG-LMs. Such a categorisation is shown in Table 2-4 and graded in five levels.

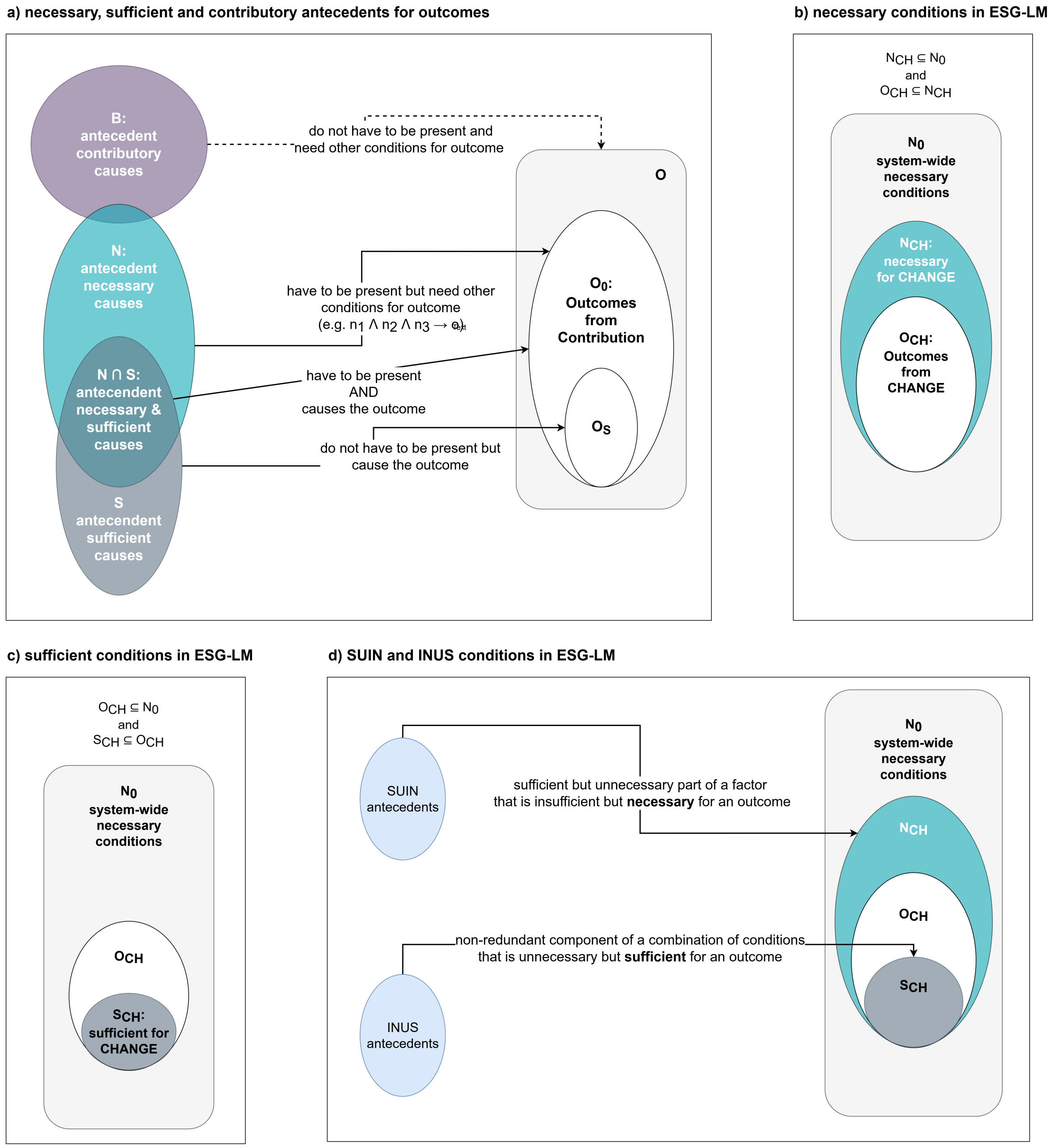
Both indicator quality and indicator robustness tend to be lower for Long-Term and Intermediate Outcomes. It is less likely that potential high quality indicators can be actualised, given the complexity of the relationships and the additional data required. It is also less likely that such indicators have a high robustness, since modelling and additional assumptions are usually needed to quantify them. On the other hand, indicators at the beginning of the outcome pathways are often easier to measure and their quantification requires fewer assumptions and less data from secondary sources (improving the robustness of such metrics).

2.1.6.2 Contribution and Attribution

The ESG-LM is based on a ToC and as such provides case-based causal explanations for projects and measures that are assessed with it. I discuss in this section how this affects questions of Contribution and Attribution (the "Rules of Attribution" are discussed in Chapter 4.2).

For that, I am interested in whether causal claims by ESG-LMs are plausible and aligned with the implicit theories of stakeholders. If that is the case, any identified actor in the ESG-LM contributes to its Outcomes with a certain level of Attribution. A common solution to such causal propositions (e.g., "if P than Q") is the consideration of different types of causes for an outcome, based on logical conditions and set theory (see Mahoney & Barrenechea, (2019)). Although these causes are logical conditions for causal explanations and not means for falsification, they are useful to broadly describe different types of such explanations. I distinguish five types of causal configurations that precede the outcomes described in the ToC for an ESG-LM: necessary causes, sufficient causes, SUIN conditions, INUS conditions, and contributory causes. Their relationship in the context of a causal proposition (with antecedent causes leading to consequent outcomes) is displayed in the following Venn diagrams (Figure 2-2).

Figure 2-2: set and subsets of plausible causal explanations in ESG-LMs



Source: own development

This set-theoretic display can be read as follows. Figure a) shows the general principle of causation as defined in this study. For each Outcome O_o from a Contribution, a set of conditions must be true. Some conditions must be present but do not necessarily cause the Outcome on their own (antecedent necessary *events* in a probability space). Some conditions do not have to be present but sufficiently cause the Outcome on their own if they are (antecedent sufficient events that coincide with outcome events). And some conditions can be present but are neither necessary nor sufficient. These contributory causes can coincide with necessary ones but never with sufficient conditions.

Figure b) describes necessary conditions within the ESG-LM. Causal sets are necessary for change (N_{CH}) if, all other things being equal (N_0), they are a superset of the desired outcomes from that change ($O_{CH} \subseteq N_{CH}$). Figure c) describes sufficient causal sets with the ESG-LM. Causes are sufficient for change (S_{CH}) if, all other things being equal (N_0), some portion of desired outcomes from that change are a superset of these causes ($S_{CH} \subseteq O_{CH}$). However, such clear sufficient or necessary causes are seldom observed in reality, even if the surrounding system is assumed to be fixed (all other things being equal). This is why two additional types of causal sets are introduced that represent *partial necessity* or *partial sufficiency*: SUIN and INUS conditions.

Figure d) describes SUIN and INUS conditions in the context of the ESG-LM. Both conditions refer to factors that are outside of the direct causal link, as they are non-redundant antecedents of other causal conditions. SUIN sets are a "sufficient but unnecessary part of a factor that is insufficient but necessary" for the desired change. They contribute to necessary causes. For example, planting crops as a source of bioenergy is neither necessary nor sufficient for electricity production from biogas, but it is a sufficient antecedent to a set of necessary conditions for this desired outcome.

INUS sets are complementary to SUIN as they are a "insufficient but necessary part of a factor that is unnecessary but sufficient" for the desired change. They enable additional sufficient causes. For example, developing carbon air-capture technologies is neither necessary nor sufficient for carbon removal but it is a necessary antecedent to a set of sufficient conditions for negative carbon emissions.

Based on these sets, **Contribution** in the ESG-LM can be defined as follows:

> Actors in the ESG-LM (Main Actors, Other Actors, Initiators) *contribute* to desired changes (Outputs, Intermediate Outcomes, Long-Term Outcomes, Impacts) if, all other things being equal, their actions are either necessary, partial necessary, sufficient, or partially sufficient for this change.

Attribution on the other hand is any kind of measurable Contribution that can be traced back either fully or partially to Inputs by specific actors. The concept of Attribution is closely related to the *ceiling of accountability* in a ToC since Attributions can only be shown for some part of the outcome pathway. The Main Actor usually has operational control of the Activity in an ESG-LM and is therefore responsible for the Output. The societal success cannot be ensured though, which translates into an Attribution between 0% and 100% up to these Outputs but (usually) no Attribution beyond this point.

Accordingly, I define **Attribution** in relation to Initiators for ESG-LM outcome pathways:

> Initiators in the ESG-LM *attribute* to specific desired changes if their contribution up to this point is at least partially necessary or sufficient for Outputs. The degree to which Attribution is ascertained is described by the ratio (%) of an actor's financial commitment compared to the overall investments necessary for the desired effect.

This limitation to Attributions from Financing is in line with objectives of this dissertation. It excludes other forms of Attributions, but only in regard to the estimation of its degree. For example, someone who advised the Main Actor on the most effective manner in which the effect can be achieved, certainly attributed to desired changes. Such Attributions are not assessed in a quantitative manner though.

2.1.6.3 Additionality of Financing

The term Additionality is often discussed for carbon offsetting methods but is also named as an important principle of the European Structural and Investment Fund. In both cases, Additionality refers to interventions that result in surplus benefits for the public compared to a baseline (see also Swift, (2002) in Gillenwater, (2012)). In other words, additional impacts would not have occurred without the original intervention. There is also a subset of additional effects that would not have occurred at all without an intervention. For example, a freshly formed company might need capital investments to start its operations in the first place. In this case, the additional effect might relate to the entirety of the operation, even if venture capital only covers portions of the total investment costs. Both options can thus be also described by a counterfactual world, in which the non-actualisation of certain causes would have led to different outcomes (as described by Lewis, (1973) and others). By contrast, one can refer to "dead weight" (Boiardi, 2020), if the outcome could be achieved regardless of the input. And there is a fourth option of actors being necessary, but not sufficient to induce change (such as a loan at standard market conditions that could have been provided by any financial institution). One way to identify these different options of additionality is by imagining a many-worlds interpretation of sustainable investment and financing (see Teubler, (2023)).

I use as set-theoretic logic of counterfactuals (Mahoney & Barrenechea, 2019) to categorise and define different types of Additionality for Financing. For now, I am only discussing what types of Additionalities are considered in this study. Chapter 4 will then present Rules of Additionality for the purpose of measurement.

I start by defining the general base-case of **attributable Financing** as follows:

> (1) Let N be a set of necessary causes for an outcome[16] from contribution O in the ESG-LM such that $O_{CH} \subseteq N_{CH}$. (2) Let F_{att} and N_0 be exhaustive subsets of N_{CH} and O_{att} be a subset of O_{CH} so that $O_{att} \subseteq F_{att}$. Then the general base-case for *attributable Financing* is defined as: “The non-presence (¬) of attributed Financing is sufficient for the non-presence of attributed outcomes”
> ($F_{att} \wedge N_0 = O_{att}$ and $\neg O_{att} = \neg F_{att} \vee \neg N_0$).

This definition entails that there are actions by financial actors that are not necessary for the outcomes. I call this set **deadweight ESG Financing** F_D with $f_D \notin N_{CH}$. It is defined as being not necessary for the outcome, and thus not sufficient for an Attribution, such that

> “The presence or non-presence of *deadweight Financing* is irrelevant for attributed Outcomes” ($F_D \vee \neg F_D = O_{att}$ but $N_{CH} = O_{CH}$).

Out of the necessary actions by financial actors, there are some that are consequential for certain outcomes to be realised at all (O_C), and some that lead to additional outcomes (O_+). An example of the first case is the provision of venture capital that is required for the market breakthrough of a sustainable innovation. I call this set *consequential Financing* F_C. An example of the second case is a promotional loan with an interest rate well below the standard market conditions that reduces capital costs and enables others to do more than they would be able to achieve otherwise. I call this set *favourable Financing* F_+.

The mere presence of F_C or F_+ is not sufficient for Additionality in either case. Funds might have been available regardless and capital costs savings do not have to be used for additional investments. Additional causal conditions therefore need to be considered. I employ the method of forward projection for that (Mahoney & Barrenechea, 2019, p. 24). This method compares a chains of causal sets in the actual world with their counterfactual counterparts. It is based on the idea that necessary antecedents are sufficient for a non-actualisation in a counterfactual world. If P is necessary for Q so that $Q \subseteq P$, then not-P (¬P) is sufficient for not-Q (¬Q). This holds true even if P is but a subset of SUIN conditions, that is, a condition that is a “sufficient but unnecessary part of a factor that is insufficient but necessary for an outcome” (Mahoney & Barrenechea, 2019, p. 6).

I first look at the end of the outcome pathway, where (ESG) measures are either implemented or not. The following Figure 2-3 shows a set-theoretic display for such consequential outcomes from implementing measures. Here, the negation of implementing measures also negates consequential outcomes.

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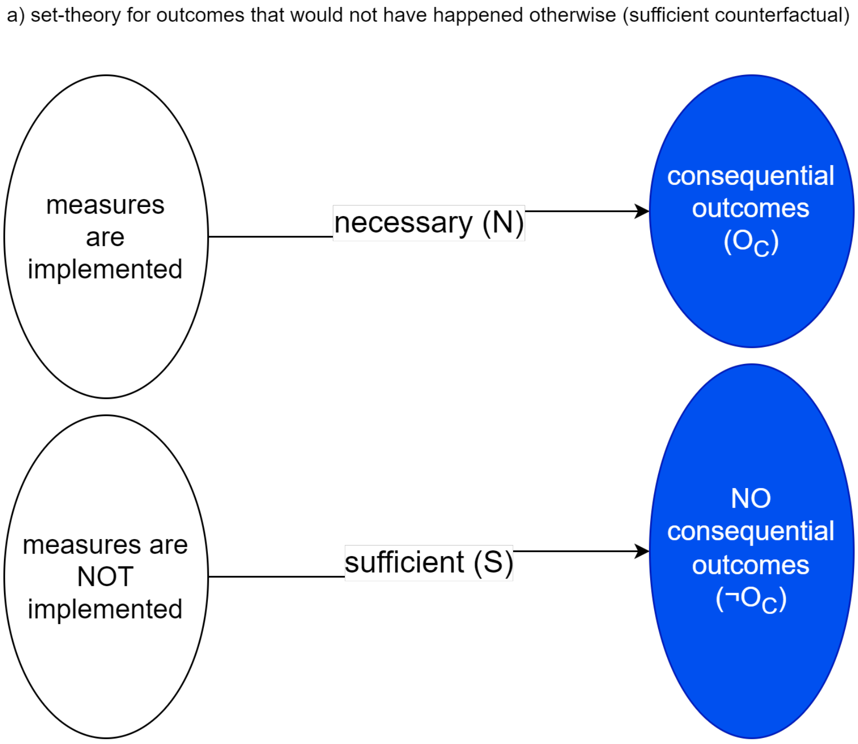
[16] As indicated in Chapter 1.4, this non-capitalisation of the term indicates that it is not restricted to the use in the ESG-LM but can relate to all types of effects.

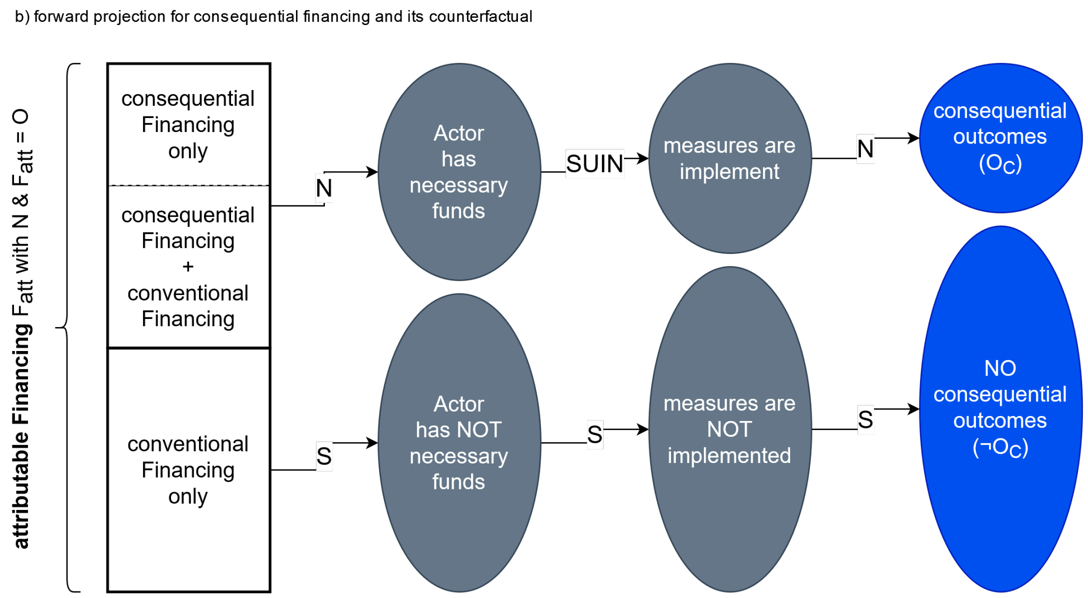
Figure 2-3: set-theoretic display of consequential Outcomes



Source: own development

Therefore, a case for consequential Financing would be any type of capital provision whose absence would have caused the measures not to be implemented. This is shown in the following Figure 2-4 as a forward projection. The overall size of each set indicates its likelihood in a probability space, whereas the differences in size between antecedents and descendants indicate either necessity or sufficiency (see also previous section).

Figure 2-4: set-theoretic display of a forward projection for consequential Financing



Source: own development

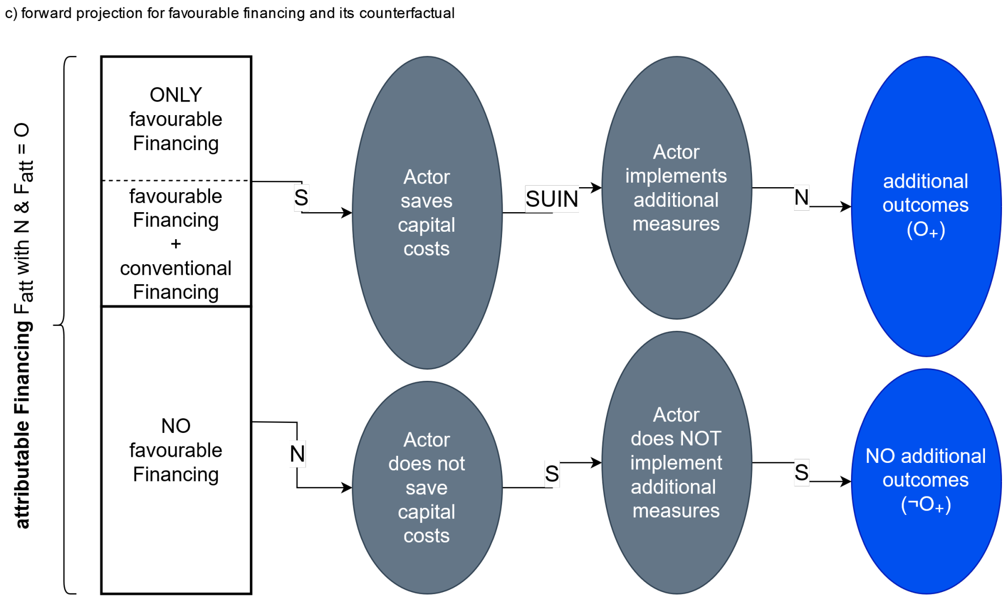
The realisation in the actual world (upper causal chain) is often difficult to proof for certain, since the availability of funds is insufficient by itself to implement the measures and only necessary in conjunction with other factors (SUIN condition). It is not distinguishable from other types of conventional financing, if measures have already been implemented. However, it does show that the absence of venture capital or grants leads to the prevention of some portion of outcomes. This can be reasoned with the following argument from set theory:

1) There are cases in which non-equity capital is required to achieve desired outcomes ($F_{att} \wedge N = O$; as described before for attributable Financing F_{att}).
2) In some of these cases, conventional financing (F_0) such as loans are not approved or do not cover the size of the necessary investments ($\neg F_0 = \neg O_c$ with $F_{att} = F_0 \vee F_c$).
3) Out of the set of cases in which conventional financing is not approved or does not cover the size of the investments,
   a) some actors will receive grants or venture capital (F_c) and implement measures for desired outcomes ($N \wedge (\neg F_0 \vee F_0) \wedge F_c = O_c$),
   b) and some actors will not receive grants or venture capital and cannot implement measures for desired outcomes as a consequence ($\neg F_c = \neg O_c$).
4) Then it follows from 1) to 3) that the presence of grants or venture capital (F_c) increases the number of overall cases with outcomes that would not have been achieved otherwhise.

This argument covers only a fraction of all possible consequential outcomes, since there are possible cases in which the absence of any type of Financing denied potential outcomes. However, the forward projection showed that the absence or presence of conventional Financing is not a likelihood raiser for Additionality, whereas the presence of consequential Financing is.

The forward projection for favourable Financing looks different (see Figure 2-5), because the likely capital savings can, but do not have to lead to additional measures and thus outcomes. However, it shows that the presence of such favourable financing conditions is sufficient for capital cost savings. Out of all possible cases in which capital cost savings led to additional effects, some cases were a consequence of favourable Financing (likelihood raiser), whereas the presence or absence of conventional conditions was inconsequential for Additionality.

Figure 2-5: set-theoretic display of a forward projection for favourable Financing



Source: own development

Neither of the two cases provided conclusive evidence for Additionality from knowledge about the financing conditions alone. It did show however, that at least a portion of total sustainable capital provided must have either made outcomes possible in the first place (**consequential Financing**) or led to additional outcomes (**favourable Financing**). This allows me to define both cases as follows:

(1) *Consequential Financing* is the provision of private equity or grants for ESG measures or projects. Doing so makes it more likely that desired sustainable outcomes occurred that would not have occurred otherwise.

(2) *Favourable Financing* is the provision of capital for ESG measures or projects at conditions that lower the capital costs for the borrower. Doing so makes it more likely that additional desired outcomes occur.

2.2 Heuristics for ToC development

The development of a ToC is seldom grounded in an already established theory. This is even more so the case for impact assessments in the SF market because such assessments are usually not conducted by agents with expertise in social theories or environmental risk assessments. Whereas this study intends to show how the credibility of its claims can be assessed using BR (see Chapter 5), a developer of a ToC might need guidance in coming up with the necessary outcome pathways in the first place.

I suggest three heuristic tools that can help with this endeavour based on the following methods: Inference to the best Explanation (IBE) and PrT. Heuristics are usually understood to be mental short-cuts for explanations and hypotheses. They are particular useful for quick decision-making or if the available information is insufficient to make a more reliable inference. The following sections introduce each guide. All three heuristics also facilitate indicator selection and epistemic justification in later stages of an impact assessment, because they are consistent with Bayesian Epistemology.

2.2.1 IBE for comparing working hypotheses

Heuristic IBE (Inference-to-the-Best-Explanation) is an abductive process by which an agent chooses the hypothesis or explanation the fits the data the best. Criteria for this fitness can be (among others) *explanatory power* and *antecedent plausibility*. The first selection criterion favours explanations that explain more facts and the second criterion favours explanations that one already finds plausible. Although abductive reasoning from IBE can lead to errors, it is usually considered an effective process to compare different working hypotheses and then focus on the most promising working hypotheses.

I suggest, in accordance with Dellsén, (2018), that IBE heuristics are compatible with BR in that they provide good guidance on how to assess the comparative probability of hypotheses. This process is of course not bullet-proof, and it usually does not provide agents with absolute credences (as provided by BR). However, finding the hypothesis that best fits IBE heuristics (*leads the ranking* so to speak), is a good starting point for collecting further data and evidence.

The logic behind can be summarised as follows. Let's assume that given the background knowledge b of an actor and some evidence E, there are two non-exhaustive hypotheses H_a and H_b providing competing explanations. Then there are two ways in which we can rank the hypotheses to each other:

I. **Antecedent Plausibility**:
If the prior probability P of explanation H_a is considered to be clearly higher than H_b from the outset given our background knowledge b ($P(H_a|b) >> P(H_b|b)$), then, all other things being equal, H_a is antecedently more plausible than H_b.

II. **Explanatory Power**:
Given our background knowledge b, if the available evidence E is clearly more expected on H_b then on H_a ($P(E|H_b.b) >> P(E|H_a.b)$), then, all other things being equal, H_b explains more evidence than H_a.

Although this heuristic does not consider all possible explanations (and can thus neglect an even better explanation) and although it does not always lead to a clear ranking (consider both I and II being true at the same time), it will guide actors in most cases to a preferred option. I thus operationalise this approach for ToC development with the following six steps in Figure 2-6.

Figure 2-6: guide to IBE heuristic

Step	Instructions	*Example*
1 Formulate the Research Question	Consider the intervention to be assessed and the overarching goal this intervention is supposed to be aligned to. Now formulate a question that asks how the intervention contributes to this goal.	*How does the modernisation of Hospitals contribute to"Good Health & Well-being?*
2 Check for primary Data	Consider the available data from the Initiator. Is there evidence that is relevant to this question?	*Loan data indicates an expansion of and new equipment for intensive-care.*
3 Find two or more explanations	Assuming that the contribution is true, imagine how this change could come about. Sketch out at least two explanations in form of a narrative.	*(a) Hospital modernisations reduce hospital costs and thus costs of healthcare for patients.* *(b) Hospital modernisations result in better equipment and thus better health-care.* *(c) Hospital modernisations increase the number of beds and thus lead to better health-care.*
4 Assess Explanatory Power	Consider your explanations in light of the evidence. Which one of your explanations explains the evidence the best and/or the worst. If you can, rank your explanations accordingly.	(b) >> (a) AND (c) >> (a) AND (b) ≈ (c)
5 Assess Antecedent Plausibility	Now consider what you general know about the effects of your intervention. Do you find that one, or more, explanations are more likely – that is, are more frequent or more often observed?	(c) >> (b) AND (b) >> (a)
6 Find the best explanation	Given your ranking, which one of the hypotheses would you rank first? If you are unsure, pick the explanation that seems a bit more plausible (or pick randomly) and formulate the outcome-pathway but keep other competing explanations in mind for later on. You can also repeat the process for each pair of explanations.	*Inference to the best explanation:* *(c) Hospital modernisations increase the number of beds and thus lead to better health-care.*

Source: own development

2.2.2 Heuristic PrT of CMs

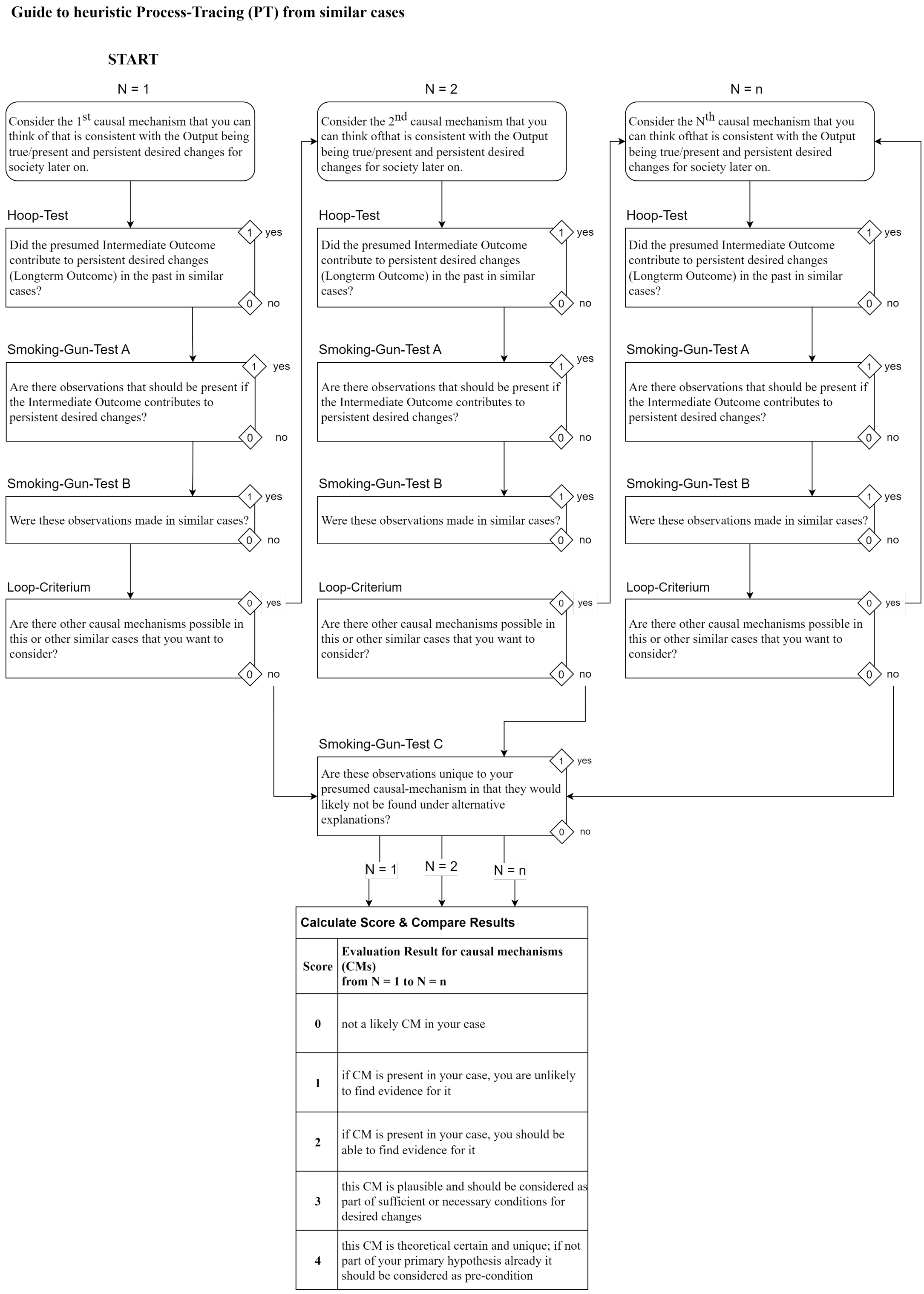
The neuralgic points of a ToC are those parts where the actual causal mechanisms need to be sketched out: Activities and Intermediate Outcomes. Activities explicate the tasks of important actors shortly after the initial intervention for the realisation of Outputs. Intermediate Outcome are the means by which these Outputs multiply and interact with the system towards perpetuated desired changes. CMs are heterogeneous, because different CMs can exist at the same time or work separately towards the same effects. It is thus sometimes difficult to hypothesise which mechanism is actualised and causally linked to the outcome pathways in a ToC.

I suggest using methods of PrT (Process-Tracing) to approach this issue. PrT is an evaluation strategy from the social sciences that is intended to provide evidence for CMs in case studies or to better understand the limits of already explicated theories. It can be used as tool for causal inferences but also for theory-building, which is what the user of the ESG-LM is doing abductively when developing a ToC. Beach & Pedersen, (2019) investigate the role of "mechanistic evidence" in qualitative social research and Befani & Mayne, (2014) adapted PrT as a tool for evaluation in ToCs. I draw on the concepts of these authors to develop a heuristic for CM explanations. I distinguish two applications: PrT heuristics from similar cases and PrT heuristics from specific evidence.

2.2.2.1 PrT heuristics for similar cases

Users of the ESG-LM usually have no expertise for evaluating effects of their specific interventions on the societal level or the means to commission empirical studies to that end. It is also very unlikely that primary data is available that attests to these claims. However, it is likely that some forms of Intermediate Outcomes towards overarching goals have been investigated in the past by scholars or organisations and that their insights can be applied heuristically to the ToC that the user of the ESG-LM currently develops. I formulate the following guiding questions in Figure 2-7 that allow the analyst to compare competing causal mechanisms on the societal level. It can be based on the background knowledge of the analyst and backed-up by desk research. Whereas the guide here is tailored towards finding plausible Intermediate Outcomes in a ToC for the ESG-LM, it can also be used to investigate other CMs (such as Activities).

Figure 2-7: guide to heuristic PrT from similar cases



Source: own development

2.2.2.2 PrT heuristics from evidence in specific cases

The second PrT heuristic can be applied when relevant information is available that attests to at least some of cases in the set of cases the impact assessment is investigating. This usually applies to the first part of the outcome pathway where the intervention is known, tangible targets are measured, and Activities are often traced to some extent. I use the concepts of CPOs as well as Theoretical Certainty and Empirical Uniqueness (Beach & Pedersen, 2019) to develop a set of guiding questions for theory-building of Activities as CMs. These concepts, as well the resulting process steps in Figure 2-8, are grounded in Bayesian Epistemology and thus directly facilitate epistemic justification of causal claims later on. The example also shows what type of empirical fingerprints one expects to find and which of these fingerprints are unique to a particular CM (here: hiring of new nurses and doctors towards the end of the process).

Figure 2-8: guide to heuristic PrT from evidence

START

Define the Intervention

1a) What is your Input (intention, asset class)?
1b) What is your **desired** Output (tangible effects)?

Collect Data

2a) What are the observables in your case?
2b) When did the observables occur in the time-line?
2c) Which observables occured after the intervention was implemented but before tangible results are achieved?

Qualify Data

3a) Who or what caused the observables between Inputs and Outputs?
3b) How reliable are these observations?
3c) Which of these observations were surprising (Sur)?

Postulate Causal Mechanisms (CMs)

4a) Which tasks performed match (some of) the observables from 2a) to 3c)?
4b) Which actors perform these tasks?
4c) Can you describe one or more Activities that match some or even all of the observations?

Ranking of Theoretical Certainty (tc)

5) Rank the Activities by prioritising CMs that concur with the observations that are expected to be found.
5a) How many and which likely observables can be matched with your "best" explanation?
5b) How many and which likely observables can be matched with your "second-best" explanation?
5c) to 5z) Repeat process with additional Activities if there are any

Ranking of Empirical Uniqueness (eu)

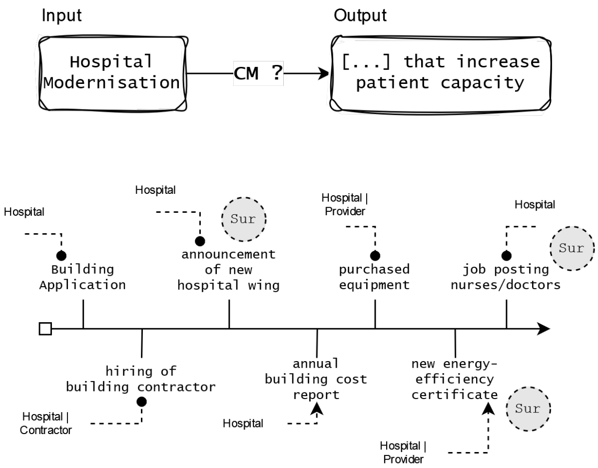
6) Rank the Activities by prioritising Observations that could be matched to at least one but as few as possible Activities
6a) Which observations could only be matched to 1 Activity? Assign the highest eu to these Activities.
6b) Which observations could only be matched to 2 Activiies? Assign the second-highest eu to these Activities.
6b) to 6z) Repeat process with 3:1, 4:1,...;n:1 observations matched to Activities.

Scoring and Evaluation

7a) Assign Score 0 to Activities with the lowest tc (bottom of table), Score 1 with the second-lowest tc,..., Score n with the highest tc
7b) Assign Score 0 to Activities with the most "shared" observations (bottom of table), Score 1 with the second-most "shared" observations, Score n with the least amount of "shared" observations
7c) Prioritise CMs that scored the highest in both assessments combined

STOP

Example



- CM-1: The Hospital constructs a new energy-efficient building to save energy-costs per patient.
- CM-2: The Hospital constructs a new wing to increase the number of beds.
- CM-3: The Hospital constructs a new building to replace an out-dated wing in the long-run.

Rank	Suggested Causal-Mechanism (CM)	No of observations
1	CM-2: building construction for additional beds	6
2	CM-1: building construction for lower energy-costs per patient	5
3	CM-3: building construction for hospital-wing replacement	4

Rank	Observation	CMs	Rank	Observation	No of CMs
1	job posting nurses/doctors	CM-2	2	purchased equipment	CM-2 CM-3
2	new ee-certificate	CM-1 CM-2	3	hiring building-contractor	all
2	announcement new wing	CM-1 CM-2	3	building application	all

Suggested Causal-Mechanism (CM)	tc	eu	Total Score
CM-2: building construction for additional beds	2	2	4
CM-1: building construction for lower energy-costs per patient	1	0	1
CM-3: building construction for hospital-wing replacement	0	1	1

Source: own development

2.3 Criteria-based evaluation of ESG-LM

The purpose of defining evaluation criteria for the ESG-LM is to align its desired application as closely as possible to the features it needs to provide for its users. These users are divided into two groups that often work closely together in a co-dependent relationship: the Initiator (financing or implementing measures) and the analysts or contractors (conducting the impact assessment).

In my opinion, the needs and interests of Initiators and assessors coincide in three areas that can be translated into the following attributes along two types of criteria:

(1) Criteria for the Adequacy of the ESG-LM
  a. Goal Certainty
(2) Criteria for the quality of the EST-LM
  a. Sufficiency
  b. Measurability

The attributes defined can be used to evaluate any ESG-LM. The following sections discuss the source and reasoning for the selection of these attributes as well as a scaling for what contributes a good performance of the ESG-LM for each attribute. All three attributes assess partly, but not exclusively, the *Explanatory Power* of any ESG-LM.

2.3.1 Goal Certainty

Measuring sustainable impacts can be described as the compartmentalisation of a desired societal or environmental change into smaller changes within ever smaller parts of the society. Deciding whether any factors contributed at all or are going to contribute to future effects can be achieved with the help of scientific tools (e.g., empirical studies). Even common sense might suffice in some cases. A Main Actor that aims to achieve an overarching sustainability goal by financing or implementing a certain measure prospectively, usually applies common sense or intuition. However, there is need for a high degree of certainty that their input contributes to that goal. I use the term *Goal Certainty* for this attribute of the system.

According to a recent report commissioned by the UN finance initiative (Freshfields Bruckhaus Deringer LLP et al., 2021, pp. 35–36), "goal certainty" for an investor relates to three types of targets: a) the overarching sustainability goals or impacts, b) the goals or outcomes on the portfolio level, and c) the specific steps necessary to achieve both goals[17].

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[17] The original source used the term "overarching sustainability outcomes" for a) and "impact goals on the portfolio level" for b). As the terms "Outcomes" and "Impacts" are well defined for the ESG-LM, I decided to translate the three steps accordingly.

The model logic developed here mirrors these goals by connecting preceding entities causally with consequent entities (visualised by arrows). Inputs by the Actors need to be aligned with the related Activities and Outputs. This does not mean that all Inputs and Activities need to be provided by the same actor or that all causal conditions need to be described. However, the Inputs by the Actor need to be part of a set of necessary or sufficient conditions for achieving the Outputs if all other parts of the system function as usual. The same holds true for the connection between the intervention and the surrounding system. All Outputs by the Actor should clearly contribute to at least one of the Outcomes necessary or sufficient for long-term societal changes. I define **Goal Certainty** as follows:

> *Goal Certainty* describes the alignment of interventions by the Actor with the overarching sustainability Impacts as well as the desired Outcomes on a societal level. In a fully aligned model, no Output can be achieved without at least one previous Input and each Outcome needs at least one Output to be realised.

The control question for this criterion aims at the exclusion of non-necessary and non-sufficient contributions. Thus, to achieve adequacy, the ESG-LM only describes either necessary causes or sufficient causes or both. I use the following control question to evaluate this criterion:

Are Inputs, Activities, Outputs, Intermediate Outcomes, and Long-Term Outcomes necessary or sufficient for a contribution to at least one of their descendants in the ESG-LM?

If the answer is yes, then the model is adequate in this regard. If the answer is no, the ESG-LM must be revised in a way that the entities become necessary or sufficient causes or are part of causal configurations that are necessary or sufficient (partially necessary, partially sufficient). This can be achieved for example by lowering the scope of Outcomes (e.g., some but not all houses need to be renovated) or by conditioning the causes (e.g., if and only if residential buildings are renovated).

2.3.2 Sufficiency

Looking at the literature, it is unclear what constitutes contribution in the context of ESG financing and investments. By a very broad definition, all financial actors participating in the SF market are contributors, even if they only hold shares of a company deemed to be sustainable. An argument for that is that they also inherit parts of the risks of these companies. One could also argue that they enable ESG-aligned companies to grow and thus increase their sustainable impact. However, if one takes this position, any involved actor can contribute to the desired goals (such as for example a service provider maintaining the offices of a sustainable company).

On the other hand, there are certainly such actors that are not only contributors in this sense, but whose actions are necessary for the achievement of sustainability goals by means of ESG-aligned interventions. This means that, without their contribution to interventions, the desired outcome cannot be achieved or is achieved to a lesser degree. There are also interventions that lead to these outcomes on their own in that they are sufficient causes or part of a set of causes that are jointly sufficient (INUS) for desired outcomes. A ESG-LM of high quality should identify them so that they can be prioritised. This is tested with help of the criterion of Sufficiency during ESG-LM development.

An inadequate model in this regard includes interventions that are not needed at all for the desired change (contributory but not necessary causes). Although interventions can still be linked to impacts in such a model, not acting could lead to similar results, or other interventions would cause the same service for society. I therefore define the criterion of **Sufficiency** as follows:

> Sufficiency describes the degree to which interventions in the ESG-LM are sufficient causes for Outcomes in the first place or sufficiently lead to additional desired Outcomes.

Since the criterion of Goal Certainty tests for both necessary and sufficient causes for the entire outcome pathways, the criterion of Sufficiency is contigent on depicting meaningful causal connections within parts of the ESG-LM. The control question therefore reviews whether the different parts of the ESG-LM are sufficient for their effects. I formulate the following control question to evaluate this criterion:

Is Goal Certainty achieved for the entire ESG-LM (1)? If so, are all Inputs fully or partially sufficient for their designated Outputs (2) and all Outputs fully or partially sufficient for their designated Long-Term Outcomes (3)?

Accordingly, two additional scores can be achieved (assuming that the minimum requirement for Goal Certainty is achieved).

2.3.3 Measurability

Most impact assessments use metrics to represent the current state or the result of change in the system. I use the term *indicator* to describe any information that assesses whether a change can be achieved at all (*qualitative indicators*) and what progress between entities was achieved (*quantitative indicators*).

Some indicators presented in sustainability impact assessments are easy to collect and measure but only loosely related to the overarching goals. Examples of this type of indicator are the number of projects funded, the amount of money invested, or the number of people receiving a loan. By contrast, there are some indicators that provide *robust* and *unique* evidence for success even beyond the scope of the Initiator. Such values can usually only be drawn from *ex post* evaluation (e.g., number of successful operations for life-threatening diseases in a developing country) and projects where considerable effort is put into the monitoring of outcomes.

I argue that any indicator can be placed on a scale between these two extremes and that its ability to show progress can be described as its quality. Knowing the quality of indicators is certainly of importance to the Initiator but more so to any third party reading the impact assessment. With better indicator quality as well as better indicator robustness, better evidence for goal achievement is presented (see Section 2.1.6.1). In addition, if that evidence is unique in the sense that it is very likely within the proposed causal hypothesis, but unlikely in any other, it can most likely be concluded that the intervention works as intended (see Chapter 5).

However, the Measurability of indicators can be assessed as well and used as a criterion for the quality of the model. Measurability describes the degree to which the propositions of an ESG-LM can be measured with the help of indicators. An adequate model is one for which at least best-needed indicators can be identified that allow to assess the interventions at the beginning of the outcome pathways (on the level of Outputs) at least in theory. By contrast, if best-available indicators can be found for all Outcomes, the best Measurability is achieved (see Section 2.1.6.1 for a definition of best-needed and best-available).

I therefore define the criterion of **Measurability** as follows:

> The criterion of *Measurability* is tested with help of all identified potential best-available or best-needed indicators for an ESG-LM. The highest Measurability is achieved if all Outcomes can be associated with best-available rather than best-needed indicators. By contrast, if not all Outputs can be associated with either best-needed or best-available indicators, the ESG-LM is likely inadequate for impact measurement.

It is expected that entities at the end of the ToC (towards sustainability impacts) are often described with best-needed indicators. Nonetheless, if best-available indicators can be quantified there, they have both the highest indicator quality and Measurability. The control question for this criterion reviews if and what indicators exist for all Outputs and Outcomes:

> *Can all Outputs be measured with either best-available or best-needed indicators (1)? If so, are there best-available indicators for all Outputs and at least best-needed indicators for Intermediate Outcomes (2) or even best-available indicators for each Outcome (3)?*

Accordingly, scores can be awarded from 1 to 3 in this category (assuming that the minimum standard of Goal Certainty was achieved).

2.3.4 Scaling and scoring of system attributes

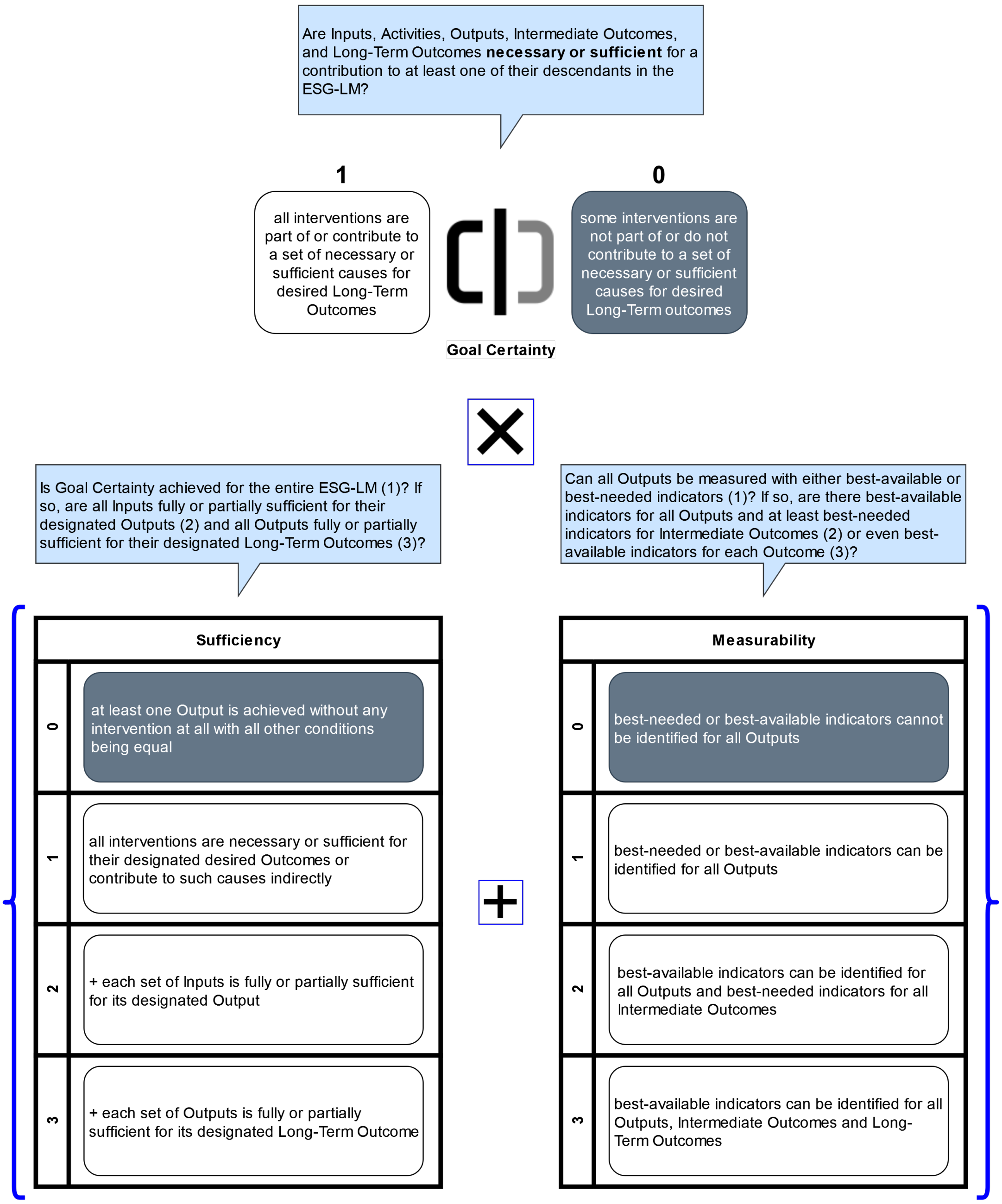
The attribute Goal Certainty can either be adequate (true or 1) or not adequate (false or 0) for any ESG-LM. The attributes Sufficiency and Measurability with scores from 0 to 3 on the other hand are both conditioned on adequate ESG-LMs. The formular used to score the quality of an ESG-LM reflects these conditional relationships and is shown in Figure 2-9. The score for Goal

Certainty, 0 or 1, is multiplied with the sum of the scores for Additionality and Measurability with each requiring a score of 1 to achieve the minimum requirement. Thus, this evaluation can have one of the following outcomes:

- 0: The ESG-LM is not adequate regarding Goal Certainty
- 1: The ESG-LM is not adequate regarding its Measurability
- 2-6: The ESG-LM is adequate (with higher scores indicating higher quality)

As this scoring system is mainly intended to be used during the development of ESG-LMs, models that are inadequate should be revised until they achieve at least a score of 2. It also illustrates how smaller models usually have an advantage over larger ones, as it is easier to ascertain the sufficiency of causal links and to identify good indicators when fewer outcome pathways are described.

Figure 2-9: criteria, control questions, and formular to assess the quality of any ESG-LM



Source: own development

This criteria-based evaluation can also fulfils two additional purposes: it is a tool (i) to gain knowledge on the overall causal soundness of the model and (ii) to partition ESG-LMs into sub-models for a prioritisation of stronger over weaker causal packages.

2.4 Language of the ESG-LM

One of the main advantages of the framework proposed in this work is its ability to break down complex cause-effect chains into a narrative on how a given input contributes to an overarching goal. The different levels not only reflect the position in this narrative but help to translate this information into data types, presumed CMs, and requirements.

To further facilitate this process, the scheme is intended to be understood using plain English in the structure of one or more sentences. I call this translation step *language of the ESG-LM* and describe here how this can be achieved. Each of the entities as well as their interactions with other entities can also be understood as specifications of more general concepts. The following table shows how two main hypotheses can be formulated using this scheme.

Table 2-5: toolbox for formulating a ToC from entities in an outcome pathway

Entity	**Description**	**Example**
Financing	This part refers to the description of the financing mechanism (e.g., “financing”, “lending”, “investing”).	*The* [financing] *of* [...]
Input	This part refers to the sector or branch of the main actor who implements the change.	[electricity production] *from* [wind energy] [...]
Activity	This part refers to the physical materialisation of the activity that has been triggered.	*leads to* [operating] [wind farms] [...]
Output	This part refers to the tangible results from the activity.	*with* [minimum GHG emissions].
Intermediate Outcome	This part refers to the causal relationship between singular cases on the level of Outputs and societal effects that are triggered by them. Causal conditions can either be: (i) sufficient	(ii) partially sufficient (INUS)	(iii) necessary	(iv) partially necessary (SUIN)	[These wind farms] *are* [partly sufficient] *for* [replaced GHG emissions from electricity] [...]
Long-Term Outcome	The final part refers to the desired change on the societal level that helps to achieve overarching goals.	*which contributes to an* [absolute GHG reduction] *in* [Germany].

Source: own compilation with an example from Case Study A (Chapter 6)

Almost all outcome pathways in this dissertation use this scheme as a basis. However, it is merely intended to facilitate the formulation of ToC descriptions and hypotheses. Alternative or more detailed descriptions of the causal pathways and pre-conditions can suffice or even improve the underlying narratives.

2.5 PoC

The PoC (Proof-of-Concept) tested the ToC logic during the methodological development. Its goal was to demonstrate how a generic ESG-LM is conceptualised and to adapt the definitions and attributes of the ToC entities if necessary. It was limited to the core mechanic (Contribution) without considering Attributions and Additionality.

I used a real-life policy framework on the European level (*EU Sustainable and Smart Mobility Strategy*) to test how

- outcome pathways can be drawn heuristically,
- Intermediate and Long-Term Outcomes can be distinguished consistently,
- asset classes and intentions can be identified that help to categorise different types of interventions,
- purposes and Inputs can be translated into Activities,
- and what Outputs would constitute the most plausible causes for subsequent Outcomes.

The process steps, intermediate results, and final generic ESG-LM are shown in Annex A-2. The following sections only summarise the lessons learned.

The PoC demonstrated successfully how an existing framework for desired changes can be translated into a model that logically links Inputs into and by the economy as contributions to overarching societal goals. The definition of each step (entity) for these outcome pathways was useful, and so was the characterisation of Actors, assets, purposes, Activities, and the physical objects provided in the previous chapters. Moreover, the evaluation process enabled me to identify the weakest inferences in the overall ToC and provided me with insights on how such models can be improved.

The first lesson drawn from this exercise has already been briefly discussed in Section 2.3.4. Since the underlying European strategy tries to integrate a large number of different solutions to achieve its diverse goals, the ESG-LM of the PoC reflected this diversity as well as a broad range of potential CMs. While this is helpful for an initial idea of how the desired changes could be achieved, it also has the disadvantage of decreasing the plausibility of its causal pathways. Several Activities need to be present at the same time for a number of outcome pathways which required the inclusion of additional effects for Intermediate Outcomes to be triggered. Such an adaptation decreases the Empirical Importance of the causal relationships (see Section 1.9.5.3). A much simpler solution would be to separate the total ESG-LM into several separate models, either by focusing on a cluster of Activities or single issues to be addressed.

The second lesson learned is that the mere depiction of causal arrows between entities is not sufficient to describe the underlying causal configurations. Instead, it would be helpful to explicitly describe whether Outputs are thought of as necessary, sufficient, partially necessary, or partially sufficient causes. The next chapter will incorporate these lessons into the **Prototype (PT)**, that is later used and adapted for the case studies in Chapter 6.

3 PT FOR CLIMATE CHANGE MITIGATION

The following sections describe the PT (Prototype) and how it was developed. The PT is then evaluated using the evaluation criteria from Chapter 2.3. I use the EU taxonomy framework for contributions to climate change mitigation as basis — or implicit stakeholder theory — for the prototype development.
The final ESG-LM is also shown in the Annex in a larger size (see Annex Figure c).

3.1 Characteristics of the EU Taxonomy Framework

The EU taxonomy listed 95 different activities in 13 sectors until the middle of 2022. 88 of these activities[18] in nine sectors can be, in principle, aligned to the taxonomy by not violating the DNHS criteria and showing a significant contribution to climate change mitigation.

These contributions differ widely regarding the type of criteria used but are usually consistent within sectors. For example, the production of basic materials (activities 3.7 to 3.17) within the sector “Manufacture” all relate to a threshold for maximum carbon emissions during production, while activities from “Forestry” (1.1 to 1.4) all require a climate benefit analysis that compares the GHG effects from eligible activity with the absence of that activity. Nonetheless, not all contribution criteria within a sector are consistent in this manner and the requirements for significant contributions between sectors differ greatly in terms of ambition and plausible causes for climate change mitigation.

As many activities are not included at all, such as activities from agriculture and most processes on industrial level, a large portion of GHG emission sources is not covered by the taxonomy. This means, for the purpose of developing an ESG-LM, many factors outside of the intervention logic can compensate or overcompensate contributions to the overarching goal of climate change mitigation. Given that some activities explicitly include the development or sale of low-carbon solutions, it can also not be ensured that all activities directly contribute to European goals of GHG emission reductions.

Using the EU taxonomy as a stakeholder theory for achieving overarching goals is a challenge for ESG-LM development, as it is non-consistent in its application of technical criteria and non-coherent in its assumptions on how (European) environmental goals can be achieved.

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[18] The prototype is based on the EUT from October 2022. More recent updates include additional activities concerned with fossil gaseous fuels and nuclear energy as well as suggestions on substantial contributions for other environmental targets other than climate change mitigation and adaptation.

3.2 Development of the PT

A ToC in line with the EU taxonomy framework does not require the implementation of all development steps laid out in Annex A-2. The Inputs and Outputs as well as the Impact are already defined by the framework itself. Any economic activity under the framework can be understood as an intervention, and as such, an Input towards a desired change in the system. Most of these Inputs are already matched to one or more NACE classifications and can be applied to companies but also to the financing of projects and measures within broader sectors (e.g., financing the purchase of a building or financing a real estate company). The desired Outputs on the other hand can be directly associated with achieving a significant contribution towards climate change mitigation (especially specific thresholds for GHG emissions or energy use) and the overarching environmental goal is quantified in the form of GHG emission reductions on a European level (55% GHG emission reduction by 2050).

The gaps in the ToC and thus the ESG-LM are activities on company or project level (financed actions), Intermediate Outcomes for changes to GHG emission sources, and persistent societal changes (Long-Term Outcomes) in the form of absolute reductions of GHG emissions. Each economic activity could be mapped to at least one outcome pathway towards the overarching goal and each of these outcome pathways could be evaluated for *Goal Certainty*, *Sufficiency*, and *Measurability*. Together, these pathways could then also be tested for overall coherence of the hypothesis on how financed actors, according to the taxonomy, contribute to climate change mitigation in Europe.

However, such a detailed map could not be visualised in a meaningful manner and would be of limited use to either investors or evaluators. This bottom-up (b-u) approach is therefore only the starting point for a more top-down (t-d) and logically coherent description of the change mechanics. This development is conducted in six steps: (1) Intention Model (b-u), (2) Input Model (b-u), (3) Outcome Model (b-u), (4) Sector Model (b-u), (5) Aggregated Outcome Model (t-d), (6) Lean Logic Model (t-d).

First, an **(1) Intention Model** is developed that focuses solely on the sorting logic of the taxonomy (sectors, possible sub-categories of these sectors, economic activities) as well as the implicit intention of each activity for a significant contribution. To that end, each set and potential subset of economic activities (e.g., "Basic Materials" within "Manufacture") is looked at regarding the actions by companies that are eligible for each Activity (translated into purposes[19] and physical objects) as well as the intention of the TSCs for contribution (translated

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[19] The "EU Taxonomy Climate Delegated Act" (https://eur-lex.europa.eu/eli/reg_del/2021/2139/oj) describes eligible actions (e.g., purchasing, constructing, leasing, etc.) for each economic activity under "Description of the activity" and its

into a descriptor for the Input). Examples of the first characteristic are purposes such as “purchase”, “construction”, “operation”, “maintenance”, or “upgrade”. The second characteristic is needed to specify what type of outcome pathways can potentially follow from the intervention. I define and distinguish four types of intentions that are based on a 2021 framework by the Joint Research Centre (JRC) for climate change contributions (European Commission. Joint Research Centre., 2021): climate-positive, climate-friendly, climate-efficient, climate-enabling. The following Table 3-1 shows how these intentions relate to the JRC methodology, indicates what type of system change is expected to occur, and provides examples for economic activities from the taxonomy.

Table 3-1: definition and logic of descriptors for purposes of Inputs

Descriptor (Purpose)	**Types of substantial contributions according to JRC**	**Expected system change**	**Example of economic activity**
climate-positive	net-negative emission activities	removal of GHG emissions	1.1: afforestation
climate-friendly	low-carbon activities	replacing GHG emission sources	4.3: electricity generation from wind power
climate-efficient	transitional activities	reducing GHG emissions	3.7: manufacture of cement
climate-enabling	enabling activities	enabling others to remove, replace, or reduce GHG emissions	5.6: anaerobic digestion of biowaste

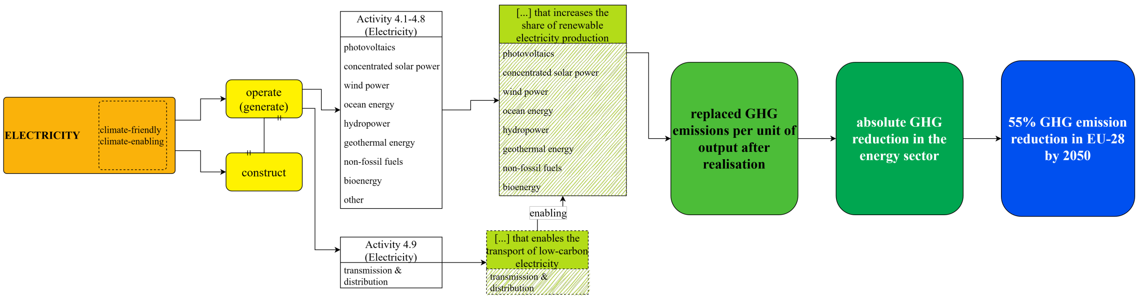
Source: own development based on European Commission & Joint Research Centre, (2021)

The second step is to develop an **(2) Input Model**. This represents the most detailed expression of outcome pathways, as it describes a causal hypothesis of each economic activity along each of the ToC components. At this point, only sectors or subsets of sectors are looked at regarding the consistency of the pathways (18 separate models overall). For example, the two sub-sector Input Models for sector 5 (waste, sewerage, waste management) point to different types of Outputs: the climate-efficient activity of “constructing a waste water system” within the sub-sector of “water supply & waste water” aims at the Output of “reducing final energy demand per output”, while the climate-efficient activity of “constructing a material collection system” within the sub-sector of “material waste” aims at the Output “saving GHG emissions compared to virgin materials”. Although a narrative can be developed from these Input Models for each of the 88 activities with a potential substantial contribution to climate change mitigation, they also relate to very different mechanisms to achieve the same outcomes.

technical screening criteria (used to deduct a purpose) under “Substantial contribution to climate change mitigation”.

The third step, an **(3) Outcome Model**, aims at harmonising the activities (ToC activities) and outcome pathways of each Input Model. It defines for each intervention at which point in the lifecycle of products or the value chain of economic services the desired changes to GHG emission budgets occur. Some activities relate to GHG emission changes during the use phase (e.g., zero tailpipe emissions of operating climate-friendly vehicles) and some to the production phase of inputs (e.g., manufacturing from secondary materials). Accordingly, of the variety of possible eligible actions by actors, some directly relate to these Outcomes, while others are associated with the up- or downstream of an Input. Any deviation from this shortest and most direct causal strand are indicated by additional Outputs (representing "climate-enabling" Inputs) as well as additional activities connected to the main activity via a link of "attribution" (see Figure 3-1 on the example of the sub-sector "electricity").

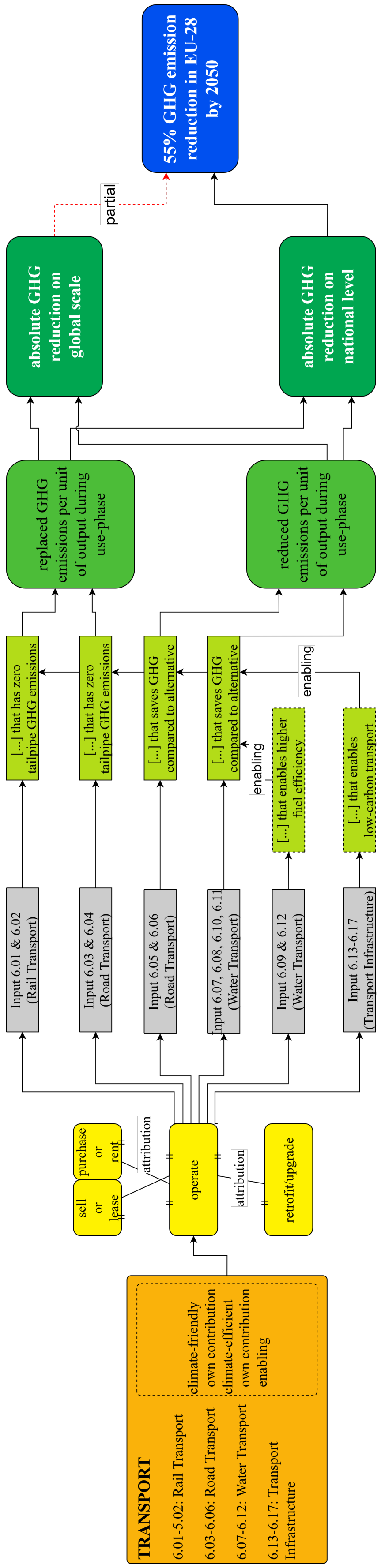
Figure 3-1: example of an Outcome Model from the energy sector (inputs 4.1 - 4.9)



Source: own development

The final bottom-up logic relates to the **(4) Sector Model**, where Outcome Models of sub-sectors are combined and listed beneath each other in a coherent manner. The aim of this step is to develop sector-wide ToCs that explain if and how each sector (and its Inputs) can contribute to either national or global GHG targets (see Figure 3-2).

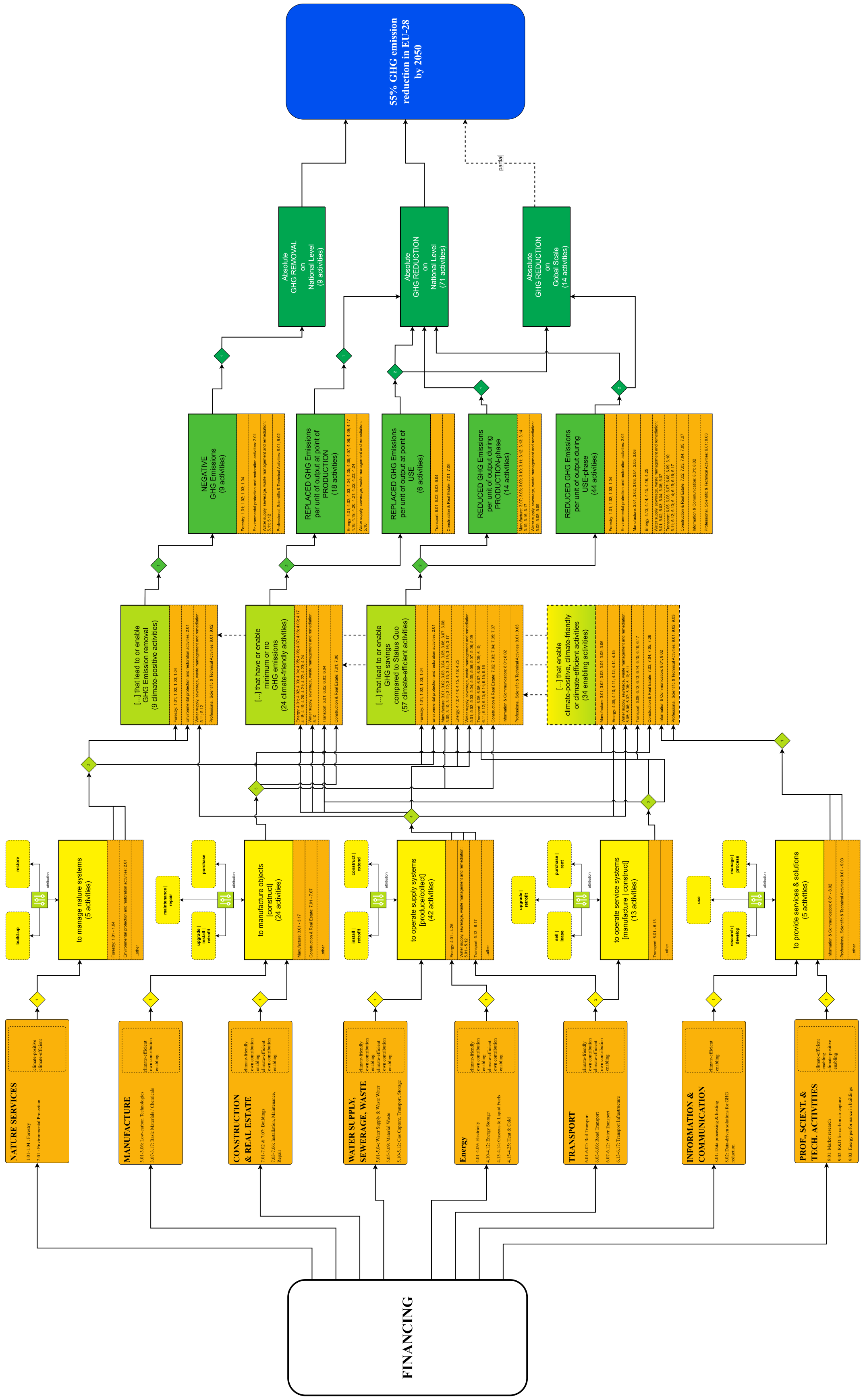
Figure 3-2: example of a Sector Model for the transport sector (inputs 6.1-6.17)



Source: own development

The next step is the development of a detailed top-down logic of all combined sectors. The **(5) Aggregated Outcome Model** shows how each cluster of Inputs relates to different types of Activities, the four intentions of desired Outputs and the five hypotheses for relative (intermediate) changes to GHG budgets as well as the three types of absolute GHG reductions and removals. In this model (shown in Figure 3-3), each economic activity of the Taxonomy is associated with at least one Activity, Output, Intermediate Outcome, and Long-Term Outcome.

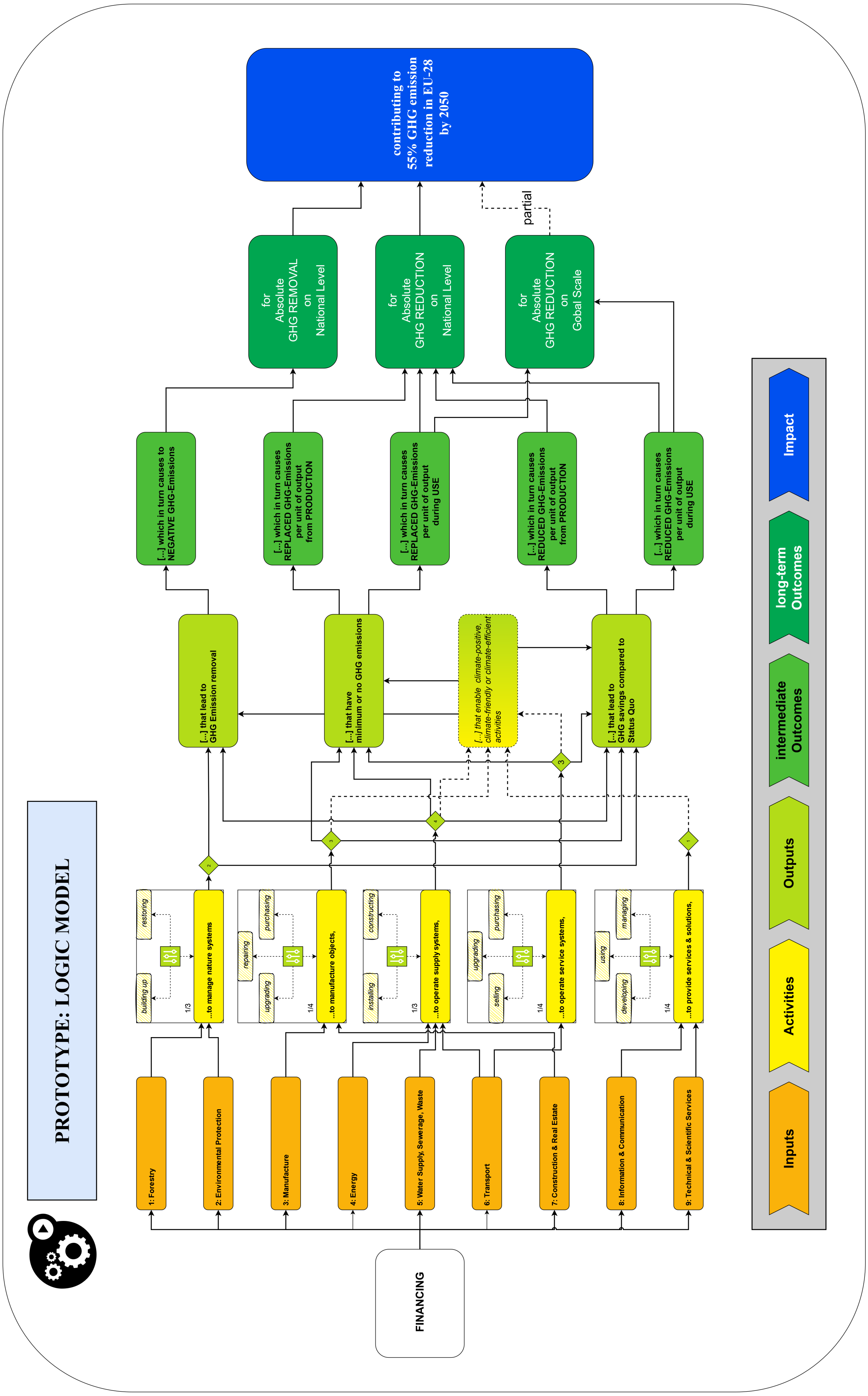
Figure 3-3: Aggregated Outcome Model of EUT for climate change mitigation



Source: own development

The **(6) Lean Logic Model** (see Figure 3-4) is the prototype for the methods developed in this study. It summarises the principles in a consistent and coherent ToC for climate change mitigation in the EUT. It is the basis for possible expansions or adaptations and the point of view for the consideration of Hazards and Rebounds.

Figure 3-4: Simplified Logic Model for climate change mitigation in the EUT



Source: own development

3.3 Characteristics of PT

The logic model can now be characterised regarding different types of Inputs (the sectors of the taxonomy):

- Inputs from the sectors **Forestry** (1.1 – 1.4) and **Environmental Protection** (2.1) are the only Inputs where individual activities are associated with more than one Output, as it is possible that either or both Outputs are achieved (reduced or removed GHG emissions). They are — apart from Input 5.11 — also the only Inputs that lead to GHG removals based on their own performance.
- Inputs from the sector **Manufacture** (3.1 – 3.17) only lead to GHG emission reduction on their own performance from the production phase (3.7 – 3.17), while reductions during the use phase (3.1 – 3.6) require additional actors (mostly from energy supply). These six Inputs are also associated with climate change mitigation targets on a global rather a European scale.
- Inputs from the sector **Energy** (4.1 – 4.25) can, depending on the actual economic activity, contribute to both GHG reductions and replacement, but it is assumed that all interventions lead to benefits for European GHG emission budgets (full contribution to the Impact). On their own performance, renewable electricity production (4.1 – 4.8) and renewable production of heat/cold (4.17 – 4.25) directly cause the replacement of GHG emissions in the system (climate-friendly). All remaining Inputs either enable other actors in reducing GHG emissions (4.10 – 4.12; 4.14 – 4.15) or do so on their own accord (4.13, 4.16, 4.25).
- Inputs from the sector **Water Supply, Sewerage, Waste** (5.1 – 5.12) contribute to GHG removals (5.11, 5.12), GHG replacements (5.10), and GHG reductions (5.1 – 5.9) but do so partly in form of enabling activities (5.5, 5.6, 5.7, 5.8, 5.10, 5.11). All 12 Inputs are associated with operating, constructing, or the retrofitting of supply systems, which in turn can lead to long-term GHG benefits on the European level.
- Inputs from the sector **Transport** (6.1 – 6.17) contribute to replacement of GHG emissions (6.1. – 6.4) and the reduction of GHG emissions during the use phase (6.5 – 6.17). Ten out of 17 Inputs do so by their own performance. Regarding the Long-Term Outcomes, four Inputs (6.3 – 6.6) are associated with GHG reduction on a global rather a national or European scale.
- Inputs from the sector **Construction and Real Estate** (7.1 – 7.7) either contribute to reducing (7.2, 7.3, 7.4, 7.5, 7.7) or replacing GHG emissions (7.1, 7.6). All of these are considered full contributions to European goals from the manufacturing/constructing, installing/upgrading, purchasing, or repairing of objects. Four of the seven Inputs are considered enabling activities (7.3 – 7.6), while three Inputs contribute to desired outcomes on their own (7.1, 7.2, 7.7).

- Both Inputs from the sector **Information and Communication** (8.1 – 8.2) are linked to enabling activities for a reduction of GHG emissions during the use phase. Since the associated Activities of providing, using, managing, or developing service systems can take place on a global scale, they do not necessarily contribute to the European climate change mitigation goal.
- Inputs from the sector of **Professional, Scientific, and Technical Activities** (9.1 – 9.3) also provide, use, manage, or develop service systems and are all considered enabling Activities. Two Inputs can contribute to GHG reductions during the use phase (9.1, 9.3), while one Input can lead to GHG emission removals in the systems (9.2). The latter is associated with a full contribution to European targets, while the first two are considered partial contributions.

3.3.1 Potential indicators

Potential indicators demonstrate which parts of the prototype have a high Measurability (best-available) or low Measurability (best-needed). As discussed in the ESG-LM framework (see Section 2.3.3), an ideal model would provide best-available indicators for all outcome pathways in a generic manner, but it is not always possible.

The three Long-Term Outcomes relate directly to national and intranational GHG accounting. They are easily measured as their values of "GHG removals" (A_a), "Absolute GHG Reduction on National Level" (A_b), and "Absolute Reduction on Global Scale" (A_c) can be found in official statistics in the form of changes to GHG emissions or GHG budget. However, it is very difficult to infer a direct causal relationship between the Inputs in the model and these desired changes. Thus, it is crucial to establish robust contributions to these Long-Term Outcomes first, that in turn can be traced back to the Activities by Actors. This step therefore focuses on potential indicators for Intermediate Outcomes and Outputs.

The indicators in the following table are sorted according to their causal connections in the value chain and qualified according to their quality. Indicators of quality A indicating contributions to Impacts, indicators of quality B contributions to Long-Term Outcomes, and indicators of quality C contributions to Intermediate Outcomes (see also Section 2.1.6.1).

Table 3-2: list of potential indicators for the ESG-LM of the PT

No		**Indicator Suggestion**	**Type**
B1	annual negative GHG emissions from activity		available$_{best}$
	C1.1	negative GHG emissions over lifetime of activity	available$_{best}$
	C1.2	carbon storage/removal capacity over lifetime of activity	available$_{best}$
B2	annual replaced GHG emissions from production		needed$_{best}$
	C2.1	change in GHG emissions per unit of output	available$_{best}$
	C2.2	capacity of low-carbon source over lifetime of activity	needed$_{best}$

No		Indicator Suggestion	Type
B3		annual replaced GHG emissions from demand	available$_{best}$
	C3.1	change in GHG emissions per unit of demand	available$_{best}$
	C3.2	capacity of low-carbon source over lifetime of enabled system	needed$_{best}$
B4		annual reduced GHG emissions from production	available$_{best}$
	C4.1	GHG emission reduction per unit of output	available$_{best}$
	C4.2	upstream GHG emission reduction per unit of input	available$_{best}$
B5		annual reduced GHG emissions from demand	available$_{best}$
	C5.1	GHG emission reduction per unit of demand	available$_{best}$
	C5.2	GHG emission reduction over lifetime of enabled systems	needed$_{best}$

Source: own compilation

3.3.2 Generic target conflicts

The PT is developed to align the ESG-LM methodology with the EUT, which already considers a significant portion of risks to other objectives. The Generic Hazards in the model, defined as risk-indicators for reduced desired Outputs or reduced Outputs for Other Actors, are therefore already covered by the additional requirements for a substantial contribution as well as controlling for DNHS. Regarding risks of compensated Outcomes, I identify and list Generic Rebounds in the following table with the numbering indicating which outcome pathway is affected.

Table 3-3: identified Generic Rebounds for the PT

No	Identified generic target conflicts	Risk type
$F_{n.m}$	All Outputs are conditioned on the achievement of additional technical and regulatory requirements as well as the non-violation of DNHS to other objectives.	Generic Hazard
G1	There is risk that activities were not necessary for the anticipated GHG net benefits (e.g., conserving forests that would not have been negatively affected).	Generic Rebound
G2	There is risk that climate-friendly energy production from gaseous fuels or from district heating does not replace energy production from sources with higher GHG emission intensities.	Generic Rebound
G3	There is risk that the additional production of products and services with low GHG emission intensities compensates savings from reduced GHG emissions during use.	Generic Rebound
G4	There is risk that an increase in production compensates the lower GHG intensities of the products.	Generic Rebound
G5	There is a risk that increased demands compensate GHG reductions per unit of demand.	Generic Rebound
G6	There is a risk that replaced or reduced GHG emissions from activities lead to climate mitigation benefits outside the European Union.	Generic Rebound

Source: own compilation

3.4 Evaluation of prototype

The evaluation of the PT requires the identification of potential indicators and the characterisation of the causal conditions for change. As discussed in Section 2.1.6.2, these causal conditions are assessed in the light of non-changes to the surrounding system (all other things being equal). For example, replacing GHG emissions per kWh of produced electricity is sufficient for an overall GHG reduction, because it is assumed that the overall electricity demand does not change.

The following tables show the results of the Goal Certainty evaluation of the pathways from Outputs to Intermediate Outcomes (Table 3-4) and from Intermediate Outcomes to Long-Term Outcomes (Table 3-5). I argue that all other causal connections are sufficiently described by the ESG-LM, because the Long-Term Outcomes are direct contributions to the impact (Long-Term Outcomes are sufficient for net benefits to GHG budgets in Europe) and the interventions themselves are defined by the technical criteria of the EUT.

Table 3-4: evaluation of Goal Certainty from Outputs to Intermediate Outcomes

Intermediate Outcomes	Outputs as antecedents and Goal Certainty evaluation of causal condition(s)		Reasoning
O1: negative GHG emissions	leading or enabling GHG emission removal by own contribution	S	can be present & cause outcome
	leading or enabling GHG emission removal from enabling activities	INUS	sufficient in conjunction
O2: replaced GHG emissions per unit of output from production	have/enable minimum or no GHG emissions by own contribution	N	must be present
	have/enable minimum or no GHG from enabling activities	SUIN	necessary in conjunction
O3: replaced GHG emissions per unit of output during use	have/enable minimum or no GHG emissions by own contribution	N	must be present
	have/enable minimum or no GHG from enabling activities	SUIN	necessary in conjunction
O4: reduced GHG emissions per unit of output from production	lead/enable GHG savings compared to Status Quo from own contribution	S	cause outcome
	lead/enable GHG savings compared to Status Quo from enabling activities	INUS	cause outcome in conjunction
O5: reduced GHG emissions per unit of output from demand	lead/enable GHG savings compared to Status Quo from own contribution	S	cause outcome
	lead/enable GHG savings compared to Status Quo from enabling activities	INUS	cause outcome in conjunction

Source: own evaluation

Table 3-5: evaluation of Goal Certainty from Intermediate Outcomes to Long-Term Outcomes

Long-Term Outcomes	Intermediate Outcomes as antecedents and Goal Certainty evaluation of causal condition(s)		Reasoning
a: absolute GHG removal on national level	O1: negative GHG emissions	S	can be present & cause outcome
b: absolute GHG reduction on national level	O2: replaced GHG emissions per unit of output from production	S	can be present & cause outcome
	O3: replaced GHG emissions per unit of output during use	S	can be present & cause outcome
	O4: reduced GHG emissions per unit of output from production	S	can be present & cause outcome
	O5: reduced GHG emissions per unit of output from demand	S	can be present & cause outcome
c: absolute GHG reduction on global scale	O3: replaced GHG emissions per unit of output during use	S	can be present & cause outcome
	O5: reduced GHG emissions per unit of output from demand	S	can be present & cause outcome

Source: own evaluation

For the evaluation of the model (see Section 2.3.4), I first consider the criterion of *Goal Certainty*. Since all causal connections constitute either necessary (N), sufficient (S), SUIN, or INUS conditions, a score of 1 is achieved. Regarding *Sufficiency*, a score of 1 is achieved as well. Although the right or societal side of the ESG-LM consists of sufficient conditions (except for global GHG reduction only partially contributing to European climate mitigation goals), most of the links between desired Outputs and desired Intermediate Outcomes describe sets of necessary conditions. They are needed, but do not automatically lead to desired changes. Moreover, all "enabling" activities can only be considered SUIN conditions if they enable *climate-friendly* Outputs and INUS conditions if they precede *climate-efficient* Outputs. This is indicated by dotted arrows in the graphical depiction of the model.

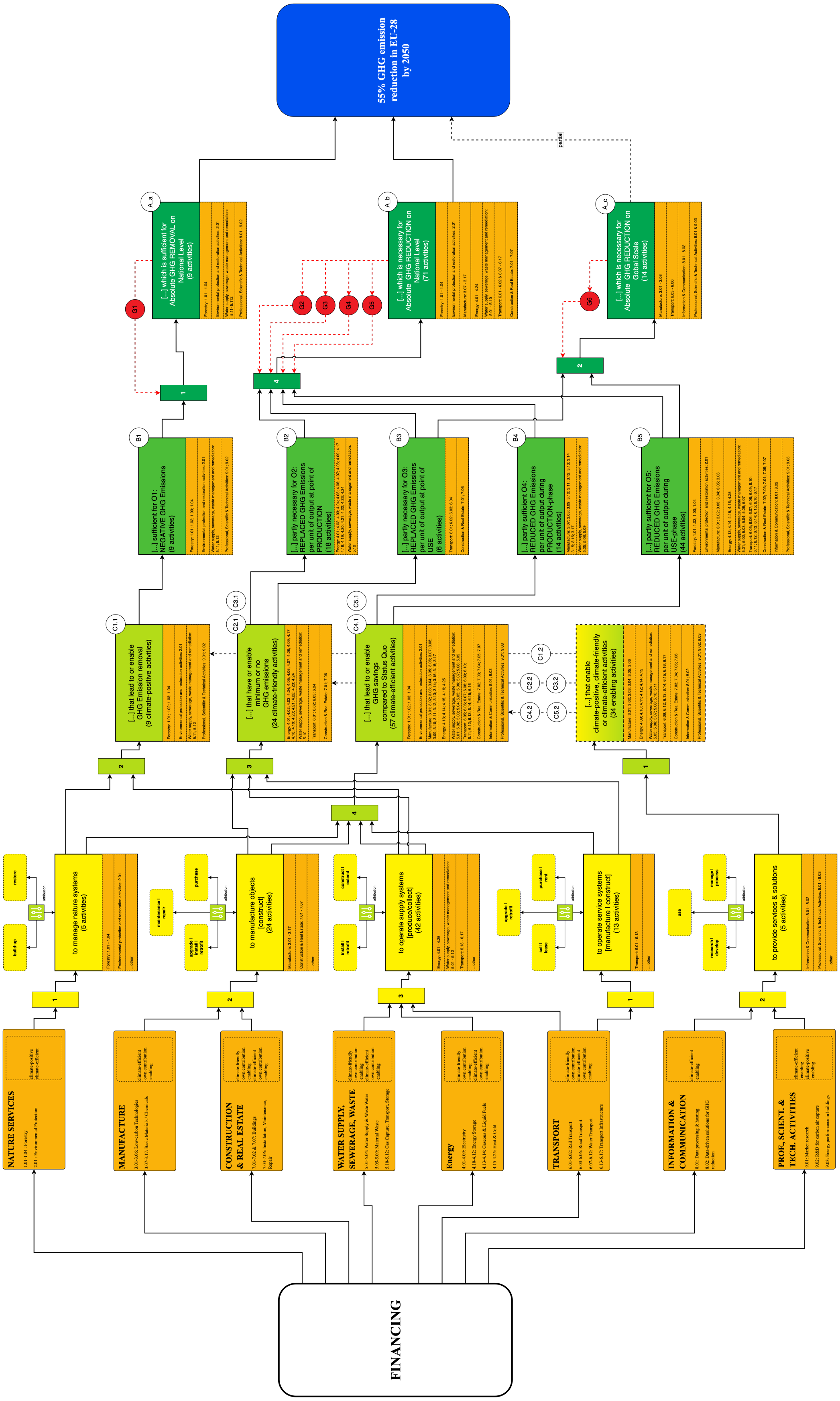
For *Measurability*, 15 potential indicators could be identified, of which 11 indicators (best-available) are expected to be measurable with currently available methods and data. For four indicators (best-needed) such a Measurability cannot be ensured generically but would have to be investigated on a case-by-case basis. This results in a score of 1 regarding *Measurability*, because three of these indicators are located between Outputs and intermediate Outcomes.

Overall, a score of 2 is achieved (1*(1+1)) for the entire PT, which describes an *adequate* ESG-LM. This means that no revision is necessary. Nonetheless, revisions could improve the model and parts of the model could potentially score higher, since some parts of the PT are more robust in terms of *Sufficiency* or *Measurability* or both. For example, removing "enabling" activities from the ESG-LM would increase *Measurability* and thus lead to a score of 3. Without these activities and focusing solely on Outputs that are sufficient for their related outcome pathways (O1, O4, O5 without 1.2, 4.2, 5.2), *Sufficiency* increases to 3 and *Measurability* to 3. Thus, this section of the model could achieve the full score of 6.

3.5 ESG-LM of PT

The following figure shows the listed ESG-LM of the PT after evaluation (the full ESG-LM is also shown in Annex A-3). Solid arrows indicate causal connections that are necessary or sufficient and dotted arrows that are SUIN or INUS. White circles indicate potential generic indicators and circles in red Generic Rebounds (F). Both are further defined by their location in the outcome pathway (C indicates output-indicators B indicators for intermediate Outcomes) as well as their connection to one out of five outcome pathways.

Figure 3-5: ESG-LM for PT after evaluation



Source: own development

3.6 Employing the PT

The ESG-LM developed here refers specifically to the EUT, but its logic is still generic. It shows how an economic operation in the taxonomy is expected to contribute to climate change mitigation, what indicators should be measurable and which risks need to assessed or integrated in the quantification.

It does not include information on the various physical objects that are part of the realisation and does not specify any particular threshold. Nor does it identify every potential Actor involved in a contribution. This needs to be specified on a case-by-case basis depending on the specificity of the project or measure to be assessed. For example, investments in the construction of buildings that are merely considered "energy-efficient" could be easily explicated using the model at hand. Such a model would provide a plausible causal strand for climate change mitigation but without the benefit of having explicit and specific causal hypotheses that can be tested. The results of any quantification could therefore be strongly over- or underestimated while at the same time neglecting specific Hazards for some unknown portion of the sample. This might be all that is needed for a broader empirical prediction but would not be the main purpose of model. For a more accurate and warranted assessment, such buildings would have to be further specified and based on a known set of projects.

This is why, in Case Study A, the model is used as a blueprint for electricity production from wind energy, but further specified regarding the underlying hypotheses, the involved Actors, and projects, as well as the specific risks and baselines for quantification.

4 IMPACT MEASUREMENT

This chapter starts with a brief discussion of the different types of impact assessment methods that facilitate impact measurement from an ESG-LM. I then proceed to introduce tools for a further quantification of impact assessment results: Rules of Attribution and Rules of Additionality.

4.1 Impact assessment methods

The ESG-LM methodology is open to any appropriate method to derive *ex post* or to estimate *ex ante* effects, because the assessment of indicators is epistemologically different from assessing the causal inference. Indicators might, but do not have to, build on each other to strengthen the causal claims, but the effect of each part of the outcome pathway can also be measured separately and with different methods. I think that the following are the best applicable methods for ESG-LM impact measurements: (1) Monitoring, (2) empirical studies, (3) LCA-based methods, (4) IOMs.

(1) I define **Monitoring** to comprise a broad family of data collection and evaluation methods that have one thing in common. The main body of data, or otherwise relevant information, is collected and reported by the actors directly involved in an ESG-LM (e.g., by physical measurements, reports, or surveys). This primary data can then be directly used to quantify or qualify indicators along the outcome pathways. Indicators that are derived this way constitute an ideal case. Even in cases where the method of data collection and reporting needs to be scrutinised, it usually leads to more reliable results than any other method with the exception of a full-scale state-of-the-art empirical experiment. Using monitoring has also the advantages of transparency and repeatability. It is easy to show the influence of additional assumptions and auxiliary variables, since most direct calculations are linear (e.g., multiplication of monitored electricity consumption with its price to derive energy costs). In addition, some already existing frameworks for metric selection and data collection might be used to facilitate the assessment process (see for example GIIN, (2017)). Moreover, such data can also constitute evidence for the causal hypotheses explicated by the ESG-LM.

(2) The second method family of **empirical studies** is broadly defined referring to any method that uses or collects data on the cases entailed by an ESG-LM and then applies some form of statistical analysis to derive indicators along the outcome pathways. To my knowledge, no such study has been conducted for projects in Bonds or for promotional loans aligned specifically with tangible, desired, societal impacts (the existing literature is focused on firm-level data). However, such studies would in fact be preferable to any other method of estimating

incremental changes from causal inferences. In turn, similar studies designed for a broader academic audience could benefit from explicating causal strands in an ESG-LM (or from CDs according to Pearl, (2009); see Section 5.5.3). There is also a subset of empirical assessment *results* that can facilitate impact measurement. Already existing empirical studies in similar cases can, given careful considerations of scope and case-selection, be used as a basis for *ex ante* estimations. If, for example, a significant average treatment effect has been found and is applicable, it might be possible to apply its X -> Y relationship to estimate an indicator.

(3) The third, and most common, method family comprises all **LCA-based methods** and models (LCA-M). Such methods are already widely in use for Green Bond reporting and some of its derivates have already been used to quantify indicators for social dimensions in similar cases (for example by applying LCC in Teubler, Hennes, et al., (2023)). The advantages of such methods are (i) detailed methodological discussions and case-specific results in academic literature, (ii) established CMs, (iii) availability of databases for underlying process in value chains and lifecycles, and (iv) data and guidelines by practitioners on already established indicators. LCA-based models are also usually linear on the *frontend* of the measurement, that is, the analyst can directly input primary data to derive a reasonably accurate indicator value. This facilitates impact measurement for practitioners and ensures some transparency, especially if the analyst is trained in developing or adapting LCA models. The weakness of a LCA solutions, similar to using results from previous empirical studies or IOMs, is that the underlying relationships are not explicated or are even *black-boxed*. This usually means that using such methods requires a more thorough assessment of the credibility of the causal claims independent of the indicator value estimation. An alternative approach could be, as shown by Suski et al., (2021), to integrate LCA models into existing theories from the outset instead of forcing theories to comply with LCA methodologies, supply chains, and datasets.

(4) The final method family comprises all methods and models (IOMs) that apply **Input-/Output relationships** in economies — including hybrid models that combine IOMs with LCA-Ms. There is an abundance of academic literature on different types of *satellites* (see Section 1.5.4.2) for such models that can be used to estimate environmental and socio-economic indicators from *shocks* (interventions) or from scenario-based changes in the overall system. Many IOM-based approaches have the advantage that they refer to publicly available statistics which are vetted professionally and updated on a regular basis (e.g., data from EUROSTAT, UNSTAT, OECD databases). This is particularly useful for dealing with indicators that are highly dependent on their surrounding system, such as renewable energy production or household activities. However, the high level of aggregation as well as the high degree to which the specific dependencies are *black-boxed*, makes them less useful for providing evidence for causal claims.

All four method families fit into a scale for the robustness of indicators in the ESG-LM (see Section 2.1.6.1).

4.2 Rules of Attribution in ESG-LMs

Attribution describes the allocation between the full effect of a Contribution to a specific effect in the ESG-LM and the financed portion of it (see Section 2.1.6.2). I distinguish two types of Attribution that are combined to allocate the financed effect or degree of Attribution:
(i) attributions between the financing institution (C_t: outstanding capital without capital costs to be repaid at a certain point in time) and its business partners (I_{BP}: investment costs), and
(ii) attributions α_k between Actors of the outcome pathway. This can be expressed by the following formular.

$$\text{Attribution}_{fin} = \text{Effect } x \, \frac{C_t}{I_{BP}} \, x \, \frac{\alpha_{BP}}{\alpha_{BP} + \sum_{k=1}^{n-1}(a_k)}$$

If we know the full effect of a Contribution (Effect), the financed effect (Attribution_{fin}) is the result of multiplying this effect with the Initiator's share of financing to the Contribution as well as the share of the attribution of this business partner to all attributing Actors. This means that there are also cases in which the Initiator is the Main Actor or the Initiator's contribution is initially 100%. It also means that if the share of financing is unknown, no financed effect can be reported, although an unspecified contribution to the full effect might still be claimed. The indirect Attribution is often quantifiable if it relates to the transfer or provision of capital. Loans and grants can be allocated to the total investments, and equities to the value of economic operations. The PCAF-Standard (PCAF, 2022) provides allocation rules for different types of such financial transactions and can be used for this purpose. Another methodological option is to derive such relationships from an LCC model.

However, there also cases where the intervention cannot be expressed as part of the investment costs. A state Actor might for example fund a programme that contributes to the overall outcome. One solution here is to add these investments to the actual investment costs, thus considering the Initiator to be a part of all Actors that contribute to desired outcomes. This might not be warranted in many cases, especially if the actual intervention has a high likelihood of happening anyway. A more valid claim can therefore stem from the fact that Initiator's actions were necessary for the intervention in the first place or sufficient for additional desired effects. In both cases, the question of Additionality must be answered first (see Section 2.1.6.3).

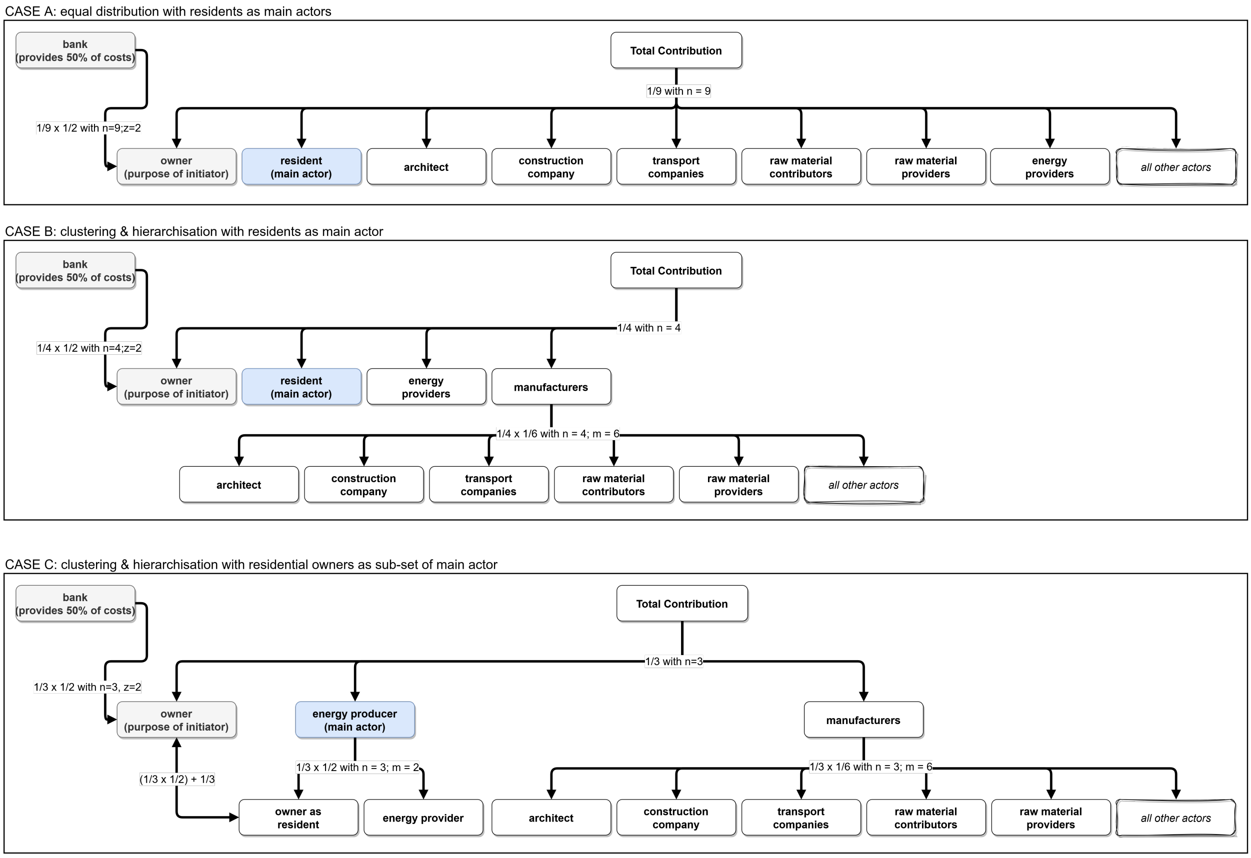
The direct Attribution of the business partner is often difficult to quantify, because usually not all contributions are known. I suggest a simple heuristic in cases where the Actors can be identified, but there is lack of data on the investments of each Actor. The set of Actors in the system can consist of different compositions between the Main Actor and all Other Actors (both of which can consist of additional subsets). The Initiator is usually considered apart from this set but does not have to be. A reasonable initial assumption is that every Actor contributes equally to the outcome. This can be described by the *Principle of Indifference* (see Section 5.4.3), which states that the probability of possible events is equally distributed if no knowledge is available that would indicate otherwise. Transferring this principle to the question of Attribution means that each Actor contributes equally. However, Actors can also be clustered to reduce the number of contributors in a plausible manner.

To illustrate such a clustered and hierarchised use of the Principle of Indifference, let's consider the Activity of "constructing energy-efficient residential buildings for climate change mitigation" with the following Actors: owner (loan recipient), residents, architect, construction company, transport companies, raw-material distributors, raw-material providers, energy providers, bank (loan provider), and all Other Actors. By only considering these Actors (more could be thought of) and assuming that the bank provides a loan (making it a matter of financed attribution), the direct attribution for each Actor is merely 11.1% (1/n with n=9). This is not only a rather small contribution, but it also does not seem to be plausible from a causal point of view. Clearly, some contributions are more important than others as the number of causal connections increases with every Actor in the upstream of the value chain. Those Actors not only constitute a much smaller portion of the total costs or total material and energy flows required, but they can also much more easily be replaced than Actors at the core of the intervention, such as the owner. It is therefore reasonable to cluster these Actors in a way that adheres to the Principle of Indifference but does not place all Actors on the same level of an attributional hierarchy.

To do so, first the Main Actor must be identified as this Actor should always be placed at the highest level. Again, the physical interaction is more closely aligned with the residents of the building than the owner. This leaves the owner in a co-relationship with the bank that finances the building, the energy provider, and a large set of Actors responsible for its construction. The latter can be clustered into a set of "manufacturers and all other Actors" with different subsets if need be (e.g., one for planning and consulting, one for the construction-phase, and one for all preceding activities in the upstream of the value chain). In this case, a direct attribution of 25% (1/n with n=4) can be allocated each to resident (Main Actor), the owner (Other Actor 1), the energy provider (Other Actor 2), and the manufacturers (Other Actors 3).

We can also consider an alternative case where the energy provider and the residential owner (as "energy-user") are subsets of a new Main Actor "energy-producer" (responsible for overall and reduced emissions). In this case, the direct attribution for this Main Actor can be assigned at 50% (1/6 for owner as resident plus 2/6 for owner as equal Actor alongside energy producers and construction companies). For the bank, that covers only 50% of the construction costs, the attribution would be only at 16.7% and not 25% in this case. The following figure illustrates all three cases.

Figure 4-1: examples of heuristic attribution for constructing residential buildings



Source: own development

The high variance in attributing the effects in one example with different methods of estimation and reasoning shows that attribution rules need to be specifically tailored to the interventions involved (at best on the level of single measures), but that these rules, once defined and documented, must also be used consistently over the assessment of a portfolio. I provide an example of such a loan in Annex A-7.

4.3 Rules of Additionality

The question of Additionality should specifically be applied to the Initiators from the financial industry in the ESG-LM. While the inner causal mechanics of the model intend to establish contributions caused by interventions, they should also provide evidence that these financial transactions were necessary for that change. Additionality, as defined in this dissertation and in line with relevant literature, addresses a counterfactual question. Either the Initiator provided capital in such a way that the Outcomes would otherwise not be achieved at all (consequential financing) or would have been smaller (favourable financing). It is thus not possible to quantify it as some form of ratio or share of financing that relates to the actual Financing in a coherent manner for all possible cases. Instead, the financing Initiator should either (i) directly report the amount of capital that is consequential for desired Outcomes, (ii) directly report the amount of non-reimbursable grants, (iii) directly report the amount of dispensed earnings for lending at favourable conditions, or (iv) estimate any of these values on the basis of available information.

The latter is described here only for the case of favourable Financing of loans with below-market conditions, as all other cases should correspond directly to the capital provided or an estimate thereof. These dispensed earnings can be described as a counterfactual utility for the lender, as the Initiator would have otherwise either demanded a higher interest rate (or fixed such a rate over a shorter period of time), or a lower maximum annual rate for unscheduled repayments, or no form of debt relief. Comparing this non-actualised utility to the actual earnings therefore provides the lower capital costs for the borrower. Annex A-7 demonstrates how such a calculation could look for the example already used to apply the Rules of Attribution.

5 EPISTEMIC JUSTIFICATION FOR THE ESG-LM

The PT described here, as well as any ESG-LM employing the same *modus operandi*, has two foundations for *belief*. First, the Initiator defines how interventions contribute to overarching sustainability goals. This is what I call "implicit stakeholder theory" in line with core principle 1b in Coryn et al., (2011). In a second step, the evaluator or analyst describes how these causal paths or *causal strands* develop with the help of a ToC. The ESG-Logic model uses a "linear complicated" model for that purposes, that describes either or both simultaneous and alternative causal strands in line with the definitions in Rogers, (2008).

The result constitutes a causal inference for a rational actor's credence in the ToC propositions and the process itself is subject to the background knowledge of both Initiator and analyst. It can be based on full or partial empirical evidence but does not depend on it. It describes some, but not all pre-conditions for change as well as some, but not all potential target conflicts. There are, for example, no emergent effects or feedback loops considered (both of which will develop for any interventions over time). It is therefore a heuristic simplification of cause-effect relationships. This is a limitation of the model that relates directly to the issue of "SDG-washing" in SF (Boiardi, 2020, p. 8). If outcomes or even impacts are promised as a result of financing, it is crucial to understand if such claims are warranted or not (see also Teubler & Schuster, (2022) on the relevance of this criterion).

This means that any third party looking merely at the ToC or a summary of indicators in the impact assessment has no justification for the belief that any particular ESG model is true or that some model describes the actual causal relationship better than another model. This chapter deals with the question of how such a belief can be justified or rather, to what degree our belief (credence) in different causal strands within the presented ESG-model approach is warranted. And subsequently, it asks how different ESG-LMs fare in this regard compared to one another or any ESG model fares compared to reality. To that end, a set of tools is discussed that should enable the analyst to approach this question with a pragmatic epistemic standard that can be conveyed to any third party. The solutions developed here operationalise tools that are already used in other contexts (and even disciplines) both in an informal and formal manner. Any adaptations are, if not otherwise stated, restricted to changes in names of variables or specifications and explications for the purpose of the study at hand.

5.1 Definition of justified belief

The following section provides a definition of justified belief[20]. Whether and how *beliefs* can be *justified* is discussed in philosophy. A Deontological Justification (DJ), for example, merely requires that the actor is not obliged to believe otherwise (epistemically, morally, or otherwise), although such a belief might be involuntary (see Alston, (1988b)). From this perspective, it is justified in believing that taxonomy-aligned investments contribute to environmental goals because there is no (epistemic) obligation to refrain from doing so.

However, the problem and question discussed here are more closely aligned with the model of **Sufficient Likelihood Justification** (SLJ). SLJ can be summarised by the following statement: "S is justified in believing that p if and only if S believes that p in a way that makes it sufficiently likely that her belief is true" (Steup & Neta, 2020). What type of experience constitutes "sufficiency" in that context is open to debate though (see Alston, (1988a) for a comparative view of so-called *Internalism* and *Externalism*).

The tools discussed here also adhere mostly (but not exclusively) to **Reliabilism**, as described by the following sentence: "A belief is justified if and only if it is produced by a process that reliably leads to true beliefs" (Conee & Feldman, 1998, p. 1). There are several objections to the theory, of which the so-called "generality problem" is most important. The problem of generality states that any process of forming a belief relies on a large and different number of belief-forming process types (e.g., perception under different conditions), but that we have no way of knowing or defining which of these types is relevant (as in "reliable"). This objection is so severe that some scholars even argue that "reliability theories of justification and knowledge look hopeless" (Conee & Feldman, 1998, p. 24).

The definition I use in the following sections incorporates some these objections by applying Comesaña's theory of "Fine-Grained Evidentialist Reliabilism" (Comesaña, 2010). Although this theory does not counter all the objections, it is, in my opinion, sufficient in addressing the question of the validity of claims from ToCs and thus of the ESG-LM.

[20] This definition is not intended to add to the body of knowledge regarding this issue in the field of epistemology or to solve any disputes philosophers may have in regard the types of justified beliefs or what constitutes evidence (for example in regard to the Generality Problem of Reliabilism).

A slight adaptation of the original theory[21] states (Comesaña, 2010, p. 7) that a credence *cr* in proposition *p* by an actor *S* is justified if and only if (with Pr being a probability function, conditioned on evidence E and compared to a threshold r):

1. S's undefeated experiences provide him with p; or

2a. S's undefeated experiences provide him with E;

2b. S's credence cr in p is based on E;

2c. Pr (p|E) = cr;

2d. There is no more inclusive body of Evidence E' had by S such that Pr (p|E) ≠ cr; and

2e: S's resulting credence overcomes a pre-defined threshold r, such that cr ≥ r

Regarding the question of credence in the claims of an ESG-LM, only the second part (2a to 2e) is relevant, as the first option entails that no evidence is needed (making the ESG-LM obsolete in the first place). **Justified belief** towards the propositions in an ESG-LM can thus be defined as follows:

> A belief in the claims of causal strands in the ESG-LM is justified if its propositions are probabilistically conditioned on evidence, the credence of actors in these propositions can be shown to be above a reasonable threshold, and no additional evidence lowers this probability below this threshold.

Any tool must therefore establish that there is a body of evidence E, that raises the probability of a probability function cr of a proposition p being true equal or above the threshold r. On the other hand, this belief is not warranted if cr is below r or if E' was omitted that would lower the probability so that cr (p|E) < r.

It could be *reasonable* to set the threshold in such a way that indicators in the impact report are entailed by it. If, for example, the impact report estimates that the actions by 75% of the recipients of a loan programme will lead to a specific desired outcome, the threshold for a rational credence could be set at 0.75 or higher. Another, at least not entirely arbitrary threshold could be requirement of the majority of cases, such that r is greater than 0.5 (which is applied throughout the application of informal BR later on).

Any such threshold is obviously subjective, but so are all credences by actors even if they follow some common set of rational constraints in their reasoning (what convinces person A

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[21] I replaced the nominator x for credence with the nominator cr. This reduces the potential of misunderstandings when considering sets of causes (with x ∈ X) and is also more commonly used in the context of Bayesian Reasoning. Both are addressed later on in this chapter.

does not necessarily convince person B). This limitation is intentional though. It allows to establish joint thresholds by stakeholders (in e.g., a common reporting standard) but it also allows the notion of considering individually what degree of credence would convince a specific reader.

5.2 Causal inference in the ESG-LM

An epistemic justification process can be applied to any proposition being true or false, likely, or not likely. However, the ESG-M is a model of causal inference. Its underlying ToC describes how desired change comes about and what causes this change. Therefore, and in addition to an epistemology of warranted belief, a framework of this causal inference is needed as well. For a definition of causal inference in the ESG-LM, I mostly rely on arguments and epistemic considerations by James Mahoney and Gary Goertz (especially regarding set theory and differences between quantitative and qualitative cultures in the social sciences), Derek Beach and Rasmus Pederson (regarding within-case investigations), and Judea Pearl (regarding the distinction between “What”, “How”, and “Why” questions of causation).

Causality can be understood as merely a sequence of events in time (with causes preceding effects), but our own, everyday understanding of causal relationships usually involves additional conditions and relationships. Such relationships, and propositional arguments based on them, can be formal or informal as well as depicted by terms, sentences, and logic or with the help of graphical illustrations (e.g., with the help of Venn diagrams). While some causes or sets of causes are sufficient for effects, others might be necessary but insufficient or become only sufficient in conjunction with other causes. Classical population-oriented, or cross-case analytical models do not address questions of single causes from the outset, as they investigate variations of pairs of variables in some form of a weighted distribution. Looking at larger samples of cases with many independent as well as dependant variables, the actual causal relationships are deemed to be too complex to derive any *true-* or *not-true* relationship between single causes X and the observed outcomes Y. Although statistical methods exist that link correlating variables to causal relationships as a function of “difference-making”, such relationships are usually only looked at as “effects-of-causes” rather than “causes-of-effects” (see also Goertz & Mahoney, (2012) for an extensive discussion of the methodological consequences of both perspectives).

As described in the overall challenges relating to my model, such approaches would rarely be applicable anyway, as they require large sets of consistent empirical data in sufficiently large samples of cases for both the presence and absence of the interventions modelled. Instead, analysts usually deal with smaller sets of specific cases (e.g., a particular loan programme) with sparce empirical data, almost no monitoring of *ex post* effects, and stakeholder theories focusing on the presence of interventions. Such asymmetric causal claims (Beach & Pedersen, 2019;

Goertz & Mahoney, 2012) require other tools for investigation more often associated with qualitative rather than quantitative methods.

The different types of causal inferences in the ESG-LM are based on Logic and Set Theory instead (equivalent to my considerations regarding Contributions and Additionality). To that end, I distinguish cases where the presence of the intervention and the presence of an anticipated CM are either necessary or sufficient for the anticipated outcome. If the outcome is present anyway, no causal inference can be drawn.

The causal inference mechanic should also integrate all conditions that are not explicitly included in the model. This set of sufficient or necessary causes must include all configurations beside the included entities (with $x \in X$). I do so by defining a set of causal configurations X_{sys} that are necessary for the ESG-LM causal inference to be potentially valid and sufficient for everything else (invalid causal inferences from the ESG-LM per definition). These represent the current system as it is, or, or worlds with *all other things being equal*. It is assumed for example that a constructed residential building is inhabited at some point in the future, that produced electricity is consumed, that money is required to purchase services and goods and so on. These must be distinguished from requirements, or pre-conditions, outside of the scope of the ESG-LM that are required additionally (X_{add}) for the desired outcome (e.g., changes to laws and regulations, reactions by others reacting differently as a consequence and so on).

If that is the case, the following general cases can be distinguished for all possible worlds in which the outcome Y is present (Y=true=1) and a set of causes X is present (with the set of additional conditions (X_{add}) potentially being empty):

(1) **The intervention X_{int} is necessary** in every instance in which Y is a subset of X, and this superset consists of an intersection of X_{int}, X_{sys}, and X_{add}, so that
$\mathbf{Y \subseteq X_{int} \cap X_{add} \cap X_{sys}}$

(2) **The intervention X_{int} is sufficient** in every instance in which Y is a superset of an intersection of X_{int} and X_{add}, and that intersection is a subset of X_{sys}, so that
(2a) $\mathbf{X_{int} \cap X_{add} \subseteq Y}$ and (2b) $\mathbf{X_{int} \cap X_{add} \subseteq X_{sys}}$

(3) **The intervention X_{int} is neither sufficient nor necessary** in every instance in which the complement of X_{int} (X^c_{int}) is part of a subset or part of a superset of Y, so that
(3a) $\mathbf{X^c_{int} \subseteq Y}$ or (3b) $\mathbf{Y \subseteq X^c_{int}}$

Only conditional configurations depicted in (1) or (2) can be valid for causal inferences, as (3) does not even require any interaction with ESG-LM entities. However, there are additional configurations where Y is true and some part of the intervention is present, but not the entire mechanism depicted in the ESG-LM is necessary nor sufficient. The latter consists of propositions requiring at least two sets, so that one of those sets being absent makes the mechanic itself invalid (at least in the fraction of events where this is the case). Valid causal inferences in the ESG-LM can therefore described by the following set-equations.

(1a) The cause X_{cau} as well as its anticipated causal mechanism X_{cm} are present and they are sufficient but unnecessary parts of a causal condition that are themselves insufficient but necessary conditions for the desired effect (Y_{SUIN}), so that

$$\mathbf{Y_{SUIN} \subseteq (X_{cau} \cap X_{cm}) \cap X_{sys} \cap X_{add}}$$

(2a) The cause X_{cau} as well as its anticipated causal mechanism X_{cm} are present and they are insufficient but non-redundant parts of an unnecessary but sufficient condition for the desired effect (Y_{INUS}), so that

$$\mathbf{(X^{cau} \cap X^{cm}) \cap X_{sys} \cap X_{add} \subseteq Y_{INUS}}$$

All the above can also be summarised by adopting a contrafactual perspective. Necessary conditions for a proposition being true (at least $X^{cau} \cap X^{cm}$) in the actual world become sufficient for the non-presence of outcomes in a contrafactual world if they are absent.

Invalid causal inferences are cases in which Y=0 or $\neg Y_{valid}$
and either or both X_{cau} and X_{cm} are absent, so that

$$\mathbf{\neg Y_{valid} = \neg X_{cau} \vee \neg X_{cm}}$$

It follows that any justification must start by stating what the causal conditions in the intervention look like if they are present. These ESG-LM hypotheses are based on propositional logic and shown in the next section.

5.3 ESG-LM hypotheses from propositional logic

I use propositional logic, which is one of the most basic forms of logic reasoning, to derive hypotheses for the ESG-LM. It relies on different types of *connectives* (the following considerations are mainly based on Kashef's pre-print of *In Quest for Universal Logic* (Kashef, 2023). Connectives connect two or more statements with these propositions usually depicted as small letters or variables such as p, q, z, and r. There are five types of connectives that connect statements and define logical conclusion: Negation (¬), Conjunction (∧), Disjunction (∨), Material Implication (→), Material Equivalence (↔).

The previous considerations regarding valid causal inference in a world in which the surrounding system works as intended, align logically with a conjunction of a cause (p) and a related CM (q or z) for a desired effect (r) so that $p \wedge q \rightarrow r$. If p is true and q is true with all other things being equal, r follows. This is synonymous to the ESG-LM depiction of an Output r_1 from an Input p_1 and an Activity q_1 as well as a long-term Outcome r_A from that Output r_1 and an Intermediate Outcome z_1.

For example, the disjunct of two Outputs ($r_1 \vee r_2$) that either can be present for a long-term Outcome r_A and that are based on two separate conjuncts of Inputs and Activities, could be depicted in the following sentence:

(1) $(r_1 \vee r_2) \wedge z_1 \rightarrow r_A$ with

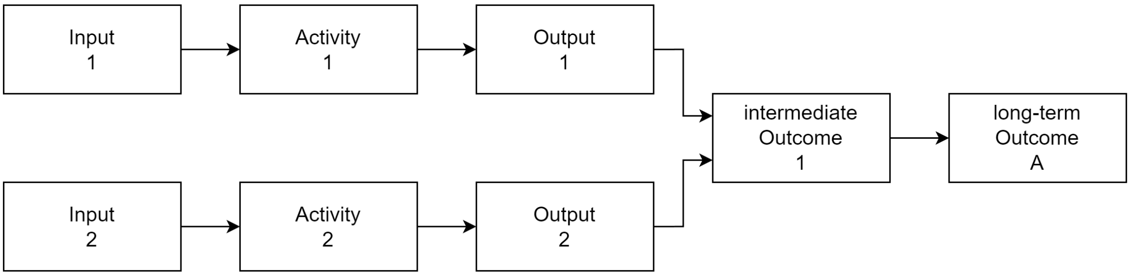
(2) $p_1 \wedge q_1 \rightarrow r_1$ and (3) $p_2 \wedge q_2 \rightarrow r_2$

so that the entire pathway can be described as

(4) $\{(p_1 \wedge q_1) \vee (p_2 \wedge q_2)\} \wedge z_1 \rightarrow r_A$

and which is equivalent to the following ToC in Figure 5-1.

Figure 5-1: example of propositional logic for a disjunct of two Outputs

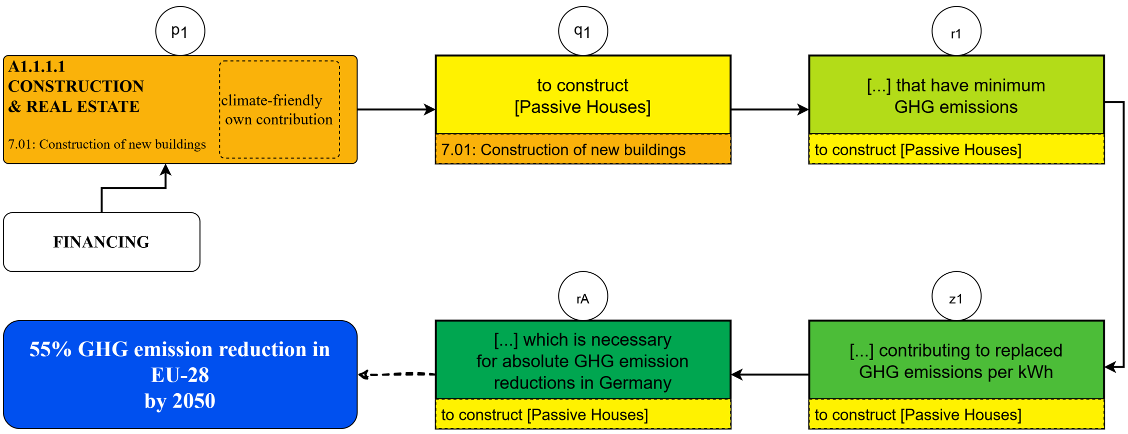


Source: own development

This propositional logic can also be depicted using the "language of the model" (see Section 2.4) and separated into propositions on the level of projects (from Inputs to Outputs) and propositions on the societal level (from Outputs to Long-Term Outcomes). Each outcome pathway can thus be described by two or more hypotheses in plain English that can later be tested and justified with other tools.

To illustrate this, I assume an ESG-LM that describes an Outcome Pathway from financing favourable loans for the construction of low-emissions residential buildings which are supposed to reduce the total German GHG emissions from energy demand. This can be displayed as an explication of the EUT (see Figure 5-2).

Figure 5-2: example of graphical propositional logic from the ESG-LM PT



Source: own development

This entails two logical sentences, or hypotheses H, that can be tested separately, but must be jointly true for a justification of the entire pathway.

(H_1) $p_1 \wedge q_1 \rightarrow r_1$
The loan programme provides capital for the EUT activity 7.1 that lead to the construction of residential homes that have minimum GHG emissions.

(H_2) $r_1 \wedge z_1 \rightarrow r_A$
The residential homes from the loan programme have minimum GHG emissions during use. This contributes to the replacement of GHG emissions in the use phase and thus is necessary for absolute GHG emissions reductions in Germany.

However, the process of justification (see next sections) could also trigger the identification of additional pre-conditions for success or an overall rework of the logic.

5.4 BR for ESG-LM Hypotheses

Bayesian Reasoning (BR) refers to arguments that are based on Bayesian Epistemology and Bayes Theorem (BT). They are used to investigate credences, and to argue for or against causal inferences conditioned on evidence (see Carrier, (2012) for both a formal and informal application). I use BR to test the ESG-LM hypotheses in an informal manner, resulting in some degree of confidence in the truth of the propositions. All Bayesian arguments rely on at least five core rules or rational constraints for belief and belief-updating from which BT can also be directly derived: the three Probability Axioms by Kolmogorov, the Ratio Formula, and Conditionalisation (I rely on *Bayesian Epistemology* by Titelbaum, (2022) for describing the main aspects of BR).

5.4.1 The five core rational constraints of Bayesian Epistemology

Kolmogorov's axioms are not unique to Bayesian Epistemology and are in fact common rational constraints for most probabilistic distributions. They define, regarding questions of belief, that credences are always higher or equal 0 (Non-Negativity), that a credence of 1 is true in every possible world (Normality), and that mutual exclusive propositions (disjuncts) in a complete set add up to a total credence of 1 (Finite Additivity).

The **Ratio Formula** states that an agent's credence in some proposition H conditioned on E is equal to the ratio of his credence in both propositions divided by his credence in E alone, so that for any H and E in Language L and if $cr(E) > 0$, $cr(H|E) = cr(H.E) / cr(E)$. It describes how conditioning on evidence (here E) restricts the set of possible worlds to those worlds in which that proposition is true. Our (probabilistic) credence in an evidenced proposition (H|E) therefore relates to a world in which both propositions are true compared to a world in which only the evidence is present.

The rule of **Conditionalisation** refers to beliefs over time. It states that the credence of an agent with evidence at a later time (t_j) is the same credence as supposing this evidence at an earlier time (t_i), so that cr_j (H) = cr_i (H|E) if cr_i (E) > 0. It is thus a rule for updating belief over time and conditioned on evidence. This evidence can be supplied as a whole or looked at one piece at a time.

5.4.2 Bayes Theorem

BT combines these rules (see Titelbaum, (2022) for a mathematical proof) by applying it to at least two competing hypotheses. Its propositional form is the basis for BR. It can be formulated in one of two ways:

$$cr\ (H_0|E.b) = \frac{cr\ (H_0.b)\times cr\ (E|H_0.b)}{\sum_n cr\ (H_n.b)\times cr\ (E|H_n.b)} \text{ (BT-1)}$$

$$cr\ (H_0|E.b) = \frac{cr\ (H_0.b)\times cr\ (E|H_0.b)}{[cr\ (H_0.b)\times cr\ (E|H_0.b)+ cr\ (\neg H_0.b)\times cr\ (E|\neg H_0.b)]} \text{ (BT-2)}$$

Equation BT-1 describes an agent's confidence in a hypothesis H_0[22] conditioned on both his background knowledge b and the presence of some body of relevant evidence E (the **posterior** probability). Note that, in Bayesian Epistemology, credences of 0 are restricted to logical fallacies and credences of 1 to tautologies[23]. One can also see that the probability of evidence being present is required to be higher than 0 for deriving any meaningful results from BT and that background knowledge is not evidence or vice versa.

BT-1 incorporates all mutually exclusive hypotheses from 0 (our focus) to n that sum up to a credence of 1 (Finite Additivity). The term cr (H_0.b) (equivalent to cr (H_0|b)) is called the **prior** probability, or our prior confidence in the proposition before considering the evidence. Claims on everyday events and causations usually have a high likelihood of being true (cr approximates 1), while extraordinary claims often come with a very low prior (cr approximates 0). The remaining components constitute the **consequent** probability (or consequent or so-called Bayes Factor). This is an agent's confidence in the probability of evidence being present conditioned on the main hypothesis compared to its probability conditioned on all the other hypotheses[24]. Note that, according to BT, evidence can be as likely on one hypothesis as on any other

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[22] The use of the index 0 does not indicate that this is a Null hypothesis, although BT can include and compare a Null hypothesis to other hypotheses in general.

[23] The formal BA in the case studies in Chapter 6 will indicate this by using ≈ for evidence that is fully expected under a hypothesis.

[24] The p-value in a conventional statistical analysis corresponds to cr (E|¬H_0) via cr ∼ Pr. A low p-value therefore usually corresponds to a high consequent probability that can, but does not have to, overcome a low prior probability.

hypotheses (the probabilities of E conditioned on different H's does not have to sum up to 100%). These components can be translated into more colloquial statements (based on Carl Sagan's original quote as well as its Bayesian adaptation contributed to Gwen Barnwen in Soares, (2016)):

(i) Extraordinary claims require extraordinary evidence.
(ii) Ordinary claims only require ordinary evidence.

Equation BT-2 is a short-cut of the propositional form. It compares the main hypothesis H_0 to all cases where it is not true (depicted by $\neg H_0$). This entails per definition a world in which one of all the other possible hypotheses are true and is thus an easier way to test hypotheses in ESG-LMs.

Two additional equations follow from BT that are useful for BR.

$cr\ (H_0.b) = 1 - cr\ (\neg H_0.b)$ (BT-2a)

$cr\ (E|H_0.b) = 1 - cr(\neg E|H_0.b)$ (BT-2b)

Equation BT-2a is simply a consequence of Kolmogorov's "Finite Additivity". If we know to which degree an agent's hypothesis is true, it follows that the remaining probability space is occupied by all other explanations (and vice versa). The same rule applies to the presence or absence of evidence. If the absence of evidence ($\neg$E) conditioned on the hypothesis is likely, it follows that it is unlikely to be present (and vice versa). This relates to arguments from silence for which absence of evidence is not necessarily evidence of absence.

5.4.3 Additional objective rational constraints

The previous considerations are true in every garden-variety of Bayesian Epistemology, as all Bayesians consider them rational constraints for agents. However, there is also a distinction between so-called subjective Bayesians, who only adhere to these rules and objective Bayesians, who allow for additional rational constraints. For the purpose of this study, I select two of the most common additional rational constraints, as they facilitate the confirmation process.

Lewis's **Principal Principle** functions as a rational constraint for a hypothetical prior probability (Titelbaum, 2022). It supposes that (i) there is a theoretical prior probability for any proposition (the hypothetical prior) and (ii) suggests that this prior can be defined by looking at the *objective* chance of *real* events. According to this principle, it is rational for agents to approximate their prior credence in the truth of hypothesis cr_H by comparing it to the objective chance (Ch) of events that align with this hypothesis (Ch_i (A) = x): If E is any proposition compatible with Ch_i (A) = x and that is admissible at time t_i, then cr_H (A|Ch_i (A) = x & E) = x. I adopt this principle because propositions from the ESG-LM refer to events that could be, at least in theory, shown to happen in some empirically determined ratio. For example, if there is evidence that 75 out of 100 loans in previous loan programmes resulted in the construction of residential passive homes, our prior credence in this hypothesis should be at or near 0.75.

The second additional rational constraint the ESG-LM adheres to is the **Principle of Indifference** as defined by Keynes in 1921 (Titelbaum, 2022). It simply states (summarised in this way by Titelbaum in his glossary):

> "If an agent has no evidence favoring any proposition in a partition over any other, she should spread her credence equally over the members of the partition" (Titelbaum, 2022, p. 565).

I have already showed how this principle can be used to derive a general Rule of Attribution if no additional information is available. In the context of BR, which is an informal and quick path to testing ESG-LM hypotheses, it can function as a tool in cases where we have no, insufficient, or ambiguous background knowledge. It is thus considered the default option, whenever we cannot or do not want to commit to a particular range of credence for the prior probability. Since at least two, but as many as *n* different explanations can be relevant, the prior probability of a hypothesis without know properties cannot be higher than 50% ($1/n$ for $n \geq 2$).

5.4.4 The integration of ranged credences and probability canons

Bayesian Epistemology is intended to provide a numerical distribution of credences with distinct values from 0 to 1 (which are results of the more formal BA discussed later). Critics of Bayesian Epistemology have argued that assigning concrete and definitive numerical values to the credences of agents is somewhat arbitrary and not justifiable from the application of BT alone[25]. By contrast, we often use probabilistic language if we think that a proposition is *likely* or dismiss a hypothesis out of hand because it is *highly improbable* or *virtually impossible*. One can therefore argue that BR is just a descriptive of our arguments for and against propositions. Although it is useful to have numerical credences to show *how much more* confident we are in one proposition over another, it is not necessary for deciding the overall credibility of individual claims. Good solutions to this problem, which I also use in my decision tree for BR, are so-called Ranged Credences and the application of a Canon of Probabilities.

The idea of **ranged credences** goes back to Levi ((1980) in Titelbaum, (2022)). Although it is a tool to investigate an agent's credences over several of doxastic attitudes at once, it can also be applied to a single hypothesis. Agents that adopt a ranged credence, with a lower and an upper bound value for cr, find it (i) permissible given the evidence and (ii) want to suspend judgement

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[25] Titelbaum (2022, p. 22) argues that we should not think of numerical credences as part of the content of a proposition, but rather as "a sort of property or adjustable parameter of a particular doxastic attitude-type: credence".

until further evidence emerges. An agent might for example have a lower credence of 0.6 in the feasibility of nuclear fusion in the near future in a *business-as-usual scenario* and a higher credence of 0.8 *under the best conditions* (given their background knowledge and the evidence available). This also means that applying a majority threshold for epistemic justification (as suggested in Section 5.1) can lead to more ambiguous results (e.g., with r=0.5 and cr between 0.4 and 0.6), and thus points to a representation of *we do not know (yet)*. The idea of ranged credences aligns neatly with the engineering praxis of assuming conservative estimates to be on the safe side of a quantification. It also aligns with arguments from **a fortiori** (arguments from the stronger reason) sometimes used by philosophers or in a court of law (d'Almeida, 2017). Both are very similar tools for inferences that can be used in BR. If, for example, an agent is confident in a proposition using their lowest permissible credence ($cr_{\text{a fortiori}}$), they are even more justified in believing that if their highest credence is considered (see Carrier, (2012) as an example of using a fortiori estimates in a BA).

Another tool that is helpful for a pragmatic solution to the quantified justification problem is the use of a **Canon of Probabilities**. Such a canon is any coherent translation of probabilities in everyday language that is consistent to credences larger than 0 and lower than 1. It simply depicts numerical credences or ranged credences as non-numerical probability statements. Such a canon can easily be constructed for any arbitrary number of types of probabilities by adding or removing escalations to probability terms we use in everyday language (e.g., *very probable*). However, if such a canon is too fine-grained, it might be difficult to distinguish between very similar descriptions of probability. On the other hand, a ranking that is too coarse defies the purpose of Bayesian Epistemology since it might prevent any identification of meaningful credences that represent our confidence in propositions. One can compare this problem to developing semi-quantitative rankings for items in surveys. Rating something on a scale of 1 to 20 allows for more fine-grained distributions than a scale of 1 to 10, but it also becomes increasingly difficult for actors to do so consistently across a large number of questions. The scaling should also include statements of almost certainty as well as statements of ambiguity to be useful. An example of the first would be a causal proposition where the effect is entailed in the CM. If, for example, an intervention leads to additional cycling by actors, the Output "increased physical activity" is a tautology and thus justified with almost 100% ($cr \approx 1$). An example for the latter would be a contradiction such as "constructing single-family homes leads to less living space" ($cr \approx 0$).

As a result, I developed the following Canon of Probabilities to be used for the Bayesian Argument and Decision Tree to be presented in the next section. I use everyday language to describe the prior conditioned on background knowledge, the consequent of evidence given the hypothesis, and the posterior representing the credence after a belief-update. It incorporates the notion of a threshold for epistemic justification (r=0.5), it allows for ranged credences, and it enables actors to distinguish credences that require judgments from those that do not. Note that, when using the table, it implies in accordance with Bayesian Epistemology that any hypothesis has an ever so slight chance of being true and vice versa ($0 \prec cr \prec 1$).

Table 5-1: Canon of Probability for informal BR in ESG-LM

Prior cr (H|b)	**Consequent** cr (E|H.b)	**Posterior** cr (H|E.b)	**Credence** cr = P
tautology	fully expected	certain of H_i	$cr \approx 1$
extremely probable	extremely likely	extremely confident in H_i	$0.95 \preccurlyeq cr \preccurlyeq 1$
very probable	very likely	very confident in H_i	$0.80 \preccurlyeq cr \preccurlyeq 0.95$
probable	somewhat likely	somewhat confident in H_i	$0.60 \preccurlyeq cr \preccurlyeq 0.80$
no judgement	not surprising / expected	unsure about H_i	$0.40 \preccurlyeq cr \preccurlyeq 0.60$
improbable	somewhat surprising	somewhat confident in $\neg H_i$	$0.20 \preccurlyeq cr \preccurlyeq 0.40$
very improbable	very surprising	very confident in $\neg H_i$	$0.05 \preccurlyeq cr \preccurlyeq 0.20$
extremely improbable	extremely surprising	extremely confident in $\neg H_i$	$0 \preccurlyeq cr \preccurlyeq 0.05$
contradiction	impossible	certain of $\neg H_i$	$cr \approx 0$

Source: own development based on Carrier, (2012)

5.4.5 Bayesian Reasoning in ESG-LMs

I use all of the previous considerations to develop a simple tool to test any single proposition that an ESG-LM implicitly entails: a Bayesian Argument as well as a Bayesian Decision-Tree based on that argument. It is compatible to a Carnap-like[26] theory of confirmation (Titelbaum 2022, p. 208), which states that E confirms H relative to some background knowledge b just in case cr (H|E.b) > cr (H.b). And from Comesaña, (2010) follows that S is justified in believing H (as in: the claim is credible) if cr (H|E) > r and if there is no more Evidence E' had by S such that Pr (H|E) ≠ cr.

There is a last challenge to be tackled before the tool can be applied in an impact assessment and that is the question of ESG-LM hypotheses that are in a relationship with each other. Using the tools above would indeed provide an agent with a better understanding of the credibility of any causal connection between two entities in the ESG-LM. One could for example estimate the posterior for at least four such connections in each Outcome Pathway to the degree that the available background knowledge and evidence allows. However, the tool is intended to provide a process by which agents can assess quickly whether the ESG-LM pathways are reliable and

[26] I call this tool Carnap-*like*, because the original theorem of Rudolf Carnap on the degree of confirmation was applied to any regular distribution Pr and not just cr. It also included the so-called firmness concept of confirmation that only relies on cr (H|E) being *high*. The latter has been shown to be an invalid reference from Carnap's arguments alone.

credible, thus being time-efficient during assessment and helpful in future re-iterations of the model structure.

I do so by looking at more than one causal connection at once and by connecting the hypotheses on the level of projects to the hypotheses on the level of societies. It speeds up the process, but also decreases the accuracy of the results, or rather, the robustness of the arguments as additional attributes (as conjuncts) in a proposition usually reduce its credence. It also poses a problem for the availability of evidence as it is either less likely that there is specific evidence relevant to all components of a propositions, or that the evidence that is found is less likely to be relevant to all conjuncts at the same time. This is why this acceleration of the process usually results in lower credences, which is formulated in the following cases:

(1) The overall confidence of an agent in the truth of a conditioned proposition with two connected propositions (H_2 relying on H_1 being true) should be proportioned to the hypothesis with the lower degree of credence.

(2) The overall confidence of an agent in the truth of two combined propositions if both of them need to be true (conjunct) should be proportioned to the proposition with the lower degree of credence.

(3) The overall confidence of an agent in the truth of proposition, if either one of them can be true (disjunct), can be proportioned to the proposition with the higher degree of credence.

Case (1) relates to any relationship between the hypotheses on the project level (from Inputs to Outputs) and their dependent hypotheses on the societal level (from Outputs to Long-Term Outcomes). Disconfirming the first does not disconfirm the second per se (desired outcomes can still occur), but it disconfirms the causal relationship presupposed in the ESG-LM.

Case (2) relates to any relationship between hypotheses in the ESG-LM and the presence of external conditions. While one can safely assume that the general surrounding system plays out as established with or without the intervention, there can be additional pre-conditions where this is not the case. Disconfirmed pre-conditions that have to be present (conjunct from necessary conditions) can therefore also disconfirm the main hypothesis in the ESG-LM.

Case (3) relates to the parallel hypotheses such as several intervention pathways contributing to the same goals (more than one Output connected to the same Intermediate Outcome). Disconfirming one of these propositions does not disconfirm the other (disjunct from sufficiency). However, this does not imply that confirming one hypothesis also confirms its parallel counterpart.

I depict these relationships, the potential results, and their interpretation along four stages in my confirmation theory. The first two stages are considered to have a low reliability. An agent knows more after considering these arguments but should refrain from bold statements of confirmation when reporting on them. The second two stages are considered to result in a higher reliability, even if considering these arguments led to an ambiguous assessment of credibility (they are still based on more knowledge). An agent not only considered the overall plausibility at this point but had evidence to confirm or disconfirm the original hypothesis. I show a full Bayesian Decision-Tree for practitioners that is solely based on yes- or no-questions in the Appendix (see A-5). A more condensed form of the logic is described in the following paragraphs.

I develop a Bayesian Argument in stages I to IV, of which only stage IV includes all elements of BR. These elements are either present or not present and either true- or not-true (e.g., E versus ~~E~~ compared to ¬E versus ~~¬E~~). They have different degrees of reliability R and comprise of the following set of variables.
The probability Pr of the main hypothesis Pr(H) and its alternative explanations Pr(¬H), the presence of E as well as its probability conditioned on the propositions Pr (E|H) or Pr (E|¬H), the background knowledge b and *objective* chances Ch (so that Ch_i (A) = x). The credences cr of the user are either based on the presence of evidence and alternative explanations so that cr (H|E) or on the non-presence of evidence and/or alternative explanations. The final conclusion is depicted at a time j compared to an earlier time i before considering the arguments, so that cr_j (H) entails more relevant information than cr_i (H). It is justified if cr_j (H) > r with r=0.5 (the majority of cases).

The terms **Hoop-Test** and **Doubly-Decisive-Test** in the following summary of the stages in Table 5-2 are drawn from Befani & Mayne, (2014), whereas the reasoning for the **Silence-Test** is based on Carrier, (2012) (all of which are aligned with Bayesian Epistemology):

Table 5-2: stage I to IV arguments for ESG-LMs (with increasing reliability)

Stage	**must be present**	**can be present**	**Argument**	**R**

Stage I: Prior-Test
Arguments from Triviality
	H; b	E; ¬H	if cr_i (H.b) ~ Ch_i (A.b) = x AND x ~ 1, then
			cr_i (¬H) ~ 0 AND cr_j (H.b) ~ 1 ≻ r OR
			if cr_i (H.b) ~ Ch_i (A.b) = x AND x ~ 0, then
			cr_i (¬H) ~ 1 AND cr_j (H.b) ~ 0 ≺ r
				very low

Stage 2: Silence-Test Arguments from Theoretical Certainty	H; b; ~~E~~	¬H	if Pr (E) ~ 0 AND cr_i (H.b) ≻ r OR cr_i (H.b) ≺ r OR cr_i (H.b) ~ r, then cr_j (H) ≻ r OR cr_j (H) ≺ r OR cr_j (H) ~ r	low
Stage 3: Hoop-Test Arguments from Empirical Certainty	H; b; E; ~~¬H~~	-	if Pr (E|H.b) ~ 1 AND E=1 AND cr_i (H.b) ≻ r, then cr_i (H|E) = cr_j (H) ≻ r OR if Pr (E|H) ~ 1 AND E=0, then cr_i (H|E) = cr_j (H) ≺ r	medium

Stage	must be present	can be present	Argument	R
Stage 4: Doubly-Decisive-Test Arguments from Empirical Uniqueness	H; b; E; ¬H	-	if cr_i (H) ≻ r AND Pr (E|H) / Pr (E|¬H) ≻ 1, then cr_i (H|E) = cr_j (H) ≻ r OR if cr_i (H) ~ r AND Pr (E|H) / Pr (E|¬H) ~ 1, then cr_i (H|E) = cr_j (H) ~ r OR if cr_i (H) ≺ r AND Pr (E|H) / Pr (E|¬H) ≺ 1, then cr_i (H|E) = cr_j (H) ≺ r	high

Source: own development

The arguments can also be described more colloquially in the following manner:

<u>Stage I:</u>
The proposition is so trivial that its probability of being true approximates 100% (or vice versa, it is extremely unlikely). It is therefore unlikely that additional relevant information would sway a rational agent with access to the same background knowledge. However, without such evidence and the consideration of alternative explanations, the agent is warranted to believe their conclusion on the credibility or non-credibility of the claim with only a very low reliability.

<u>Stage II:</u>
If an agent has sufficient confidence in the prior probability of the proposition and if it is expected that evidence for or against this proposition *cannot exist* (rather than *could not be found*), they are warranted to believe that their posterior credence equals their prior credence. However, without such evidence and the consideration of alternative explanations, the agent is warranted to believe their conclusion on the credibility or non-credibility of the claim with only a low reliability.

<u>Stage III:</u>
If an agent's proposition entails that certain evidence strongly confirms an already sufficiently high prior credence and this evidence is present, they can have medium confidence in that proposition being true. On the other hand, if such evidence is expected but not present (or present but disconfirming), they can have medium confidence that the proposition is false regardless of their prior credence (this is also often referred to as Hoop-Test in the literature). However, both arguments can easily be overturned if additional evidence E' is found and included or if the evidence is conditioned on alternative explanations.

<u>Stage IV:</u>
Only this last stage includes all components of a Bayesian Argument. It requires some prior credence (at best based on objective chances) and conditions this credence on available relevant evidence. This evidence or body of evidence confirms the hypothesis if it is more likely under

this proposition than on any other explanation. Conversely, it can disconfirm the proposition if it is more likely on the alternative explanations even to a point that an initial high credence is overturned. This argument, that provides an agent with high confidence in their credence, is still open to a belief-update. Any new evidence E' can confirm or disconfirm the previous conclusion so that cr_{j2} (H) = cr_{j1} (H|E').

All of these stages also allow for agents to suspend further judgement or to be undecided (r ~ 0.5 or r = ?). The reliability of this conclusion, equivalent to "I cannot decide if the claim is credible", still increases with having additional information though. The conclusion of being undecided on the issue from a Stage IV argument is therefore more reliable than coming to the same conclusion from a Stage III argument. Chapter 6 will apply this Bayesian Argument to test the credibility of six hypotheses from three cases.

5.5 Additional tools for epistemic justification

5.5.1 Bayesian Analysis (BA)

BA is the formalised version of BR. It is more precise, even when using ranged credences and it depicts which part of the evidence solely relies on empirical data compared to evidence that is more based on epistemic standards, estimates, and literature. It also shows the weight of each piece of evidence, which makes it easier to identify crucial evidence and to review assumptions. An example of a BA can be found in Carrier, (2014), but it was also used in one of my previous studies (Teubler & Schuster, 2022).

BA uses BT and can usually be associated with objective Bayesianism (rational constraints in addition to the five core rules of Bayesian Epistemology). It is for example useful to adhere to the Principal Principle when estimating the prior probability of a hypothesis (see Section 5.4.3). It can also be helpful to work with the odds-form of BT, as shown in equation (BT-3a) for two competing hypotheses and three pieces of evidence E_1 to E_3.

$$\frac{cr\ (H|E)}{cr\ (\neg H|E)} = \frac{cr\ (H)}{cr\ (\neg H)} \times \left[\frac{cr\ (E_1|H)}{cr\ (E_1|\neg H)} \times \frac{cr\ (E_2|H)}{cr\ (E_2|\neg H)} \times \frac{cr\ (E_3|H)}{cr\ (E_3|\neg H)}\right] \text{(BT-3a)}$$

The second part of the equation (here in brackets) is called the likelihood ratio and it can either be calculated by conditioning each piece of information on the hypothesis and its alternatives or by multiplying all ratios at once. The equation above delivers the same result if belief-updating is considered (see BT-3b) and is therefore a simple tool to show the weight of different pieces of evidence.

$$\frac{cr_j\ (H|E)}{cr_j\ (\neg H|E)} = \frac{cr_i\ (H)}{cr_i(\neg H)} \times \frac{cr\ (E_1|H)}{cr\ (E_1|\neg H)} \times \left[\frac{cr\ (E_2|H)}{cr\ (E_2|\neg H)} \times \frac{cr\ (E_3|H)}{cr\ (E_3|\neg H)}\right] \text{(BT-3b)}$$

One advantage of this presentation is that it also allows the use of empirical information directly if the odds of Pr (E_n|H) compared to Pr (E_n|¬H) are known. If for example the ratio of male to female borrowers is known and this fact is relevant to the competing claims, it can be put directly into the formula. It can sometimes also be easier to estimate the overall ratio then the probability for each part alone, especially since different probabilities can lead to the same ratios (e.g., 0.5:0.5 delivers the same result as 0.8:0.8).

Another advantage of this approach is that additional characteristics of BT can be applied when looking for relevant evidence. It follows from BT-2b (see Section 5.4.2) that the probability of the evidence conditioned on a proposition is finite additive to its absence conditioned on the same proposition so that $Pr(E|H) = 1 - Pr(\neg E|H)$. This relationship can be applied to both the numerator and denominator of the likelihood ratio. This means that a high probability of the absence of evidence under an alternative hypothesis translates into a low probability of its presence and thus to a high likelihood for confirming the main hypothesis.

All of the above are arguments in favour of BA over BR. It does require additional data though, even if the process of previous impact estimation and reporting already includes some of the necessary information. BA thus entails a much more time-consuming process and extensive documentation of background knowledge, empirical data, auxiliary variables and, if necessary, ad-hoc assumptions. All case studies in Chapter 6 will include a more formal BA as well as the informal BR.

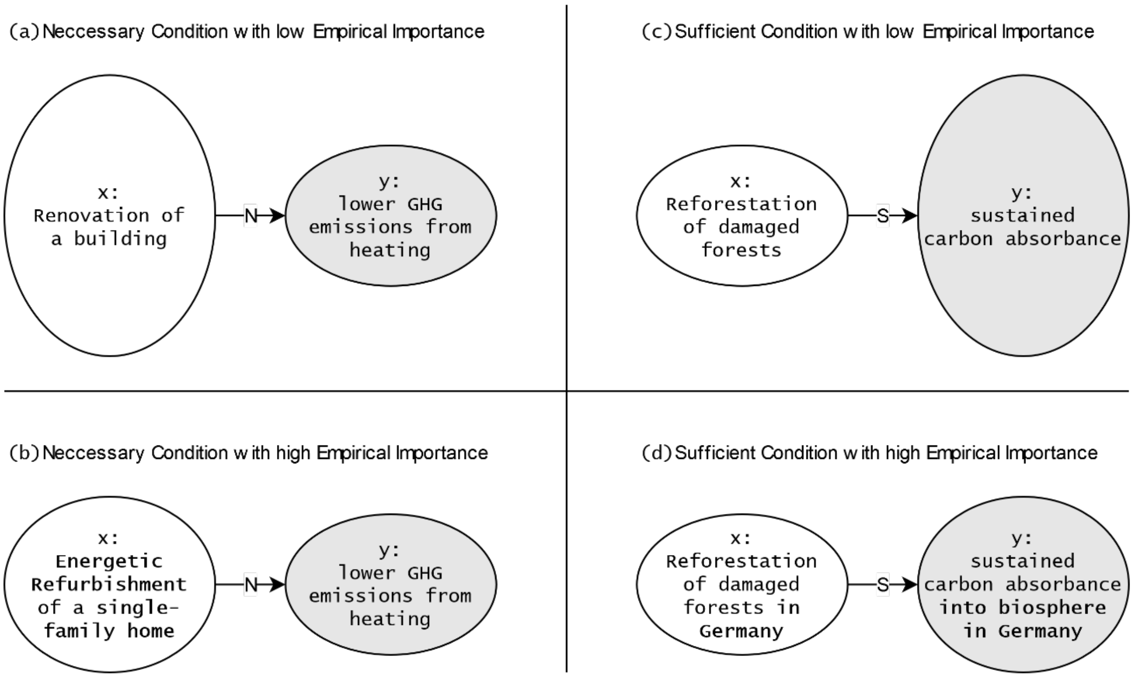
5.5.2 Counterfactual Reasoning (CR) in ESG-LMs

All the previous considerations presuppose asymmetry between causes and effects. The ESG-LM only looks at cases where an intervention on the project level is present (and outcomes on the societal level) but does not describe or investigate worlds in which this is not the case. Such predictions could be made if assessors knew — for certain — whether the interventions were necessary. A necessary but absent cause is equal to no outcome, whereas an absent sufficient intervention could have no impact whatsoever. A tool to investigate these various possible worlds could therefore also be useful in justifying our confidence in the efficacy of interventions even without considering specific evidence.

Mahoney & Barrenechea, (2019) introduced several concepts in their article on "the logic of counterfactual analysis", that could be helpful here. First, they introduced the concepts of (a) **Necessary Condition Counterfactuals** and (b) **SUIN Condition Counterfactuals** when describing counterfactual worlds for outcomes dependant on necessary conditions. In these cases, conjunct necessary antecedents in the actual world become disjunct sufficient conditions for a world in which some other, counterfactual outcome occurs, so that for example $Y = X \wedge Z$ becomes $\neg Y = \neg X \vee \neg Z$. Conversely, (c) **Sufficient Condition Counterfactuals** and (d) **INUS Condition Counterfactuals** describe conjunct necessary counterfactual antecedents, so that for example $Y = X \vee Z$ becomes $\neg Y = \neg X \wedge \neg Z$. While the latter two describe cases where the absence or presence of interventions in the ESG-LMs can, but must not be irrelevant to the desired outcomes, the first are clearly required and are thus a good indication for some credibility of the claim.

Secondly, the authors also introduce the concept of **Empirical Importance**. Empirical Importance is defined as the extent to which necessary causal conditions are also sufficient conditions and vice versa. A necessary condition that entails the outcome (the set-theoretic definition of a necessary condition) is more empirically important the more often its presence leads to that outcome. The following Figure 5-3 shows two such conditions on the left side with the figure on the bottom being empirically more important. On the other hand, a sufficient condition that is entailed by the outcome (the set-theoretic definition of sufficiency), is more empirically important the more often it is present, if the outcome occurs (the bottom-right figure compared to the top-right figure in Figure 5-3). Probabilistically speaking, empirically important conditions describe worlds in which the presence of causes and their effects are very common (similar to a high prior credence based on background knowledge).

Figure 5-3: low and high Empirical Importance from necessary or sufficient conditions



Source: own development based on Mahony & Barrenechea (2019)

Thirdly, the authors describe the **minimal-rewrite rule**. This "rule holds that the most useful counterfactuals are those that require the fewest changes to the actual world" (ibid., p. 11). This means that extraordinary counterfactual outcomes usually require implausible counterfactual antecedents or rather a chain of such conditions (so-called enabling counterfactuals) where at least one link is very unusual. By contrast, plausible counterfactual antecedents do not require much imagination in order to bring the counterfactual outcome about. This is usual true for very specific conditions leading to specific outcomes, when a minimal but plausible change to a set of causal conditions prevents the actual outcome. This does not mean that all initial plausible counterfactual antecedents are automatically also plausible after conducting a full Counterfactual Analysis (CoA). Small changes, that is counterfactual antecedents with the least changes or from a minimal-rewrite of the causal relationships, can very well be irrelevant if other conditions provide better explanations.

These three concepts can provide a good basis for iterations of the ToC logic in the scheme, but they can also be used to justify the credibility of its claims. Such a chain of arguments would be necessarily less robust than a BA or even BR from actual evidence. It should of course also not supersede any empirical knowledge (in fact, it should be based on such knowledge if available). It is therefore rather an additional tool one can use if such evidence is not available or if such evidence still leads to an ambiguous result.

Due to its set-theoretic background, it could also be used as a starting point for a multi-value or fuzzy-set Qualitative Comparative Analysis (Ragin, 2006). However, given that this does require additional empirical data (usually at least on the macro-level entailing the investigated cases) and ad-hoc assumptions, it could then be more beneficial to conduct a BA or to use Causal Diagrams (CD) instead.

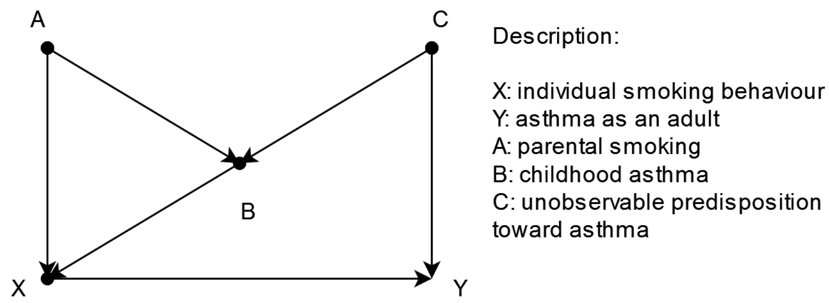
5.5.3 Causal-Diagrams from ToCs in ESG-LMs

All previous tools and the entire theoretical framework is based on the experience of analysts, that there is, typically, not sufficient data to apply more classical population-based methods such as regression analysis. Even in cases where such data might be available, such data usually only covers parts of the entire pathway. This means that even an ideal case where empirical data is available in large samples for both the presence and absence of interventions and Long-Term Outcomes, it is difficult to ascertain whether the actual intervention is responsible and if the found relationships are spurious. However, it is entirely plausible that such data is collected in a way that is at least sufficient to quantify significant difference-making on the level of projects by single entities. Some of the current reporting standards in Europe for example (CSRD, EU Taxonomy) seem at least to presuppose the existence of such data sets by reporting entities. I suggest using so-called **Causal-Diagrams** (CD**)** and J. Pearls **do-operator** and **backdoor criterion** to establish a statistical causal inference in these cases.

According to Pearl (Pearl, 2009; Pearl & Mackenzie, 2019), most variance-based (stochastic) methods cannot explain "why" something happens, but rather "what" happens "if" a set of causes is present. It is the distinction between these queries a system can answer, that allows lower and higher levels of causation to be identified. The level of associations is the lowest level (or *lowest rung on a ladder*). It responds to the query of *what if I see* by making predictions based on observed data. It is most commonly related to statistical analysis, for example whether two variables x and y correlate. The second level of interventions can be described by the queries *what if I do?*. This relates to changes that are caused by interventions and require causal propositions (or CD), even if data can be observed. Level 2 causations tell us for example *how* y changes, if we assume that x causes y. The third and highest level of causation are counterfactuals[27]. They respond to the query of *what if I had done*.

Pearl's *do-operator* identifies confounding variables if P (Y|X) ≠ P (Y|do(X)), but it is the depiction of the causal pathways themselves that allows a researcher to control only for those variables that lead to spurious relationships. The basic relationships in such a diagram are (i) chain junctions (X → Z → Y), (ii) forks (X ← Z → Y) and (iii) colliders (X → Z ← Y). Controlling for Z in (i) or (ii) *blocks* the pathway, whereas the doing the same in (iii) allows for the information to *flow through*. The same is also true for any descendants of Z (at least partially). A fully explicated causal model therefore allows one to test for confounders and to distinguish such variables from those that merely correlate. The following Figure 5-4 provides an example. Controlling only for the collider at B in this case would open a pathway that is currently blocked (the M-shaped bias from X ← A → B ← C → Y). The researcher therefore would have to control for A as well (with C being unobservable and thus uncontrollable).

Figure 5-4: example of new confounders from controlling variables



Source: Pearl, (2009, p. 162)

The ESG-LM is, for the most part, a causal model of intervention (rung 2 causation) that uses a generative framework for causal inference (see Table 1 in Befani & Mayne, (2014) for a comparison of different frameworks). It describes the outcome pathway between an intervention (Input) and a goal (Impact). CDs work in a very similar way, in that they also depict graphically how causes trigger effects via conjuncts, disjuncts, and mediating factors. It is thus possible to translate an ESG-LM into CDs for an empirical study for either or both impact measurement

[27] It should be noted that not every counterfactual logic adheres to this framework. Counterfactual Statistical Analysis (not to be confused with CoA from the previous section) for example attributes outcomes to intervention but does so via a process of association. The actual CM is therefore not investigated (or tested) with these methods. They also usually focus on single causes and single effects.

and epistemic justification. If such an empirical study is already available and is depicted in form of CDs, it can also function as the main source for ESG-LM development.

5.6 Limitations and comparison of the tools

I have developed one main and introduced three additional tools for epistemic justification. Each of these tools comes with different demands in terms of data, time, and expertise.

BR as the main tool is intended to provide analysts with a quick assessment of the credibility of the claims of an ESG-LM. Such arguments can either be drawn indirectly from a Bayesian Decision Tree or directly based on the available information and a rough estimate of Bayesian probabilities over four stages with different degrees of reliability. The main advantage of this approach is its useability in cases where relevant data is missing, stems from different sources, or can only be depicted in a qualitative manner. An expert in the subject matter of a particular ESG-LM has thus an easy tool at their disposal to quickly assess whether the underlying hypotheses are believable or even trivial descriptions of reality. A non-expert practitioner on the other hand can use BR to identify or collect relevant information and can at least assess the reliability of their credence given the available information. The limitation of this approach, as well as the more formal BA, is its dependence on the correct application of the rules of Bayesianism as well as its dependence on information (in particular evidence) that has not been collected. Both the four stages of the Bayesian Argument and the decision tree are constructed in a such a way that these effects are mitigated. However, simple misunderstandings of Bayesian Epistemology (e.g., not accounting for Additivity of all competing hypotheses or including the same piece of relevant information twice) as well as deceptive practices (e.g., leaving out a piece of crucial evidence on purpose) can lend to *impact washing* rather than mitigating it. An additional disadvantage, rather than a limitation, is that Bayesian Epistemology is not commonly applied or even known in disciplines usually associated with commercial evaluation practices. Whereas Bayesianism is a *gold standard* for rationality in philosophy and increasingly used in qualitative social sciences, it is often regarded as inferior to conventional empirical methods in quantitative social sciences or economic studies. The last disadvantage is also, or even more, relevant to the remaining tools presented in this chapter: CoA and CDs.

CoA is based on causal set theory. Its three main components (counterfactual conditions, Empirical Importance, minimal re-write rule) are helpful for theory-building, but they can also facilitate epistemic justification. The advantage of this approach is that it does not require any data (although such data clearly enhances its results). If the analyst, expert, or non-expert, can argue convincingly why the absence of a cause also denies the desired outcome, they can also better describe conditions in which the outcomes should be achieved. This type of symmetry-building for asymmetric causal claims is at best a tool for further confirmation, and at least a tool to discard interventions that have no or only minor impact on the real world. The disadvantages of the tool are associated with risks from oversimplification and high case-specificity. It is usually not difficult to come up with a specific example in a specific case where the assessed cause did or did not trigger a desired outcome — especially if the underlying system is described in broad terms. It is up to the analyst to show, and provide background knowledge, why the argument and its implications also hold for a broader set of generic cases. This, however, requires expertise in the subject matter and a robust understanding of set-theoretic causal configurations.

CDs on the other hand seem like the perfect tool from the outset. A statistical analysis that investigates the claims of an ESG-LM, has observational data, and is modelled with the help of CD, can at best both quantify and justify impacts. The main limitations are therefore lack of expertise and lack of data. CD requires large-N samples for the identified relevant variables as well as expertise in modelling, statistics, and programming. It is also a time-consuming (iterative) process that is currently not commonly used in the social sciences (CD studies are usually conducted in AI research, biology, and epidemiology). However, I added this tool to the tool-set precisely because it could become relevant in the future. This dissertation and the methods herein are intended to facilitate non-academic impact assessments, but they should also facilitate academic research where such data and expertise are present.

6 OPERATIONALISATION AND CASE STUDIES

The tools presented and operationalised here are intended to work for any ESG-LM. However, realistic examples from the world of SF are helpful in describing and understanding the advantages and limitations of each tool. I selected projects from three different Bonds as case studies, all of which have already been assessed in the past to different degrees.

6.1 Overview of process steps (operationalisation)

An ESG impact assessment from scratch in line with the ESG-LM is conducted in five steps. If final results are deemed unreliable by the analyst or more robust and detailed results are possible in principle, the process is iterative and can be repeated for each of the components.

6.1.1 Initial ToC model

The goal of this step is to understand and depict the initial underlying assumptions for change and to derive the hypotheses to be tested. The first step is to sketch the outcome pathways in a ToC. The entities and heuristics described in Chapter 2 and the PT described in Chapter 3 can be used as a blueprint for this purpose. Simpler and shorter causal relationships can be used instead if the investigated case or the desired outcomes in question are not well-understood in literature. Although the ESG-LM caters towards linear, lean, and mechanistic relationships, more complex ToCs could be useful at this point, especially if they are already established in literature or within an organisation. Such ToCs usually put more emphasis on the conditions for successful interventions, the risks involved, and the stakeholders affected. An example of such an intervention- and organisation-focused ToC can be found in Fagligt Fokus, (2015).

6.1.2 Data collection

Three types of data are useful for the ESG-LM. Background knowledge, usually derived from academic literature and white papers, establishes the general plausibility of the claims. Its main purpose is to develop the logic models heuristically and to derive the prior probability for BR. Impact data relates both to primary data that constitutes an indicator along the outcome pathways as well as any estimates and results from models and auxiliary variables. The third type of data is evidence, that is, information relevant to the causal hypotheses as it either raises or lowers an agent’s credence in the claims. Some evidence can also constitute impact data and vice versa.

Due to the rule of Conditionalisation in BT, not all data has to be categorised definitely at this point and the actual process can be repeated if new evidence is found (cr_j (H) from cr_i (H|E) can be used as prior for the next iteration). Some data might be considered evidence first and transferred to background knowledge later. It is also possible to apply typical background knowledge (as found in academic literature) as evidence if a tight comparison of cases is feasible. Both options are aligned with the method of epistemic justification, as long as the same piece of information is not used in estimating both the prior and consequent probability.

6.1.3 Explication of hypotheses and epistemic justification

The goal of the third step is to assess the credibility of claims entailed in the ESG-LM. To that end, at least one hypothesis for the effects on project level and one hypothesis for the effects on the societal level have to be formulated, refined, and tested. These hypotheses can include causal configurations beyond what I recommended in Chapter 5, as each hypothesis is assessed as a whole and in conjunction, or disjunction with its counterpart. By including, for example, the additional actions of stakeholders or pre-conditions from the surrounding systems, a more detailed set of causal conditions can be explicated. However, this usually comes at a cost, as the process becomes more time-consuming, requires more information, and is more difficult to be assessed with the simple 4-step BR developed in Chapter 5. It might therefore be more feasible to restrict hypotheses to clear and concise relationships and assess further conditions in other parts of the assessments (e.g., in the form of Rebounds and Hazards).

The degree and reliability to which the credence in the claims is estimated can differ depending on the goal of the study and it can be an iterative process as well. Establishing an argument from triviality for example might suffice for a pilot study and annual reports can build on previous collected background knowledge and evidence. A more research-oriented study (e.g., for theory-building) on the other hand, might require a full and formal BA or even empirical studies for parts of the ESG-LM (see Chapter 5.5).

The result of this step is a posterior credence for the hypotheses given the background knowledge and evidence. It shows whether a rational actor is warranted to believe in the claims explicated in the ToC. A full 4-step BR process resulting in a reliable claim will also show if the initial prior credence required this evidence in the first place to justify this credence or if the available background knowledge has already been sufficient (with evidence merely re-enforcing belief).

6.1.4 Rework of ToC and potential indicators

The fourth step preludes the actual impact assessment but builds on the previous steps. The goal is to establish an assessment framework that depicts why desired effects might occur and what the analyst looks for when reporting on the impacts. It translates the heuristic ToC and its underlying hypotheses into a full ESG-LM, that conveys the relevant background information to any third party. As noted previously, this step can be repeated several times during one or over the course of several assessments. The ESG-LM includes any additional information needed to understand how the causal relationships are understood, what additional conditions have to be met and how warranted a rational actor might be in believing the claims. It also shows how an ideal assessment, given all potentially available information, would look like. This usually requires some form of rationale or narrative, a rework of the initial ToC, and a set of potential indicators on the societal level.

The update of the ToC can be guided by set theory, as shown, and is discussed in Chapter 5. For sufficient or INUS causal configurations, causal sets should increase, and effect sets decrease as much as possible (the standard case in ESG-LMs). Vice versa, for necessary or SUIN causal configurations, cause sets decrease, and effect sets increase during the process. The set of potential indicators depicts what type of information should be ideally reported on each level of the ToC. These indicators can later be compared to the actual assessment and its limitations regarding the data collected and methods used.

6.1.5 Impact assessment and interpretation of results

An ideal impact report would only depict quantitative *ex post* primary data by the Actors involved in the outcome pathway or otherwise observed quantitative information. This is usually not achievable, as data is scarce even on the intervention side of the ESG-LM, where such data could be more easily collected. Some part of the impact report therefore relies on impact assessments that estimate *ex post* effects or predict such effects *ex ante*.

As discussed in Chapter 4, there is no reason to prioritise a certain methodology over any other to achieve this goal. If methods have proven to be reliable or an applicable model has already been developed, it can be applied to quantify or qualify the desired outcomes as well as any intermediate effect of the intervention. There is also no requirement that each assessment result relies on results from previous steps in the ESG-LM. Doing so could provide evidence for an overall causal relationship though if the data used is reliable itself.

Results for Inputs, Activities, and Outputs (if not already observed data) can usually more easily be derived and estimated by modelling the inputs bottom-up. Only a few input variables and assumptions are usually necessary, and the relationships tend to be linear at this point in time (all other things being equal). On the other hand, top-down approaches can provide easy solutions when looking at effects on the level of countries or broader societies as long as they can be connected to the intervention investigated. It can also be feasible to look for already existing datasets that contain variables that allow for a conventional statistical analysis.

Regardless of the method used, the result itself should be depicted in a way that conveys the robustness of the values (or qualitative statements) reported. A simple categorisation of this robustness, with an emphasis on primary data, statistical data, and linear relationships, is discussed and shown in Section 2.1.6.1. Other means of depicting or analysing uncertainties in the assessment, such as sensitivity analysis or standard deviations, can be helpful to the reader as well. The spatiality and temporality of indicators should also be reported in a way that conveys to the reader if they are limited to certain locations and refer to past realised or to future predicted effects. The quality of indicators can be derived from their place in the ESG-LM with higher quality indicators referring to Intermediate Outcomes or Long-Term Outcomes and lower quality indicators being limited to effects on the level of the original target group. Additional information on the size of the attribution, the type of Additionality, and the credence of the claims should be included as well, if it is available.

The interpretation of the results then relies on this information to discuss the overall results in the context of the intervention investigated and the impact dimension the intervention is aimed at. It should discuss the robustness of the results and how the data can, or should not be, used by third parties. It should also explain how and what target conflicts are likely to occur (if not otherwise quantified).

6.2 Case Study A: NRW.BANK GB (wind energy)

The first case investigated belongs to the Green Bond programme by the promotional bank of the federal state of North-Rhine Westphalia in Germany (NRW.BANK). The NRW.BANK Green Bond has been issued at least once a year since 2015 (with the first impact report published in 2016) and re-finances loan programmes and projects for renewable energy, low-carbon mobility, energy efficiency, green buildings, and water protection. The most recent impact report was published in March 2023 (Buschbeck & Teubler, 2023). The most recent methodology was published in April 2023 (Teubler, Buschbeck, et al., 2023).

The goal of this case study is to test the PT and theoretical framework for the impact assessment of a conventional Green Bond. I select the financing of wind energy projects in Germany. This represents a simple application of the ESG-LM towards the overarching goal of climate change mitigation that is also aligned with the EUT. Wind energy projects, or rather renewable electricity production projects in general, are also one of the few project types for which impact methods in SF have already been developed and refined over the last 10 to 15 years. So far, impact reporting of this and similar bonds has been focused on the estimation of reduced or avoided GHG emissions and no causal inferences have been explicitly investigated within these reports. There is, however, an abundance of literature already attesting to the fact that renewable energy production mitigates climate change (Gielen et al., 2019). The case study here is therefore a blueprint that should, if the methodology works as intended, corroborate this fact.

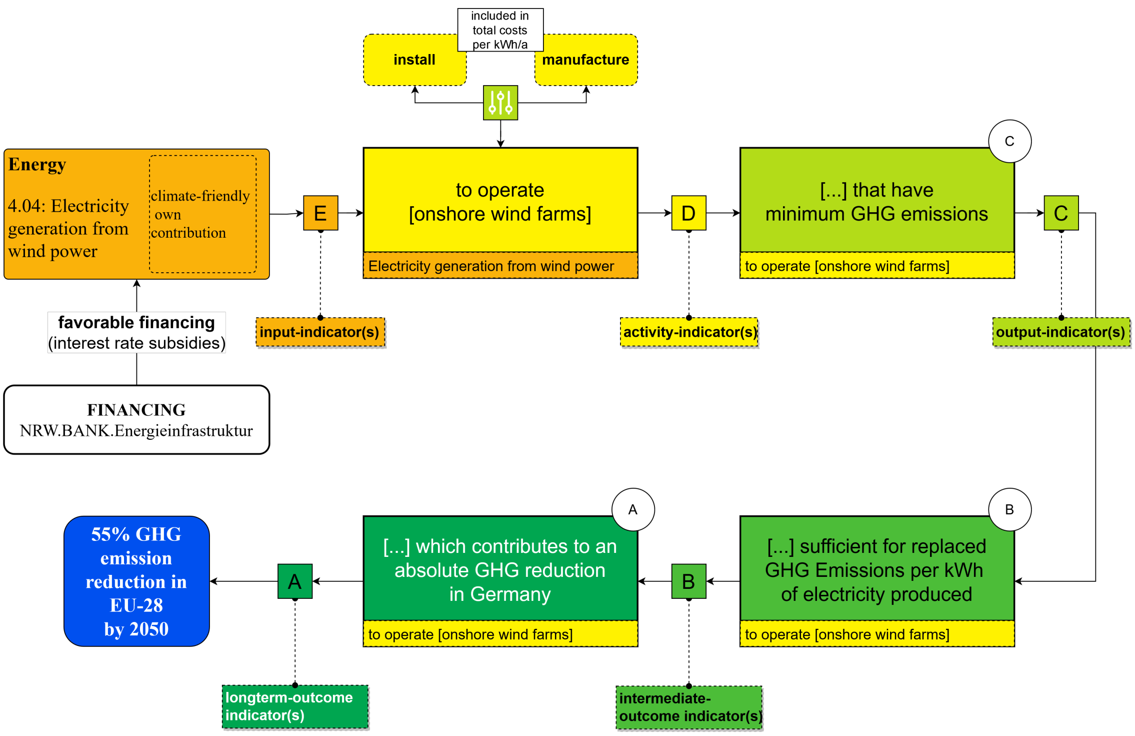
6.2.1 ESG-LM and project data

The NRW.BANK Green Bond #2-2022 includes 52 wind energy projects for loans given out in 2021 and 2022. Loan volumes range from EUR 0.28m for a single plant to EUR 32.6m for a wind farm with four plants. Loan periods range from 10 to 20 years.

With regard to the PT, these projects can be represented by the economic activity 4.3 (EUT from October 2022) on “Electricity generation from wind power”. The generic case in the PT describes the Main Actor as "operating" renewable electricity power plants "that have minimum GHG emissions" (climate-friendly activity). This Output then leads to the replacement of GHG emissions per unit of output at point of production (Intermediate Outcomes), which is deemed sufficient for an absolute GHG reduction on the national level (Long-Term Outcome). In terms of target conflicts, G_4 in the PT postulates the risk of increased demands of the service (here electricity) compensating the desired effect (see Section 3.3.2).

This scheme from the generic prototype was translated into the more specific case of loans for wind energy projects by the NRW.BANK and is shown in Figure 6-1.

Figure 6-1: initial ToC for wind farm loans by NRW.BANK (Case Study A)



Source: own development based on prototype from Chapter 3

The issuer's original loans constitute a case for favourable financing because the bank is a promotional bank for the state of NRW that cooperates with local private banks. The interest rates are below-market conditions (NRW.BANK dispenses earnings for lower interest rates and the programme is regulated by the De-Minimis regulation). The repayment options are flexible, up to 100% of the investment can be financed and interest rates can be fixed for up to 30 years. Regarding Additionality, the borrower therefore either saves capital costs or is enabled to increase the size of the investment and thus the potential benefits from new wind power plants. However, there is no information on the actual size of dispensed earnings and the re-financing conditions from the Bond only apply to future projects.

Regarding primary data, each of the loans comes with the following information: loan programme (only *NRW.BANK.Infrastruktur*), value date, end of loan, purpose (new wind farm, additional turbines for existing wind farms, re-powering), city, and ZIP code. The information on the projects differs in detail. For 38 out of 52 loans, there is sufficient information (turbine model and/or power output) to calculate the capacity of the wind farms directly. Each of the remaining loans either directly quantifies the number of new wind turbines or enabled the authors to derive this fact from the description.

6.2.2 Hypotheses and epistemic justification

The following first hypothesis can be derived from the baseline ToC.

(H_1) $p_1 \wedge q_1 \rightarrow r_1$:

The debt financing of electricity production from wind energy will lead to the operation of new onshore wind farms that have minimum GHG emissions.

A non-true first hypothesis ($\neg H_1$) comprises all cases in which ($\neg H_{1a}$) financing was not necessary, ($\neg H_{1b}$) financed wind farms are not operated, ($\neg H_c$) windfarms have higher GHG emissions than the energy suppliers that are displaced by them, or ($\neg H_n$) any other condition which makes the statement untrue.

Looking at the evidence E (with $e_n \in E$), there is primary data provided by the issuer on each loan. It (e_1) entails the location of the planned wind farm, the number and models of turbines and the capacity of each turbine. Additional evidence, or rather missing evidence, relates to the Green Bond itself. Since there is always a chance that a project is not realised despite funding approval, some of the wind farms documented might not have been built as well. This is more likely for loans that have been approved shortly before the issuance of the bond, as older loan defaults would not have been incorporated in the bond in the first place (which is scrutinised by a second-party-opinion). For the Green Bond in question, no such case is known where some fraction of the loans defaulted after issuance (e_2).

The following table summarises the argument from BR for H_1 and includes a more formal BA as well.

Table 6-1: BR for H_1 in Case Study A

Stages	Reasoning	Credences
Prior-Test	Looking at the background knowledge, we know (b_1) that there are formal conditions that have to be met for a funding approval (e.g. NRW.BANK, (2023a)) and wind farms have been successfully financed in the past by debt financing (b_2) (IRENA & CPI, 2023). We also have the background	$cr(H_1.b) \approx$ 0.95-0.99 and $cr(\neg H_1.b) =$ 0.01-0.05

Stages	Reasoning	Credences
	knowledge to ascertain that (b_3) wind energy has a lower GHG intensity than any conventional power plant with the exception of nuclear energy — even if lifecycle wide emissions are considered (Pehl et al., 2017, p. 941). With the latter not being part of the German electricity mix anymore, wind energy is therefore always climate-friendly compared to the stock of fossil fuelled power plants that it replaces. Looking at the prior probability of H_1 and given this background knowledge, an initial extremely high credence (extremely probable) seems to be justified. Only borrowers that intend to implement a new wind farm are eligible for a loan and the financing institution is obliged to review whether the project can be realised with the available equity and loan sum requested. There is also no reason to assume that such a wind farm would be acquired for any other purpose than its operation to produce electricity and we also know that wind farms have lower GHG emissions than plants in the conventional mix. H_1 therefore constitutes an argument from triviality because the initial credence approaches 1 and is well above the threshold of 0.5. Conversely, I find any of the non-true propositions at least extremely improbable, since (i) financing seems to be necessary, (ii) wind farms are constructed for operation, and (iii) operational wind farms have low GHG emissions.	from $P(H_1) + P(\neg H_1) = 1$
Silence-Test	There is no evidence which we would not expect to find. Stage II should thus not change the credence of the claim.	
Hoop-Test	The Empirical Certainty of the affirmative (prior pointing to H_1) is high considering the evidence. There is specific project related data on the wind farms in planning or progress and there is no evidence that loans defaulted (not leading to new wind farms). While this does not change the credence, it should raise the confidence in the reliability of it.	
Doubly-Decisive-Test	Given the body of evidence, it is fully expected under the main hypothesis. It is neither surprising nor expected under the assumption that wind farms with higher GHG were constructed, since the actual GHG intensity of the wind	$cr(E\|H_1.b) \approx 0.99$ $cr(E\|\neg H_1.b) \approx 0.5$

Stages	Reasoning	Credences
	farms is not included in the evidence. This is the upper limit for cr (E|¬H_1.b) though, since it would be very surprising if lenders applied for loans that were unnecessary (¬H_{1a}) or that wind farms are not constructed to be operated (¬H_{1b}). The evidence therefore makes the main hypothesis more likely than any alternative. Given this information, one can be reasonably confident (a fortiori) that almost all of the loans given out lead to the desired Output.	
BA	$cr\ (H_0 \| E.b) = \frac{cr\ (H_0.b) \times cr\ (E \| H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E \| H_n.b)}$	cr (H_1|E.b_n) = 0.97-0.99

Source: own development

The following second hypothesis can be derived from the ToC.

(H_2) $r_1 \wedge z_1 \rightarrow r_A$:
Onshore wind farms with minimum GHG emissions are sufficient for replaced GHG emissions from electricity, which will contribute to an absolute GHG reduction in Germany.

A non-true second hypothesis (¬H_2) comprises all cases in which (¬H_{2a}) absolute GHG reductions were achieved entirely by other means despite additional wind farms, (¬H_{2b}) GHG emissions were replaced entirely by other means despite additional wind farms, or (¬H_{2n}) any other condition which makes the statement untrue.

Looking at the evidence, there is no primary data collected by the issuer on the system-wide effects of the financed wind energy projects (all further information on the potentially avoided GHG emissions stem from estimations in the impact report). What is available instead is, (e_1) reliable statistical data for the state of NRW on the annual addition in wind energy capacity (IWR, 2023), (e_2) an increase in primary energy production from wind energy (LAK, 2023a) and (e_3) a continuous decrease of the CO_2-intensity of the state's gross electricity production (LAK, 2023b). Considering the time frame in question (disbursed loans in 2021 and 2022), no current data is available though (constituting secondary data instead). It is therefore possible, although unlikely, that these trends did not continue from 2021 onward. On the absolute GHG emissions for the state, (e_4) a downward trend can be shown between 2012 and 2020 with evidence for a decrease of fossil energy use in the energy industry (LANUV NRW, 2022). To the contrary, the preliminary values for 2021 show an increase of these emissions (higher than 2020 but lower than 2019). This unusual peak is explained by, among other reasons, a decrease in electricity production from wind energy though.

The following table summarises the argument from BR and also displays a more formal BA.

Table 6-2: BR for H_2 in case study A

Stages	Reasoning	Credences
Prior-Test	The background knowledge for H_2 are insights by the IPCC that (b_1) a limited overshoot requires zero net CO_2 emissions from the electricity sector and primary supply by wind energy needs to increase drastically from 5 EJ today to 104 EJ in 2060 against a lower energy demand (Jim Skea et al., 2022, p. 615 et sqq.). An older study from 2014 also estimated that an aggressive wind energy deployment would delay a 2°C warming by 3-10 years compared to 1-6 years from moderate deployment (Barthelmie & Pryor, 2014). There is further background knowledge that (b_2) additional wind energy indeed displaces conventional energy sources, although the size of this displacement decreases with higher shares of renewables in the energy mix (Göke et al., 2021). However, (b_4) there is a negative feedback from climate change on wind energy production in Europe (Gernaat et al., 2021, p. 124) and there is information that (b_5) high shares of renewables (> 75%) raise severe technological, market, and operational challenges (Jim Skea et al., 2022, p. 675). Looking at the prior probability of H_2 and given the background knowledge, it seems to me that it is extremely probable that additional wind farms installed and operated in NRW would replace fossil energy carriers for electricity production and should be, at least in the long-term, sufficient for an absolute GHG reduction in Germany. Potential rebounds could be identified, but only relate to shares of renewables in the grid that are a lot higher than today or that are negatively affected by climate change in the future. These rebounds compensate the desired effects, but do not negate them. I therefore conclude that this constitutes an argument from triviality with the credences approaching 1 well above the threshold of 0.5. Conversely, I find it extremely improbable that previous GHG reductions in the energy sector were achieved without any additional wind farms or that existing annual GHG emissions were not replaced partially by such power plants.	$cr(H_2\|b) \approx$ 0.95-0.99 and $cr(\neg H_2.b) =$ 0.05-0.01 from $P(H_2) + P(\neg H_2) = 1$

Stages	Reasoning	Credences
Silence-Test	Collection and verification of empirical data on wind energy deployment and its subsequent effect on national GHG emissions takes time. It is therefore likely that data from the relevant time frame (2021, 2022) cannot exist, especially considering that there is also a time delay between loan payment and operation of new wind farms. Although this missing data does not increase the credence of the claim, it should increase an agent's confidence in the reliability of the prior credence.	
Hoop-Test	The Empirical Certainty of H_2 is high in general. Wind energy deployment in NRW in the past has, as expected, increased primary energy demand from wind energy and lowered the GHG intensity of electricity production. There is also evidence that decreased absolute GHG emissions stem from lower fossil fuel combustion compared to an increase of renewable energy. The most recent data for 2021, albeit preliminary, points to an increase of GHG emissions from energy as well as lower energy production from wind energy. The latter corroborates the main claim of H_2. As a consequence, the reliability of the prior credence continues to improve.	
Doubly-Decisive-Test	Given the body of evidence, it is fully expected under the main hypothesis. It is less likely, but still extremely probable under alternative explanations because other renewables (and measures in other sectors), could be the sole contributors to the effect. One can therefore be reasonably confident (a fortiori) that almost any new wind farm contributes to the desired Long-Term Outcome.	$cr\ (E\|H_2) \approx 0.99$ $cr\ (E\|\neg H_2) \approx 0.95$
BA	$cr\ (H_0\|E.b) = \frac{cr\ (H_0.b) \times cr\ (E\|H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E\|H_n.b)}$	$cr\ (H_2\|E.b) =$ 0.95-0.99

Source: own compilation

The final justification step is the combination of the credences for both H. The BR for H_1 pointed to a very high credence (0.97-0.99). For H_2, a high credence of 0.95 and higher could at least be reinforced given the evidence. In conjunction, I conclude that the overall claim is credible ($cr > 0.5$) and well-within the realm of $0.95 > cr < 0.99$. I thus predict that at least 95% of the loans assessed in the bond are sufficient for an absolute GHG reduction on the national level in the long run. This assessment holds until new evidence E' emerges that lowers the credence or if one or more pieces of the relevant information up to this point turns out to be false.

6.2.3 Rework of ToC and potential indicators

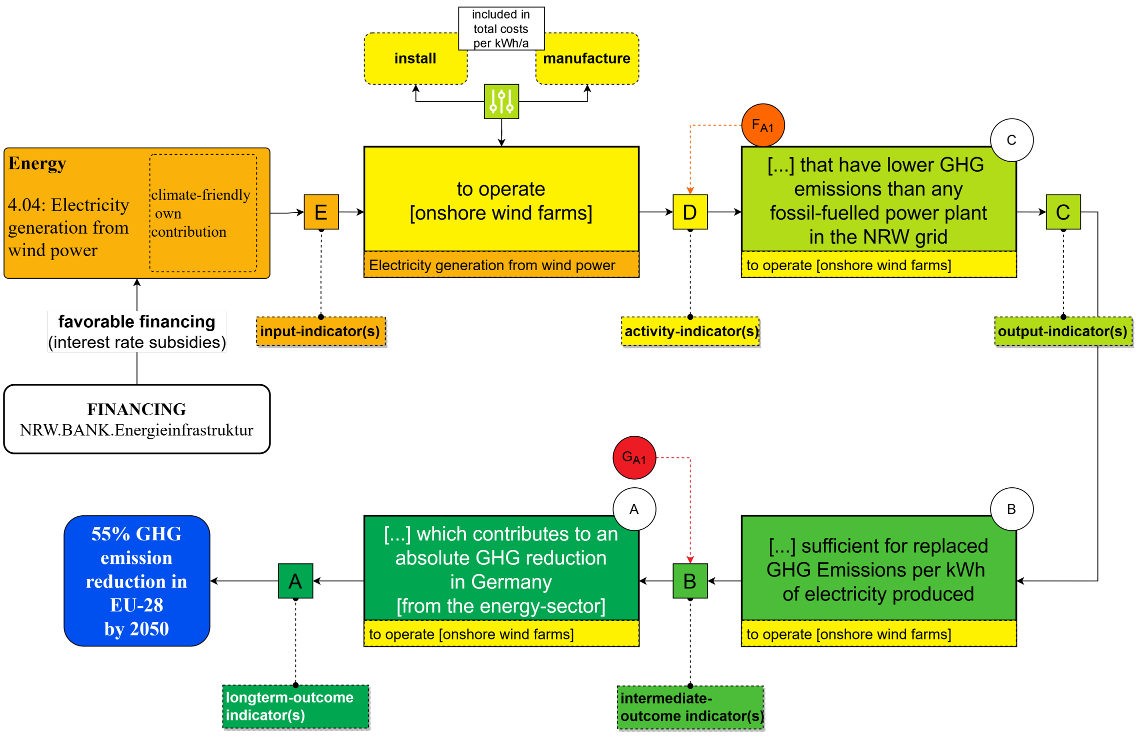
The available background knowledge and evidence can inform the ESG-LM. According to set theory, each sufficient cause needs to be entailed by the effects, but either an increase of the sets of sufficient causes or a decrease of the sets of effects should lead to stronger causal relationships. Since the first cause-effect relationship already entails the largest set of causes (financed new wind farms in the Green Bond) and the smallest set of effects (additional wind farms in NRW), no adjustment is needed there. This first hypothesis is also credited with a very high credence after looking at the background knowledge and evidence.

For the second part of the outcome pathway, an adjustment makes H_2 more reliable. First, the set of Outputs is increased so it includes not only wind farms with "minimum GHG emissions" (an ambiguous criterion anyway), but all wind farms that clearly exhibit a lower GHG intensity than any fossil-fuelled power plant in the grid. Secondly, the previous depicted effect entailed GHG reductions from all sectors in Germany. While it is not prudent to change the location (reductions can take place anywhere in the German and even European grid), the set can be meaningfully decreased by only considering GHG emissions from the energy sector.

In terms of target conflicts to be considered, the Generic Rebound of increased energy demand should still be considered, especially since it can even overcompensate the desired effect. An additional hazard stems from the fact that high shares of renewables in the grid (> 75%) have a negative effect on the displacement of fossil energies (Nicolosi & Burstedde, 2021) and also come with additional challenges in terms of costs, net stability, and additionally required storage capacities (Jim Skea et al., 2022).

The following figure shows the adapted ESG-LM for wind energy projects in NRW.BANK Green Bond #2022-2.

Figure 6-2: ESG-LM (second iteration of ToC) for wind farm loans by NRW.BANK (Case Study A)



Source: own development

The next step is to derive potential indicators for the case. Looking at the revised ToC and incorporating the target conflicts, the following table shows a list of potential indicators.

Table 6-3: potential indicators for Case Study A

<table>
<tr><th colspan="4">Indicator Suggestion</th></tr>
<tr><td rowspan="3">A_A</td><td colspan="3">Annual change of GHG emissions from the energy sector in Germany [t CO_2e]</td></tr>
<tr><td rowspan="2">B_A</td><td colspan="2">Replaced GHG emissions in the electricity production in Germany [t CO_2e]</td></tr>
<tr><td>C_A</td><td>Marginal difference in GHG intensity of sample compared to fossil mix [g CO_2e / kWh]</td></tr>
<tr><td>F_{A1}</td><td colspan="3">Risk of reduced desired outcomes from a high renewable electricity share in Germany</td></tr>
<tr><td>G_{A1}</td><td colspan="3">Risk of reduced desired impact from increased electricity demand in Germany</td></tr>
</table>

Source: own compilation

6.2.4 Impact measurement and interpretation

Case A has already been assessed in a previous impact report (Buschbeck & Teubler, 2023) based on the most recent impact assessment methodology (Teubler, Buschbeck, et al., 2023). The first step was to estimate the overall capacity to be installed, which can be reported as an activity-indicator. For loans without information on the actual power output or turbine type, an average power output of 4,098 kW was assumed (average of sample). In the following step, the average full-load hours for onshore wind energy in Germany were used for further calculations (1,800 hours per year for fully utilised onshore wind turbines in Germany according to Fraunhofer ISE, (2021)). The resulting estimate for annual electricity production (367 GWh/a) was then further processed according to the following equation.

$$GHG_{avoid,REP} = \sum_{k=1}^{n} E_{RE,k}\ x\ ghg_{IFI} \quad [kg\ CO_2 - equ./\ a]$$

with

$E_{RE,k}$: annual electricity production of selected renewable power plant in [kWh/a]

$GHG_{avoid,\ REP}$: potentially avoided GHG emissions technology [g CO2e/a]

ghg_{IFI}: GHG intensity of combined margin grid emission in country or region [g CO2e/kWh]

The required GHG intensity factor for combined margin grid emissions in Germany (a common solution in impact reporting of green assets) are derived from a UNFCC data source and are publicly available (IFI, 2022). As a result, the avoided GHG emissions from renewable energies in electricity production (compared to the German mix for remaining and new power plants) could be calculated and reported on an *ex ante* basis. For contribution, the required data on the total costs of the projects was not available. The next best estimate could be derived by comparing the loan volume to the additional capacity and the average costs in Germany to add this capacity to the grid. Based an average cost-factor of 1,567 EUR/kW (including auxiliary investment costs according to Deutsche Windguard, (2015)), an initial Attribution of 74% could be calculated. This value can be considered to be overestimated, because the cost of wind energy has probably increased since then. Regarding Long-Term Outcomes, no such indicator has been established yet.

Looking at the ESG-LM in the case study, the following indicators can be directly adopted: total loan volume as indicator from Inputs and annual electricity production as indicator from Activities. For other parts of the outcome pathway, I select a literature source that specifically refers to onshore wind energy. The German Environmental Federal Agency (UBA) publishes a report on the balance of emissions for renewables on an annual basis with the most current report referring to German energy production (electricity and heat) in 2021 (Lauf et al., 2022). It contains information on the GHG emissions of all energy sources for upstream processes (e.g., manufacturing), direct combustion, and auxiliary energy. It also models the share of conventional energy source that is displaced by individual renewable energy sources. The main result of the reports is the calculation of avoided GHG emissions by additional renewable energy production.

For the Output-indicator, a comparison of total GHG intensities best represents the ideal indicator. The following table lists the necessary data for this solution.

Table 6-4: share of displacement and GHG intensities for German energy sources (electricity)

Energy source	**Displacement [%]**	**GHG intensity (upstream + direct + auxiliary) [g / kWh]**
Wind, onshore	-	17.7
Lignite	13.7	412.6
Hard coal	63.6	380.6
Gas	22.7	247.2
Difference in GHG intensities		354.7 – 17.7 = 337

Source: own calculation based on Lauf et al., (2022)

The following step in the outcome pathway then just requires a multiplication of the Activity (electricity production) with this difference in GHG intensities. The indicator for the Intermediate Outcome can thus be estimated at 123,680 tonnes of CO_2e. Comparing this to the annual GHG emissions in Germany from the energy sector then leads to the estimation of the Long-Term Outcome. From the total GHG emissions from energy production in 2021 (240,461 kt CO_2e according to UBA, (2023)), it can be estimated that the operation of the wind farms in the Green Bond are potentially responsible for an absolute annual reduction of 0.05%.

The indicators should be depicted regarding their quality and robustness, as operationalised in Section 2.1.6.1. The following Table 6-5 lists all indicators from A to D, and also includes information on the factor for Attribution and the target conflicts involved.

Regarding robustness, the Input value is considered primary data (1) and the Activity value as a linear result on the basis of secondary sources (2). The Output value required additional assumptions as well as underlying LCA models (4). The remaining two values are considered to have a robustness of 4, because they rely on previous results and additional auxiliary variables from type 1 sources.

Table 6-5: impact assessment of Case Sudy A

(Q_R: Quality Q of the indicator and Robustness R of the indicator value)

Q_R	**Indicator** *(for A to D: ex ante; for A to C: diminishing in the future)*	**Value**
Credence (minimum threshold) for expected effects		0.95
A_4	Absolute annual reduction of GHG emissions (national energy sector)	0.05%
B_4	Replaced annual GHG emissions in Germany	124 kt CO_2e/a
C_4	Marginal reduction in GHG intensity (wind, onshore vs. conventional)	337 g CO_2e/kWh
D_2	Additional annual renewable electricity production	367 GWh/a
E_1	Loan paid out for operational renewable electricity power plants	EUR 263m
F	Risk of reduced desired outcomes from a high renewable electricity share in Germany	

Q_R	**Indicator** *(for A to D: ex ante; for A to C: diminishing in the future)*	**Value**
G	Risk of reduced desired impact from increased electricity demand in Germany	
Attribution by financing (overestimated)		74%
Additionality of Financing: favourable financing		no estimate

Source: own compilation

The interpretation of the results can be solely based on the information contained in the table. The issuer contributed to the operation of new onshore wind power plants with an Attribution rate of less than 74%, as this value might be overestimated. The financing conditions constitute favourable financing with a total loan volume of EUR 263m. The power plants will, once installed (which is probably the case at the time of this dissertation), produce around 367 GWh of electricity per year. This represents a marginal replacement of 337 g CO_2e per kWh produced and an absolute reduction of German GHG emissions for energy supply of 0.05% (124 kt CO_2e reduction per annum). The societal benefits are extremely probable (cr = 0.95) but rely on additional assumptions and secondary sources. They are based on an *ex ante* estimation and will diminish as time goes on, because higher shares of renewables in the electricity mix also reduce avoided GHG emissions. A partial or even overcompensation of desired outcomes is currently not likely, because renewable energy shares in Germany are well below a threshold of 75%. However, increasing overall electricity demand will directly, and negatively, affect the size of the contribution to climate change mitigation targets in the EU during and after maturation of the loans.

6.2.5 Lessons learned

The developed methodology and PT worked as intended and the previous assessment could be improved upon as a result. It could be assessed that (i) the underlying causal assumptions of the issuer are plausible and supported by both literature and evidence, (ii) the previous indicator set should be expanded on, and (iii) what type of risks and pre-conditions should be considered when reporting the desired outcomes. The case study also indicated how future assessments could be optimised both in regard to the credibility of the claims and robustness of results.

The latter would clearly benefit from complete information on the capacity of all wind farms and if possible, the predicted annual electricity production from them. Other relevant information for an optimisation are data on the overall costs of the projects (for a more accurate rate of Attribution) and information on the dispensed earnings from favourable financing in the specific loan programme. Regarding credibility, looking back might be advantageous. The process of epistemic justification revealed that current statistical data on the wind farms financed cannot be expected, but that there are reliable data sources reporting on important variables from past installations. Collecting data on projects from previous Bonds and investigating if these wind farms are operating now would therefore lend credence to the current assessment. Moreover, it could be a helpful data source for estimating the overall ratio of realised to financed wind projects as well as the technical parameters such as full-load hours required for GHG emission calculations.

The process itself is more time-consuming than applying common methodologies in the market. However, most of the working hours went into the development and refinement of the ToC and desk research. It is reasonable to assume that these resource investments diminish over time if only new evidence and background knowledge is considered in annual reporting. It became also clear that the initial assessment framework required expertise that is not necessarily available for all potential pathways and overarching goals. Nonetheless, even a rougher and quicker run of the process steps described in Section 6.1 would provide analysts and other parties with more and more reliable knowledge of the underlying mechanisms in the impact assessment.

6.3 Case Study B: GB-BW (biotope mapping)

The second case to be investigated is based on the 2022 Green Bond by the German federal state of Baden-Württemberg (GB-BW) which is aligned with the EUT and refers to eligible state expenditures in the year 2021. The issuer (Ministry of Finance BW) published a framework, a SPO authored by Moody's, and an impact report authored by me (Ministry of Finance Baden-Württemberg, 2022; Moody's, 2022; Teubler & Schekira, 2023b). One major finding of the report was that some projects qualified as showing contributions to EUT objectives on the level of Intermediate Outcomes.

I select the measure of "Biotope Mapping", which is one of the five projects identified in the impact report, to show "strong evidence for a substantial contribution" towards "Biodiversity & Ecosystems" (Teubler & Schekira, 2023b, p. 62). I want to test whether the PT on climate change mitigation can be adapted for the overarching goal of *Protection and Restoration of Biodiversity and Ecosystems*. A recent proposal by the European Commission explicated how a substantial contribution to this objective can look that is aligned with the EUT (European Commission, 2023c). Biotope mapping is part of a state programme that aims to increase the area of the existing biotope network ("Biotopverbund") for open land ("Offenland") to 10% in 2023 and to 15% in 2030 (Federal State of Baden-Württemberg, 2020).

Although the existing impact report established a set of indicators, these indicators were not assessed in regard to the causal relationship between the funding of biotope mapping and a contribution to these goals. Since there is further evidence and primary data that the task itself has been conducted and continues to be funded, it should be an applicable case for the assessment of a new ESG-LM.

6.3.1 ESG-LM and project data

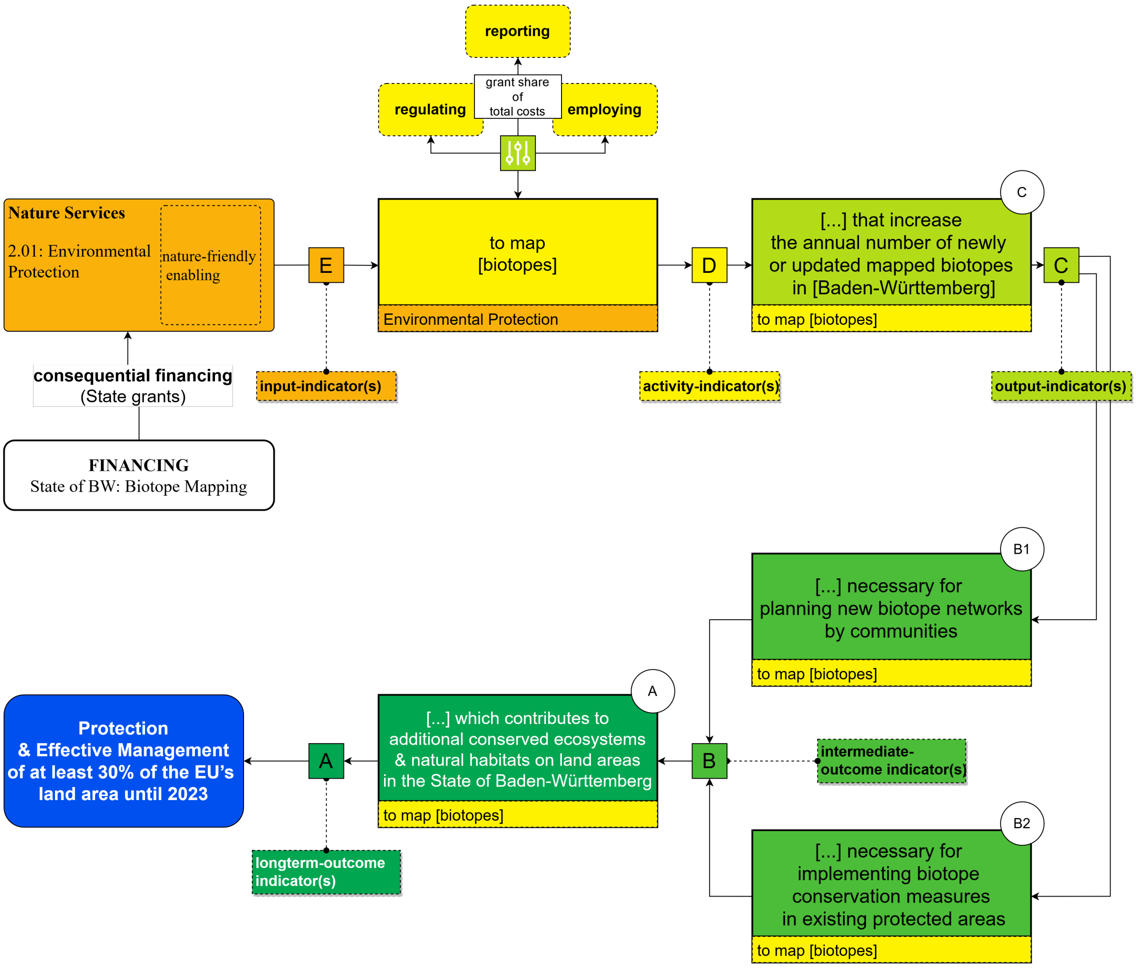
The EUT functions as the main framework for the identification of the Impact and the desired Long-Term Outcome whereas publications and statistics by the state of BW either provide background information, or evidence, or indicator data. The EUT defines a substantial contribution to “Protection and Restoration of Biodiversity and Ecosystems” in Article 15.1 with five criteria (European Commission, 2022). It focuses on “nature and biodiversity conservation” (ibid.), which is explicated in three targets in the *EU Biodiversity Strategy for 2030* (European Commission, 2020a): “1. Legally protect a minimum of 30% of the EU’s land area”, “2. Strictly protect at least a third of the EU’s protected areas”, “3. Effectively manage all protected areas, defining clear observation objectives and measures, and *monitoring them appropriately*” (ibid., *emphasis* mine).

For a substantial contribution, the current EUT proposal for Annex IV suggests “activities of in-situ conservation, defined [...] as the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings” (European Commission, 2023c, p. 2). Combining these targets, I define the desired Impact as “Protection and Effective Management of at least 30% of the EU’s land area until 2023” and the desired Long-Term Outcome as “Additional conserved ecosystems and natural habitats on land areas in the state of Baden-Württemberg”.

For a CM on the societal level (Intermediate Outcome), I first need to define an applicable Output as cause. Since biotope mapping is monitored, and the areas mapped and assessed continues to grow every year, a suitable Output seems to be “that increase the annual number of newly or updated mapped biotopes”. I then apply the “PrT heuristic for similar cases” from Section 2.2.2.1., to compare competing hypotheses for a suitable CM on the societal level (see A-6 in Annex). This process helped to identify two CMs that can be present at the same time for a set of cases (but not necessary for each case individually) and that are both deemed necessary for the Long-Term Outcome.

The final step for the development of the ESG-LM is to adapt the PT by integrating a new intention (nature-friendly) for the Input “Nature Services” and to define the object (biotopes), and purposes (mapping, regulating, reporting, employing) of the Activity by using the current proposal for a substantial contribution in the EUT. The following figure shows the first draft of an ESG-LM for “biotope mapping” within GB-BW.

Figure 6-3: initial ToC for biotope mapping by state of BW (Case Study B)



Source: own compilation

Regarding primary data, the issuer gathered data from the environmental ministry on the number of new biotopes (3.921), the number of biotopes with updated data (7.480) and the overall number of biotopes in the state (175.743 in open land, 64.359 from forest mapping). The state of BW financed the mapping with actual expenditures in 2021 of EUR 3.59m and covers 100% of the costs.

The grants by the state also constitute a case for consequential Financing. Although some of the tasks are mandatory according to national and EU regulation, the activity itself is co-financed by the state of BW. As the mapping of biotopes is dedicated to societal benefits there is no return on investment. It is therefore likely that the mapping would not be conducted without the funds or, at best, would be funded by NGOs to a much smaller degree.

6.3.2 Hypotheses and epistemic justification

The following first hypothesis can be derived from the baseline ToC:

(H_1) $p_1 \wedge q_1 \rightarrow r_1$:

The grants for nature services from environmental protection will lead to the new or updated mapping of biotopes that will increase in number over the course of a year.

A non-true first hypothesis ($\neg H_1$) comprises all cases in which ($\neg H_{1a}$) grants were not necessary, ($\neg H_{1b}$) biotopes were not mapped, ($\neg H_c$) no new or updated biotopes were reported, or ($\neg H_n$) any other condition which makes the statement untrue.

Looking at the evidence, there is (e_1) not only the primary data collected on new and updated biotopes but also a dedicated website where each protected biotope in the state is captured (LUBW, 2023). The expenditures for the mapping process (e_2) were also reported as part of the state's budget (Ministry of Finance Baden-Württemberg, 2023) and are included in the current budget plan (indicating continuous funding).

The following table summarises the argument from BR for H_1.

Table 6-6: BR for H_1 in Case Study B

Stages	Reasoning	Credences
Prior-Test	There is background knowledge that (b_1) the task of biotope mapping is prescribed by state law (Federal Republic of Germany, 2009; Federal State of Baden-Württemberg, 2020) and that this law is in line EU Habitats Directive which obliges its members to designate and (co-)finance natural habitats and their conservation (European Council, 2013). Moreover, (b_2) previous mapping was reported in form of a specialist plan ("Fachplan" by LUBW, (2014)) and a methodology is in place that categorises different types of biotopes and guides the assessment of their current status (LUBW, 2017). Looking at the prior probability of H_1 conditioned on the background knowledge, a high credence (very probable) seems to be justified. A state law requires the task. In addition, reporting on biotope mapping from previous reports have resulted in the state-wide biotope-network plan which communities are obliged to use for their individual measures and the methodology on mapping and assessing biotopes in the state has been updated after new targets were introduced in the law. One can also discard $\neg H_{1b}$ and $\neg H_{1c}$ from this information alone (extremely improbable). $\neg H_{1a}$ on the other hand	cr (H_1.b) ≈ 0.80-0.95 and cr ($\neg H_1$.b) = 0.20-0.05 from $P(H_1) + P(\neg H_1) = 1$

Stages	Reasoning	Credences
	seems at least to be possible from the outset. However, the fact that both European and federal law prescribes the definition and financing of natural habitats on BW territory, indicates that the grants are at least partially necessary for success (making the proposition of unnecessary grants extremely improbable). Although H_1 does not constitutes an argument from triviality (see Section 5.4.5), it has a credence well above the threshold of 0.5.	
Silence-Test	There is no evidence which we would not expect to find given that monitoring is the main goal. Stage II should thus not change the credence of the claim.	
Hoop-Test	The Empirical Certainty of the affirmative (prior pointing to H_1) is high considering the evidence. There is (i) specific project related data on the number of new or updated biotopes, (ii) information of all currently assessed biotopes is reported, (iii) evidence that state expenditures are allocated for this task. While this does not change the credence, it should raise the confidence in the reliability of it.	
Doubly-Decisive-Test	Given the body of evidence, it is fully expected under the main hypothesis. By comparison, it is at least somewhat surprising under the assumption that state grants are not necessary ($\neg H_{1a}$) and very surprising under any other explanation, which is why the former credence of evidence conditioned on the hypothesis is justified. The posterior credence therefore increases as a consequence (likelihood ratio in favour of H_1). Given this information, one can be very confident (a fortiori) that almost all of the grants given out lead to the desired Outputs.	$cr\ (E\|H_2) \approx 0.99$ $cr\ (E\|\neg H_2) \approx$ 0.20-0.40
BA	$cr\ (H_0\|E.b) = \frac{cr\ (H_0.b) \times cr\ (E\|H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E\|H_n.b)}$	$cr\ (H_2\|E.b) =$ 0.91-0.99

Source: own development

The following second hypothesis can be derived from the ToC.

(H_2) $r_1 \wedge (z_1 \vee z_2) \rightarrow r_A$:

An increased number of mapped biotopes is necessary for planning new biotopes and for implementing biotope conservation measures by communities, either of which will contribute to *additional conserved ecosystems and natural habitats on land areas in the state of Baden-Württemberg.*

A non-true second hypothesis ($\neg H_2$) comprises all cases in which ($\neg H_{2a}$) biotope mapping and assessments are not necessary for either or both CMs, ($\neg H_{2b}$) planning new biotopes do not lead to additional conserved ecosystems, ($\neg H_{2c}$) conservation management does not lead to additional conserved ecosystems, or ($\neg H_{2d}$) any other condition which makes the statement untrue.

Although the state does not intend to purchase new areas for the biotope networks, there is evidence that (e_1) identified core-areas are automatically protected and additional connecting-areas can be integrated by funding nature-conservation measures by their current owners (Ministry of Environment Baden-Württemberg, 2022a). In addition. (e_2) the state developed a training programme and biotope-network ambassadors have been hired in all 35 counties (ibid.). There is also direct primary data available corroborating that (e_3) the total number of biotopes has increased during 2021, which indicates that at least some of these additional areas have been designated as new protected areas in the state.

The following table summarises the argument from BR for H_2.

Table 6-7: BR for H_2 in Case Study B

Stages	**Reasoning**	**Credences**
Prior-Test	There is background knowledge that (b_1) additional state grants are available for communities that use the resulting specialist plan in their area (the main result of biotope mapping) for planning and improving biotopes (90% of costs for planning biotope networks, up 70% of direct costs for conserving habitats, animals, and plants as well as up to 100% for nature-conservation contracts) according to the landscape maintenance directive LPR (Ministry of Environment Baden-Württemberg, 2020). There is further background knowledge that (b_2) previous mapping efforts and specialist plans led to improvements of the biotope network in the state (Mayer, 2021; Ministry of Environment Baden-Württemberg, 2022b). Looking at the prior probability of H_2 conditioned on the background knowledge, we can have at least some confidence that the claim is justified (probable). Past specialist plans were the result of previous biotope mappings (BM) and these plans were used to improve the	$cr(H_2.b) \approx$ 0.60-0.80 and $cr(\neg H_2.b) =$ 0.40-0.20 from $P(H_2) + P(\neg H_2) = 1$

Stages	**Reasoning**	**Credences**
	status of biotopes and increase their size. There is also a directive in place that funds efforts by communities to designate areas for biotopes and to introduce conservation management measures in biotopes on their territory. Conversely, it is, at this point, an open question whether the planning of new biotopes or conservation measures result in additional protected areas in the state. It can also be not excluded that the size and quality of biotopes increases in the state independent of funding, regulations, and BM. H_2 therefore does not constitute an argument from triviality (see Section 5.4.5) but has a credence slightly above the threshold of 0.5.	
Silence-Test	The quantified targets to increase the size of biotopes are fairly new and thus only the current size has been evaluated so far. We would therefore not expect to find data on the development of the areas until then. This should raise the reliability of the claim, as such information (if increased over time from measures by communities) would increase its credence.	
Hoop-Test	The Empirical Certainty of the affirmative (prior pointing to H_2) is high considering the evidence. There is (i) primary data affirming that the number of biotopes increased in 2021, (ii) regulations are in place to designate new biotopes in core-areas as protected areas, (iii) funding in place that facilitates the designation of connecting-areas from measures by current owners, (iv) a training programme for communities to interpret the results of the mapping, and (v) biotope ambassadors have been hired in all counties in the state. While this does not change the credence, it should raise the confidence in the reliability of H_2 even more.	
Doubly-Decisive-Test	Given the body of evidence, it is at least very likely under the main hypothesis. By comparison, it is at least somewhat surprising under the assumption that BM is not necessary or that BM of new biotopes does not lead to the designation of new protected areas. It cannot be excluded though that the increase of protected areas would come about by other means entirely. Although I find it personally unlikely to	$cr(E\|H_2) \approx$ 0.60-0.80 $cr(E\|\neg H_2) \approx 0.5$

Stages	Reasoning	Credences
	find this body of evidence under this explanation, a more conservative assessment is called for (neither expected nor surprising). However, the evidence is less likely for all alternative explanations than for the main hypothesis. One can be confident that at least the majority of new and updated biotopes trigger the desired Long-Term Outcome.	
BA	$cr\ (H_0\|E.b) = \frac{cr\ (H_0.b) \times cr\ (E\|H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E\|H_n.b)}$	cr (H_2|E.b) = 0.64-0.86

Source: own compilation

The final justification step is the combination of the credences for both H. The four BR stages for H_1 pointed to a very high credence (0.91-0.99). For H_2, the initial credence could be at least slightly increased given the evidence. In conjunction, I conclude that the overall claim is credible, but barely meets the threshold with $0.64 < cr < 0.86$. This means that at least 64% of the grants for biotopes mapping in a given year are necessary for an increase of protected areas in the state in the long run. This assessment holds until new evidence E' emerges that lowers the credence or if one or more pieces of the relevant information up to this point turns out to be false.

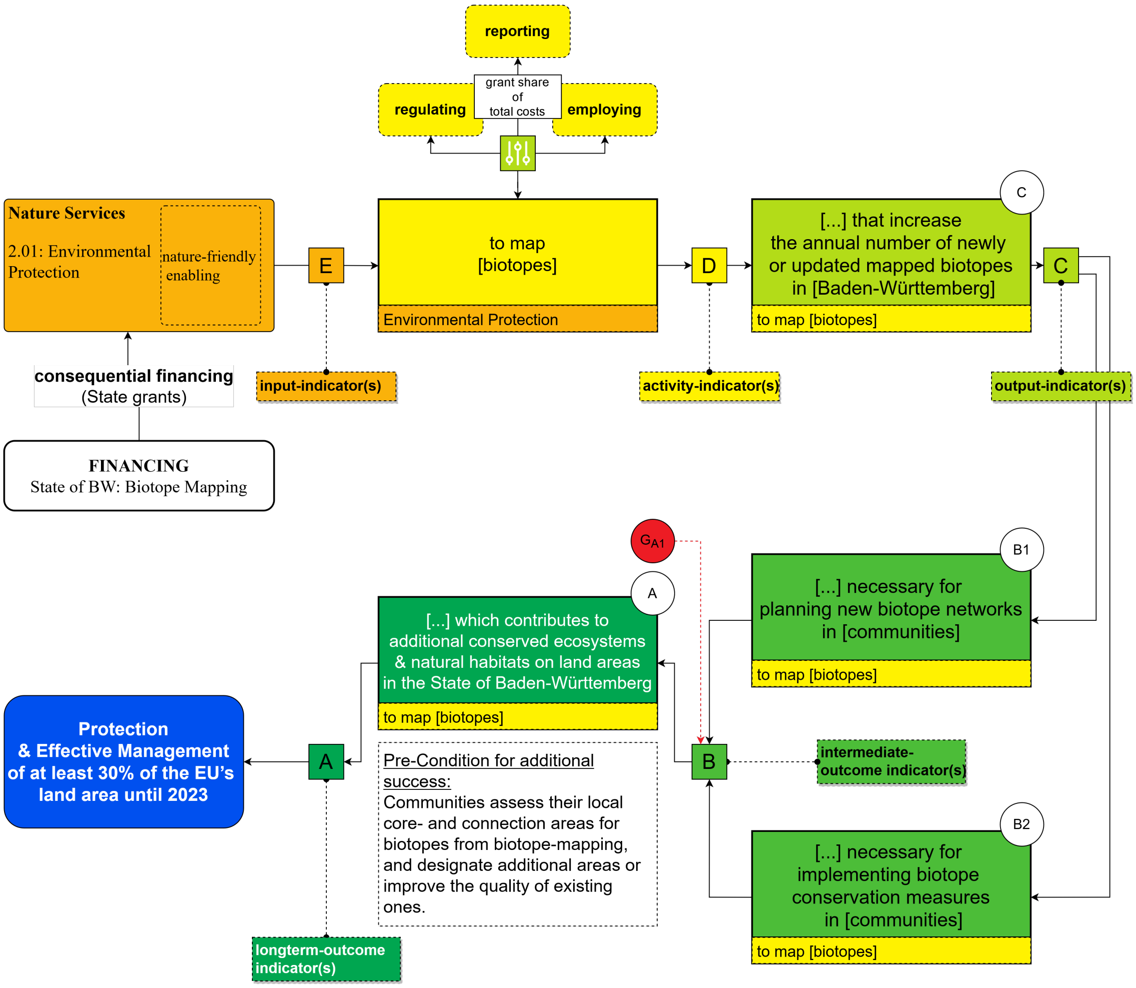
6.3.3 Rework of ToC and potential indicators

The assessment of the claims corroborated the initial assumption that biotope mapping contributes to the Impact as part of a set of necessary conditions. While some of the additional areas result from the mapping alone via designation as protected areas, further potential Outcomes also rely on the actions of Other Actors. It is up to the communities to use the findings of BM for their own spatial planning and conservation management measures. This has not been explicated in the ToC so far (and has also not been considered in the previous impact report).

There are two options to incorporate this finding into the ESG-LM. The first option is to define the contribution of communities as an additional pre-condition for change. The second option is to add a second intervention pathway from state grants to communities for biotope planning and improvement. This would thus include all efforts by all Main Actors towards a larger biotope network in the state of BW. In the context of the second Green Bond by BW, only the first option is viable, because the grants under LPR (see previous section) have not been included as eligible project category for the 2022 Bond. Additional adaptations are a re-formulation of the Intermediate Outcomes so that "in [communities]" is identified as a scope for spatiality as well as the introduction of a Rebound potential. The latter refers to the risk of reduced Long-Term

Outcomes if the designation of private property as protected areas cannot be achieved on a voluntary basis (see evidence in previous section). The following figure shows the update and second iteration of the ESG-LM for "biotope mapping" in the GB-BW.

Figure 6-4: ESG-LM (second iteration of ToC) for biotope mapping by state of BW (Case Study B)



Source: own compilation

The next step is to derive potential indicators for the case. Looking at the revised ToC and incorporating the target conflicts, the following table shows a list of potential indicators.

Table 6-8: potential indicators for Case Study B

Indicator Suggestion			
A_A	Total share of protected area in the state of BW at the end of 2021 [%]		
	B_A	Annual change in open land biotope areas in BW [ha/a]	
		C_A	Annual change in number of new or updated open land biotopes [%]
G_{A1}	Risk of reduced desired impact from non-designation of protected areas on private property		

Source: own compilation

6.3.4 Impact measurement and interpretation

Case Study B has already been assessed in a previous impact report based on primary data provided by the issuer and the responsible ministries and agencies in the state (Teubler & Schekira, 2023b). No models or additional assumptions were necessary for that purpose and the only calculation involved was the direct comparison of the number of captured biotopes from 2020 and after 2021 (indicator for Output). However, whereas the impact report indicated the change in the total number of biotopes, the explicated ESG-LM here prioritises the quantification of area changes.

Overall, there was an increase of biotope area of around 19% between 2010 and 2021 according to Table 6-9.

Table 6-9: calculation of increase in biotope areas since beginning of fourth mapping period

Metric	**Value**
total area of biotopes between 2010 and 2021	57,917 ha
newly mapped biotopes after 2010	12,508 ha
biotope areas that lost their protected status after 2010	2,531 ha
biotopes that became forest after 2010	607 ha
additional protected areas in open land after 2010 (calculated)	9,370 ha
increase in protected areas in open land after 2010 (calculated)	19.3%

Source: own calculation; data based on LUBW, (2023)

It is not possible to derive the total change in protected areas for the year 2021 from the public data on current biotopes in BW alone. However, the newly mapped biotopes in 2021 can be used as a conservative estimate for the minimal increase in the give year. According to the data and mapping service of LUBW, the total area of newly mapped biotopes in 2021 amounts to 997 ha (own evaluation from the dataset in LUBW, (2023)). This translates into a minimal increase of 1.75% compared to the data depicted in Table 6-9.

For an indicator of quality A (Long-Term Outcome) there is currently no data available that can match to the activities of all Actors involved and such an indicator can thus not be reported at the moment.

The following Table 6-10 shows the results of the impact assessment.

Table 6-10: impact assessment of Case Study B
(Q_R: Quality Q of the indicator and Robustness R of the indicator value)

Q_R	**Indicator** *(for A to D: ex ante; for A to C: diminishing in the future)*	**Value**
Credence (minimum threshold) for expected effects		0.64
B_1	Increase in open land biotope area from newly mapped biotopes	997 ha

Q_R	**Indicator** *(for A to D: ex ante; for A to C: diminishing in the future)*	**Value**
C_1	Increase in number of biotopes	3.2%
D_1	Number of updated or new biotopes	11,401 p.a.
E_1	State grants allocated to biotope mapping	EUR 3.6m
G	Risk of reduced desired impact from non-designation of protected areas on private property	
Attribution of financing to Outputs		100%
Additionality of Financing: consequential financing		EUR 3.6m

Source: own compilation

The interpretation of the results can be solely based on the information contained in the table. The issuer contributed to the mapping of biotopes with an Attribution ratio of 100% since it is the sole financer of the Activity. The financing conditions also constitute consequential financing for the allocation of state funds alone, since the Outputs could probably not be achieved without this Financing (it is unclear whether and to what extend this funding is co-financed by the federal government or from EU funds). These state expenditures amounted to EUR 3.6m. The over 11,400 new or updated biotopes in 2021 represent an increase of mapped biotopes of 3.2%. This, in turn, was necessary for an increase of the overall open land biotope area of at least 997 ha.

The societal benefits are at least probable (cr = 0.64) but the overall effect also heavily relies on the actions of Other Actors. The communities, for which the mapping results from 2021 are relevant, could have undertaken additional measures to improve the current status of biotopes or to designate additional protected areas. The results are based on *ex post* monitoring. An *ex ante* estimation of the desired Long-Term Outcome (share of total protected area in the state) could not be conducted.

6.3.5 Lessons learned

The prototype could be adapted successfully to assess an outcome pathway for the protection of ecosystems. Moreover, the previous impact assessment could be improved and the issuer’s claim on the contribution of biotope mapping towards the overarching goal was found to be credible.

The investigated case also showed (i) how different Intermediate Outcomes contributing to the same Long-Term Outcome can be heuristically identified and evaluated (ii) what role Other Actors play in the overall system, and (iii) that the financing was consequential for achieving the Output. A future report in a future Green Bond could incorporate these findings for a conjunction of grants for biotope mapping and grants to communities for biotope planning and conservation management in a new ESG-LM.

The data and evidence in this case can be considered exceptionally good. Almost all steps in the outcome pathway and all indicators could be based on reliable and relevant information provided by public sources. This is certainly an exception. However, environmental measures by institutional Actors usually require some form of monitoring and reporting. It is thus very likely that at least the intervention pathway from Inputs to Outputs can be developed and assessed in similar cases.

6.4 Case Study C: NRW.BANK SB (child-care facilities)

The third case is part of the Social Bond pool of NRW.BANK (NB-SB) and refers to loans for the acquisition or construction of facilities for childhood education in the federal state of NRW. The NB-SB comprises loans to companies and municipalities over a three-year period. Loan programmes and their resulting projects are eligible if they contribute to "Affordable Home Ownership", "SME Financing and Employment Generation", "Access to Essential Services: Health", "Access to Essential Services: Education", "Access to Public Goods & Services" and "Disaster Management" (NRW.BANK, 2022). The framework is corroborated by a SPO. I assessed the Bond in question (loans from 2019-2021) (Teubler, 2023c) in line with my published (non peer-reviewed) methodology (Teubler, 2023b).

I select this Bond as a case study because (i) it covers social rather than environmental goals, (ii) it is aligned with international commitments (SDGs) rather than European policies, (iii) impact assessment methodology for Social Bonds is fairly underdeveloped in literature, and (iv) the credibility of the already existing ToC has not been assessed so far. Since Case Study A represents a common base-case and Case Study B is an adaptation of the developed PT, I expect that this case reveals some additional insights on the limitations of my overall approach. From the broader category of promotional loans for "Access to Essential Services: Education", I choose loans mainly aimed at construction or acquisition of buildings for day-care centres for ESG-LM development.

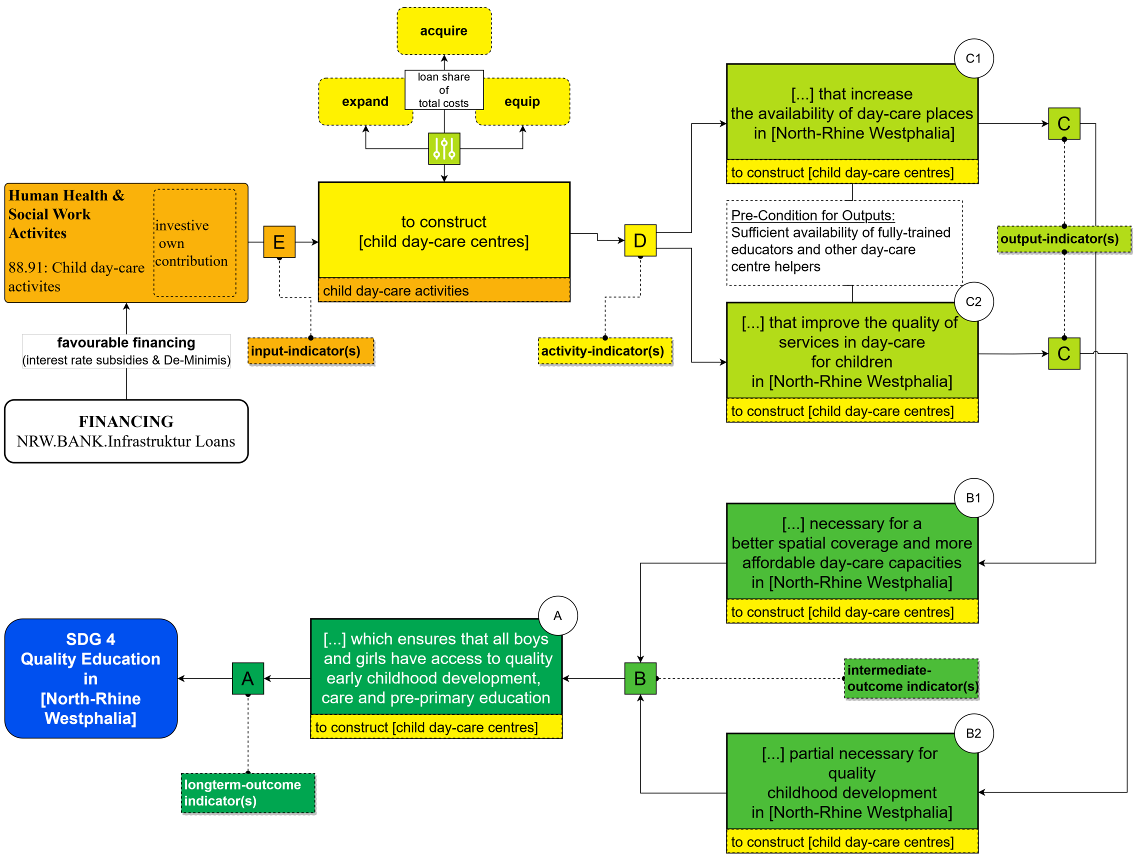
6.4.1 ESG-LM and project data

The previous method report (Teubler, 2023b) covered these loans as part of outcome pathway O2, which stipulates the following hypothesis (without additional pre-conditions):

> *"The NRW.BANK loans for educational purposes lead to increased accessibility as well as additional recreational and physical activity capabilities via the construction and modernization of educational buildings. This ensures safe, non-violent, inclusive, and effective learning environments as well as equitable and qualitative primary and secondary education (SDG 4: QUALITY EDUCATION) if it contributes to an increased access to new and beneficial educational offers as a consequence." (Teubler, 2023b, p. 16)*

The next step is to adapt the previous underlying ToC in such a way that it only alludes to buildings for children's day care rather than all types of educational buildings covered by the loans. The following Figure 6-5 shows the explication of such an attempt.

Figure 6-5: initial ToC for child-care centres in NRW (Case Study C)



Source: own development

This first iteration already looks quite different from the original ToC for different reasons. The main reason is the explication of the Long-Term Outcome. Whereas the previous ToC highlighted SDG 4 targets such as inclusive learning environments and quality primary education, child-care centres are more closely related to SDG 4.2 on desired Outcomes for early childhood development. As a consequence, the antecedents have been adapted as well. Instead of a focus on investment capacities and improved curricula, it seems to me that this particular type of activity is more closely related to a better spatial coverage of such centres (O1) as well as “quality childhood development” (O2) in the state of NRW. This in turn requires tangible results (Outputs) concerned with “increased availability of child-care places” and “improved quality of services in day care” for children in NRW. Looking at potential pre-conditions for this change (the previous ToC explicated no such conditions) and given my background knowledge (see next section), these Outputs also require a sufficient number of trained educators. This is not covered by the loans. The final adjustment of the previous ToC is not relevant in a causal sense but aligns this ToC better with the ESG-LM methodology in the dissertation at hand. The input is now explicated as favourable Financing (interest rate subsidies according to NRW.BANK, (2023b)) towards NACE sector 88.91 (Child-care activities) rather than the more generic category of “Education”.

The available primary data was provided by the issuer and contains a list of loans between 2019 and 2021 that had been aligned with the issuer's Social Bond framework in the category "Access to Essential Services: Education". Out of three different types of specific loan programmes, only loans paid out via "NRW.BANK.Infrastruktur" could be associated with child-care capacities in the previous assessment (50 out of 340 loans). Each loan in this list contains the following type of information: postal code of borrower or location of asset (only available for 18 out of 46[28] loans), year of approval, nominal value, loan duration (start date and end date), and a short non-standardised description of the measure in German (used to attribute these loans to child-care in the previous assessment).

The following table summarises and qualifies the available information regarding the initial ToC. It shows that the majority of the loan descriptions refer to investments that initiate construction activities (36 out of 46 loans) and that only 18 loans can be associated with a specific location in NRW.

Table 6-11: description of primary data for Case Study C

Information			**Value**
total number (no) of loans aligned with "Access to Essential Services: Education"			340
subset	no of loans alluding to day care for children in description		46
	subset	no of loans for "construct" (entailed, non-exclusive)	36
		no of loans for "acquire" (entailed, non-exclusive)	3
		no of loans for "equip" (entailed, non-exclusive)	6
		no of loans for "expand/modernise" (entailed, non-exclusive)	3
		no of loans for unspecified purposes	1
		no of loans with specific post-code	10
		no of loans without post-code but name of location	8
		no of loans quantifying additional places or groups in day care	9
		share of day-care loans from NRW.BANK.Infrastruktur	100%

Source: own assessment

6.4.2 Hypotheses and epistemic justification

The following first hypothesis can be derived from the baseline ToC.

(H_1) $p \land q \rightarrow r_1 \lor r_2$:

The loans for child day-care activities will lead to new, expanded or modernised day-care

[28] Four loans are attributed to kindergardens only. While there are kindergardens that also function as day-care centres, it is assumed that loans for kindergardens do not necessarily entail this service.

centres for children that will either *(r_1) increase the availability of day-care places* or *(r_2) improve the quality of offers to children in day care in NRW.*

A non-true first hypothesis ($\neg H_1$) comprises all cases in which ($\neg H_{1a}$) loans were not necessary, ($\neg H_{1b}$) loans were not used for the Activity, ($\neg H_c$) Activities neither increased the availability of day-care places nor improved the quality of offers, or ($\neg H_n$) any other condition which makes the statement untrue.

The evidence E for H_1 consists of all data comprised in the dataset provided by the issuer. It ascertains that loans were given out for the purpose of constructing, acquiring, modernising, or equipping day-care centres for children (e_1). Additional data could be collected by comparing loan descriptions for loans that could be located with publicly available information on construction activities in NRW. This information can be found in the Annex (see A-7). It corroborates that (e_2) at least 12 out of 18 loans can be associated with actual anticipated Activities (with the remaining six loan descriptions being too unspecific to be corroborated) and that ten loans lead to additional capacities for children in day care.

The following table summarises the argument from BR for H_1.

Table 6-12: BR for H_1 in Case Study C

Stages	Reasoning	Credences
Prior-Test	It can be ascertained from the background knowledge that the issuer is (b_1) a promotional bank subject to federal oversight for its financing programmes, (b_2) the state of NRW has a law in place that promotes day-care centre personnel, quality, and capacities (Landtag NRW, 2019), and (b_3) that the loan programme attributed to H_1 is earmarked for day care, that is, loans are only given out if the borrower demonstrates that capital is put to this purpose (NRW.BANK, 2023b). Looking at the prior probability of H_1 conditioned on this background knowledge, I find a slight positive credence (probable) to be justified. The promotional loans are aligned with state policies on day-care centre needs in communities and the loans themselves are earmarked. Given this information, I also attribute an extremely low credence to $\neg H_{1a}$ and $\neg H_{1b}$, as the financing is in place because there are additional day-care needs in the state and the loans are earmarked. Without considering the evidence (yet), all remaining non-true explanations ($\neg H_{1c}$; $\neg H_{1n}$) could still be credible,	cr (H_1.b) ≈ 0.6-0.8 and cr ($\neg H_1$.b) = 0.4-0.2 from $P(H_1) + P(\neg H_1) = 1$

Stages	Reasoning	Credences
	because it is possible that some Activities and Outputs are triggered that neither increase the number of places nor improve the quality of offers (e.g., office equipment or purchasing vehicles). H_1 therefore does not constitute an argument from triviality (see Section 5.4.5) but has an initial credence above the threshold of 0.5.	
Silence-Test	The loans are paid out to the borrowers via their house banks who also approve the loans. This means that not all information that is available to these house banks on the specific investments is also available to and scrutinised by the promotional bank. It is therefore expected that not all evidence pointing to H_1 is collected and present. This should increase the reliability of the initial credence.	
Hoop-Test	The Empirical Certainty of the affirmative (prior pointing to H_1) is very high considering the evidence. There is (e_1) specific project related data from a primary source, and (e_2) corroboration on additional day-care centre places from independent sources in the majority of cases (press releases and Main Actors). While this does not change the credence, it should raise the confidence in the reliability of it.	
Doubly-Decisive-Test	Given the body of evidence, it is fully expected under the main hypothesis. By comparison, it is extremely surprising under the assumption that state grants are not necessary, or loans were given out for other than the approved Activities. The evidence would also be at least somewhat surprising if the investments by the main Actors did not lead to either additional day-care places or improved quality of offers. Even in cases where buildings were replaced or day-care groups were re-located, the latter seems to be the case. Out of a set of conceivable "other explanations" ($\neg H_{1n}$), it seems at least likely that some of the desired Outputs are either not achieved in single cases or achieved by other means than financing by the issuer (constituting the highest consequent for a non-true hypothesis). However, in all cases investigated (see A-7), such donations as well as additional state grants also required the loans to be given out.	$cr(E\|H_1) \approx 0.99$ $cr(E\|\neg H_1) \approx$ 0.60-0.80

Stages	Reasoning	Credences
	The posterior credence is above the threshold and increases slightly as a result. Given this information, one can be somewhat confident (a fortiori) that the loans lead to the desired Outputs.	
BA	$cr\ (H_0 \vert E.b) = \frac{cr\ (H_0.b) \times cr\ (E \vert H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E \vert H_n.b)}$	cr (H_1|E.b) = 0.65-0.87

Source: own development

The following second hypothesis can be derived from the ToC.

(H_2) ($r_1 \wedge z_1$) ∨ ($r_2 \wedge z_2$) → r_A:
(H_{2a}) An increased availability of day-care centre places for children in NRW is necessary for a better spatial coverage and more affordable day-care capacities. (H_{2b}) A quality improvement of offers to children in day care in NRW is partially necessary for a better access to quality childhood development. Either of these Intermediate Outcomes ($H_{2a} \vee H_{2b}$) contributes to ensuring that all boys and girls have access to quality early childhood development, care, and pre-primary education in the state of NRW.

A non-true proposition for H_2 entails that either additional places for children in day care are not causally related to a better spatial coverage ($\neg H_{2a}$) or that improved offers to children in these facilities do not trigger a better access to quality childhood development ($\neg H_{2b}$). The third potential non-true proposition is that neither ($\neg H_{2c}$) of these intermediate outcomes is a contribution to ensuring access of boys and girls in the state to quality early childhood development and care. All remaining non-true propositions are explicated as $\neg H_{2n}$, which mainly entails the proposition that these Outcomes could be achieved from investments into personnel only (the pre-condition for change).

This disjunct of outcome pathways is corroborated by evidence E, but only on the first of the causal mechanisms. The statistic office of the State of NRW (IT.NRW) publishes statistics on the development of day-care capacities, children in day care and the development of personnel in these facilities. Under the assumption that most measures would have been realised within one year of granting a loan, data from 2020 and onward provide evidence for the claims. Regarding personnel (the pre-condition for change in the ToC), (e_1) the number of educators working in day-care centres has increased by 11% between 2018 and 2022 (IT.NRW, 2023c). And while there have been different developments among different types of graduates in this area, (e_2) there were more graduates in 2021 than in 2017 in a five-year trend (ibid.). Regarding H_{2a} (available places) between 2020 and 2022, (e_3) the total number of children in day care (including kindergardens) increased by 3.5% (own calculation from (IT.NRW, 2022a) and (e_4) the total number of facilities increased by 2.4% (own calculation from ibid.). Looking only at the subset of publicly funded day-care centres in the state (KiTas), (e_5) the number of children there increased by 1.7% in the same time period (IT.NRW, 2022b) with an increasing trend of the majority of children being in care for more than 25 hours per week. Moreover, (e_6) the care-ratio of care personnel to children increased between 2021 and 2022 among all age groups (IT.NRW, 2023b).

The following table summarises the argument from BR for H_2.

Table 6-13: BR for H_2 in Case Study C

Stages	Reasoning	Credences
Prior-Test	The first piece of background knowledge pertains to the overall circumstances. The Covid-19 pandemic (b_1) affected all types of care and education for children (closed frequently for short periods of time and increase of virtual education) as well as the working conditions of parents (more home office). This could have affected the statistics cited above in both directions but is an indication of a non-normal state of the system nonetheless. Regarding H_{2b} (quality of day care), no state specific evidence could be collected. However, a recent study on behalf of the Federal Government (Stöbe-Blossey et al., 2023) evaluated the success of the implementation of the federal KiQuTG[29] law in its ten fields of action. The authors show (b_2) that the use of public funds has increased in NRW in all investigated fields of actions, including "promotion of language education" or "strengthening of day care for children" (ibid., p. 22). The subsequent study on the effectiveness of the law as well as additional state funding and regulations (Ronnau-Böse et al., 2023), highlighted additionally that (b_3) the satisfaction of the personnel has decreased (reasoned as an effect of the pandemic) but dissatisfaction could be mitigated if states were willing to fund additional measures, and that (b_4) the professional qualification of educators has improved. Finally, there is also background knowledge (b_5) that previous federal and state funding programmes for the expansion of day-care centres have	$cr(H_2.b) \approx 0.5$ and $cr(\neg H_{2n}.b) = 0.5$ from $P(H_1) + P(\neg H_1) = 1$

[29] Law for the further development of quality and for the improvement of participation in day care facilities and in child day care (translated from "Gesetz zur Weiterentwicklung der Qualität und zur Verbesserung der Teilhabe in Tageseinrichtungen und in der Kindertagespflege")

Stages	Reasoning	Credences
	been successful in the past (Federal Ministry for Family Affairs, Senior Citizens, Women and Youth, 2023). The first three investment programmes (totalling EUR 3.28bn) led to 560,000 additional day-care places for children in Germany and increased the care-ratio from 17.6% in 2008 to 35% in 2020. Looking at the prior probability of H_2 conditioned on the background knowledge, there is a reliable information (probable) that day-care capacities and quality have improved over recent years on both the federal and state level. This is attributed to federal and state funding in ten fields of action. The evaluation reports on achieving the overarching goals highlight the importance of additional personnel and additional training of skilled educators, but also the need for new capacities and improved conditions in the premises of the facilities itself. Conversely, the most likely non-true proposition is the fact that the care-ratio and quality of educators has improved as well. This is expected under the assumption that this is a pre-condition for better-quality early-childhood education, but it is also possible that this is the main reason for success. Without considering the evidence (yet), I therefore find that at least one non-true explanation is as plausible as one of the main hypotheses (cr (H_{2b}) = cr ($\neg H_{2n}$)) when arguing from a fortiori. This means that the initial credence cannot be considered to be above the threshold of 0.5 if both partial hypotheses are claimed to be true.	
Silence-Test	Given the focus of federal and state regulations to improve both the capacities and care-ratio in day-care centres as well as the focus on the qualification of educators as the main variable for quality childhood care, it is not surprising that no reports or statistics could be found that investigate the effect of additional physical space and equipment in day-care centres. This should increase the reliability of the initial credence, but for H_{2a} only.	
Hoop-Test	The Empirical Certainty of the affirmative (prior pointing to H_2) is very high for H_{2a} (additional places leading to better	

Stages	Reasoning	Credences
	spatial coverage) considering the evidence. Both the overall number of facilities as well as the number of available places increased from 2020 onward. There is no evidence for H_{2b} though. Given the focus of the federal and state programmes (see Silence-Test), this is not surprising and is thus neither probable nor improbable. Given the assumption that either of the sub-hypotheses can be true in a given case (disjunct of H_{2a} and H_{2b}), this information should further increase the reliability of H_{2a}.	
Doubly-Decisive-Test	Given the body of evidence, it is fully expected under the first sub-hypothesis and at least likely under the second sub-hypothesis. By comparison, the evidence is extremely surprising under the assumption that additional places do not lead to better spatial coverage or that additional offers do not trigger access to better childhood development. However, the evidence is also at least very likely, if additional personnel and their qualifications are the main cause for quality improvements ($\neg H_{2n}$). The posterior credence therefore neither denies nor establishes the credibility of the claim. Given this information, a rational actor cannot be confident (a fortiori) in one of the two outcome pathways.	$cr\ (E\|H_2) \approx 0.99$ $cr\ (E\|\neg H_2) \approx$ 0.95-0.99
BA	$cr\ (H_0\|E.b) = \frac{cr\ (H_0.b) \times cr\ (E\|H_0.b)}{\sum_n cr\ (H_n.b) \times cr\ (E\|H_n.b)}$	$cr\ (H_2\|E.b) =$ 0.55-0.62

Source: own development

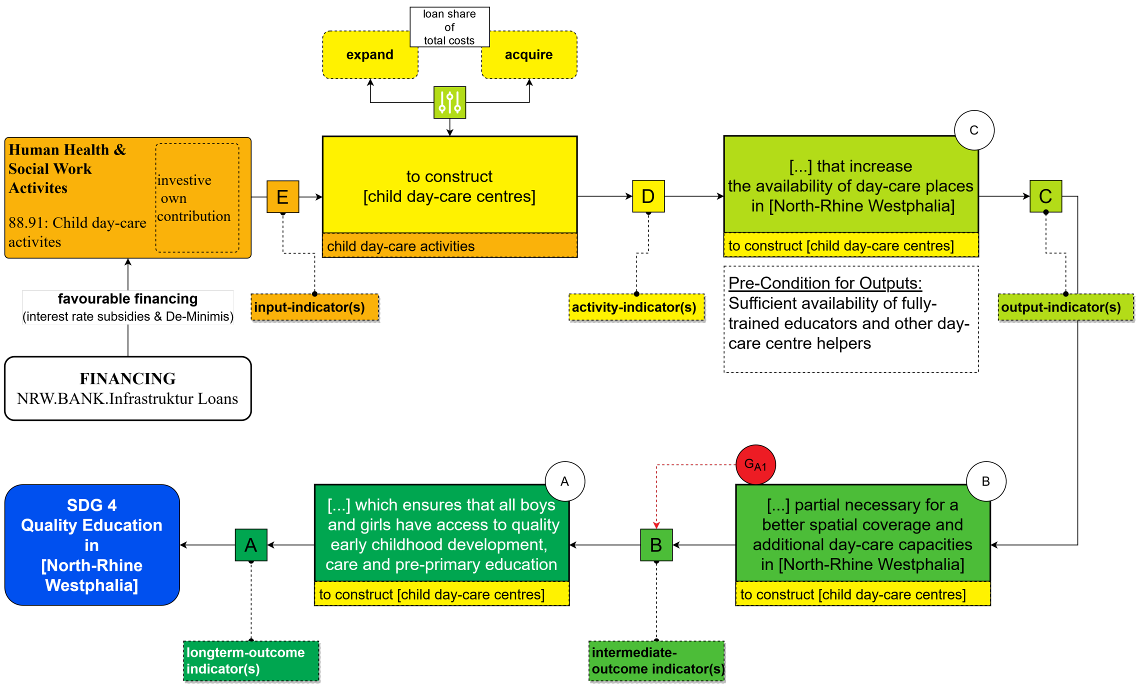
The first hypothesis (H_1) establishes that the loans either lead to additional places or some form of modernisation of existing facilities. The credence for this is above the threshold, but only slightly (0.65-0.87). By comparison, the second hypothesis (H_2) could neither be corroborated nor discarded (0.55-0.62). The reason for that is that there is not sufficient background knowledge or evidence suggesting that the modernisation and equipment of day-care facilities is a deciding factor for an improvement of the quality of early childhood education. Since the second claim hinges on the first being true, the overall claim is not justified (unless new evidence E' emerges that tilts the scale).

6.4.3 Rework of ToC and potential indicators

There are two options to improve the ToC and the credibility of the claims. Option 1 would be to include state investments into additional personnel and their education into the ToC as a separate intervention (currently included as pre-condition for change). This option is not feasible in the case at hand, because the assets considered for the impact assessment do not include such Activities (it is not part of the loan programme investigated). The second, and thus selected option, is to remove this outcome pathway from the ToC. This seems also reasonable from the perspective of impact measurement since the overall majority of the triggered activities result in additional buildings and capacities (see Table 6-11). However, this also means that only this fraction of loans can be translated into indicators, which is why the sub-purpose “equip” is dropped from the Activity. A further adaptation is to remove the requisite of “affordability” for the Intermediate Outcome. I find that this condition is also causally linked to other funding by the state rather than the loans itself.

The following figure shows the re-worked ToC for Case Study C.

Figure 6-6: ESG-LM (second iteration of ToC) for constructing day care centres (Case Study C)



Source: own development

The credibility of the claims drastically improves, given the same background knowledge and evidence as considered before. For H_1, the prior is unaffected, but since there is evidence that additional facilities could be constructed in the relevant time frame from the loans in question, it would be at least very surprising given any other explanation. This means that the prior credence of 0.6-0.80 increases to a posterior credence of 0.88-0.99 and that the first hypothesis is now well attested to. For H_2 the difference in plausibility is even more pronounced. Now the prior is clearly justified given the background knowledge. Especially the past expansion of day-care places from previous programmes (b_5) points to at least a probable relationship, whereas the other pieces of information do not affect the prior negatively (prior of 0.6-0.8 instead of 0.5). We also know from evidence that the overall capacities in the state have increased in the given time frame, which is fully expected under H_2, but at least very surprising if additional facilities would not affect this Outcome. As a consequence, the posterior for H_2 (0.88-0.99) is as high as for H_1.

The next step is to derive ideal indicators for the case and to identify target conflicts. The relationship between additional capacities and better spatial coverage can be causally inferred, but still entails the risk of an oversupply in some regions compared to an undersupply in others.

The following table shows a list of potential indicators and depicts this target conflict.

Table 6-14: potential indicators for Case Study C

Indicator Suggestion			
A_A	Share of children having access to early childhood development in NRW [%]		
	B_A	Change in average distance to next day-care centre [km]	
		C_A	Change in number of additional day-care places per annum [1/a]
G_{A1}	Risk of reduced desired impact from unevenly distributed facilities		

Source: own compilation

6.4.4 Impact assessment and interpretation

The first indicator limits the Input to those loans where day-care centres for children are either constructed, expanded, or otherwise acquired. This is true for 45 out of 50 loans, or EUR 76.2m (representing the input-indicator) out of a total loan volume of EUR 80.8m. These Activities also constitute at least 45 day-care centres that are either provided additionally in the State of NRW or represent relocations and replacements. Since there is not primary data on this question in each case, I use the fraction of loans where additional places were created definitively compared to the overall cases where relevant information could be found. Out of 12 loans with specific information, ten loans could be associated with new places for children. With this ratio of 10/12 in mind, I estimate that 37 new buildings for day care are provided with a dedicated loan volume of EUR 63.5m.

I also know from the background knowledge, that the previous day-care programmes in Germany led to 560,000 additional day-care places from total grants of EUR 3.28bn (Federal Ministry for Family Affairs, Senior Citizens, Women and Youth, 2023). It can be safely assumed that costs have increased in the meantime in general, and that it is also more costly to provide new places where such day-care centres already exist (marginal utility decreases). Given that the most recent investment programme intends to provide 90,000 places for EUR 1bn, and that only half of these grants would lead to a similar effect, I estimate for a conservative estimate that a loan volume of EUR 63.5m is equal to 2,800 new places for children in day care or 75 new places per day-care centre.

The best-needed indicator for Intermediate Outcomes cannot be estimated. Although the statistical office of the federal state of NRW (IT.NRW, 2023a) reports on the current accessibility of day-care centres in the state (e.g., footpath in minutes to next KiTa), there is no public data on how this accessibility has changed on an annual basis. I therefore decide to report a proxy instead, by comparing the additional capacities with the overall count of day-care places in the year 2021 (the most recent loans provided by the issuer). IT.NRW reported 654,119 day-care places in the state in March 2021. The additional 2,800 places therefore represent an increase of 0.4% in capacity (indicator for Intermediate Outcome). No similar indicator could be identified that represents the Long-Term Outcome of ensuring access of all boys and girls to quality early childhood development.

The indicators should be depicted regarding their quality and robustness, as operationalised in Chapter 2 (see Section 2.1.6). The following Table 6-15 lists all indicators from A to D, and also includes information on the target conflicts involved. The Attribution of the loans could not be estimated from the provided data alone and is thus considered "unknown".

Table 6-15: Impact Assessment of Case Study C

(Q_R: Quality Q of the indicator and Robustness R of the indicator value)

Q_R	**Indicator** *(for A to D: ex ante; for A to C: diminishing in the future)*	**Value**
Credence (minimum threshold) for expected effects		0.88
A	*No indicator could be found*	-
B_4	Increase in day-care capacity	0.4%
C_4	Additional day-care places for children (rounded down)	2,800
D_2	Additional day-care centres	37
E_1	Loan volume for additional day-care centres	EUR 63.5m
G	Risk of reduced desired impact from unevenly distributed facilities	
Attribution by financing		unknown
Additionality of Financing: favourable financing		no estimate

Source: own compilation

The interpretation of the results can be based on the information contained in the table. The issuer contributed to the acquisition or construction of day-care centres for children between 2019 and 2021 by providing loans with favourable conditions. The actual share of financing for these loans, or Attribution to desired effects, is not known, but the overall credibility of the issuer's contribution to quality education is high (credence of 0.88 out of 1). The total volume allocated to this Activity amounts to EUR 63.5m (primary data), which can be estimated to contribute to additional day-care centres in 37 cases (based on the ratio of known additional centres compared to re-locations). Considering the success of previous federal investment programmes, and considering increased costs and lower margins of utility, this loan volume can be equated with around 2,800 additional places for children in the state of NRW. These additional places have increased the day-care capacity in the state by at least 0.4% compared to 2021.

6.4.5 Lessons learned

The third case study explicated a desired causal relationship between loans for day-care buildings and SDG 4 on quality education. The first ToC included all loans where the Main Actors either intend to construct, acquire, modernise, equip, or expand day-care centres for children. This required two disjunct outcome pathways leading to better spatial coverage on the one hand, and better-quality education for children on the other hand. It was also clear from the outset that investments into personnel expansion and education were a necessary additional pre-condition for success, but not included in the financing provided by the issuer.

This somewhat convoluted three-way interaction of Main and Other Actors with the system was difficult to justify. Looking at the different hypotheses of this ESG-LM as well as the background knowledge and evidence, it could not be shown that the underlying causal inference is reliable and thus, that a third party is warranted in believing its claims. However, the BR also revealed the reason for this. Whereas equipping and modernising the facility is probably part of some set of necessary conditions for quality education, it is, according to evaluations, a lot less relevant compared to improving the care-ratio and qualification of educators in day-care facilities. The initial ESG-LM therefore explicated a CM in which the pre-condition has a higher Empirical Importance (see Section 5.5.2) than one of the intervention pathways investigated. The solution for this problem was surprisingly simple. Instead of incorporating the entire sample of loans, only that fraction of loans was assessed that contributed to additional capacities. The intervention pathway that was overshadowed by the pre-condition could thus be dropped, which resulted in a high credence for the remaining causal claim.

Case Study C also showed how relevant primary data and data from secondary sources can be easily identified once the ESG-LM displays a credible claim (which I could not achieve in the most recent impact assessment of this Social Bond). Although it was not possible to estimate an indicator on the level of the Long-Term Outcome and although the indicator for the Intermediate Outcome is far from ideal, a contribution of the issuer to desired societal Outcomes could be demonstrated in an example, that has, to my knowledge, not been investigated before.

7 SYNTHESIS

I separate the synthesis into three sections. Section 1 discusses the initial research questions and how my methodological framework tackles the issues. The next section translates the findings to other applications of the model outside of impact assessments for Green or Social Bonds. And the final section discusses how academic research could benefit from the theories, methods, and tools applied or developed.

7.1 Response to research questions

My initial problem description and asserted premises led to three research questions shown in Table 1-2 and repeated here in Table 7-1.

Table 7-1: research questions of the study

No	Research questions (RQ)
RQ1	**Contribution logic:** can ESG-relevant measures be classified, hierarchised, and prioritised in a consistent logic that results in adequate and plausible alignment of interventions with desired sustainability impacts?
RQ2	**Epistemic justification for contribution:** how can third parties be warranted in believing the claims of such a logic regarding the causal link between interventions and outcomes as well as the contribution of Actors towards the desired changes?
RQ3	**Contribution assessment methodology:** can the developed logic be used to identify and estimate reliable indicators that demonstrate sustainability benefits on a societal level which can be traced back to the intervention?

Source: own compilation

RQ1 addresses the focus of the study on the contributions of earmarked financing towards sustainability goals and the explication of impact chains via measures by financed Main Actors. By applying a ToC methodology against policy frameworks, I affirmed that ESG-relevant measures can function as a causal inference for tangible effects and that these effects can be shown to trigger plausible societal changes towards overarching sustainability goals. Looking at both the PoC and the PT, these two generic ESG-LM demonstrated that (i) components of the ToC can be distinctly classified and that (ii) they are hierarchised according to their place in the impact chain in a consistent manner. The adequacy of the generic models itself could be evaluated by measuring their Goal Certainty, Sufficiency, and Measurability. I also developed several heuristic tools to aid practitioners in finding plausible intervention- and outcome pathways. I thus find that the development of such a Contribution Logic could be achieved. However, the logic models shown throughout this work are still tied to specific and already existing frameworks for sustainability goals. They have to be adapted to function as logic models for other sustainability dimensions (shown in Chapter 6) or a different set of measures and Actors. Therefore, it is not guaranteed that the methodology developed here works in every case. Its mechanistic and linear logic might very well be insufficient to address more complex multi-stakeholder processes or change-processes with feedback loops.

RQ2 asks how other stakeholders are warranted in believing the heuristic pathways of the ESG-LM. A large portion of the dissertation is thus dedicated to developing a methodology for assessing the credibility of its entailed causal hypotheses. These hypotheses are described with propositional logic (with project-level hypotheses conjunct to societal-level hypotheses) and then tested with the help of Bayesian Epistemology. I developed a four-step informal BR process that facilitates this assessment (other approaches are discussed in Chapter 5.5). The Argument from Triviality (step 1) uses the prior in BT and lends credence to claims that we generally accept to be true from our background knowledge. It separates causal relationships that are trivially true from those that require a more thorough investigation and evidence to be warranted. The Argument from Silence (step 2) investigates whether evidence that is absent is fully expected to be absent. If that is the case, it can be an indication for a higher confidence in the initial claim. The Argument from Empirical Certainty (step 3) or Hoop-Test compares the available evidence in a case to its claims. Since certain relevant information is expected to be present for almost any hypotheses entailed in an ESG-LM, its absence would be surprising and thus disconfirm a hypothesis. The final step is called Argument from Empirical Uniqueness (or Doubly-Decisive Test [sic]). It completes the informal application of the propositional form of BT by comparing the likelihood of evidence under both the main and alternative explanations (the consequent in BT) as well as its prior probability before looking at this evidence. This belief-update provides the analyst, and any other interested third party, with a posterior credence in the claims between 0 (impossible) and 1 (certain). This epistemic relationship can then be used to confirm or disconfirm, but also to update the ESG-LM hypotheses for better credences (see case studies in Chapter 6). I therefore find that this tool tackles RQ2 successfully — especially in light of insufficient data and time constraints.

RQ3 is concerned with both the identification and estimation of reliable indicators for an ESG-LM. The model facilitates this identification because it (i) describes what type of effects are expected at each stage of the outcome pathway (so-called potential indicators) and (ii) the analyst knows at this point what type of information is the most crucial in regard to a reliable contribution and plausible causal inferences. Both previous steps also make it easier to understand which type of target conflicts arise and how they might affect the indicators. For estimation, the model is open to different types of measurement methods, ranging from simple linear relationships to empirical investigations and models. This openness has been made possible because the previous step already assessed the credibility of the hypotheses and thus the indicators are not typically required to *prove* any of the claims. I also developed a simple metric to evaluate the robustness of any indicator. The final result therefore not only describes what has been measured, but also how these metrics compare to a set of ideal or best-needed indicators. I find that the core process of ESG-LM impact assessments described in this study is a successful response to RQ3. Limits to the approach are mainly restricted to questions of Attribution and Additionality. Although tools and procedures have been developed for this purpose in this dissertation, they could not easily be translated into concrete values throughout the case-studies. This is clearly a part of the overall methodological framework where additional data needs to be collected by the Actors and additional research is required (see also Section 7.3).

7.2 Other applications of the ESG-LM

The main goal of this work is to facilitate impact assessments of sustainable Bonds, that is, efforts of re-financing on the basis of green or social projects in the past as well as promises to develop new projects with similar effects. Investors have a demand for such assessments because they corroborate the claims of the issuer and justify investments even if they come with a *greenium* for the issuer.

However, the methodology shown here could also facilitate the selection of such projects in the first place. Most banks and state actors already have some form of alignment in place according to which loan or grant programmes are associated with overarching goals. An ESG-LM that is developed for this purpose would thus look very similar to one for a Bond report. It could be fed by primary data from projects that have been financed in the past and inform future project selection by predicting their desired effects on the basis of such sampling. It would thus function as a management or decision tool rather than a tool for indicator reporting, although the latter is facilitated as well. An additional advantage of this approach is that the process of epistemic justification shown in this dissertation facilitates both project selection and data collection. It would help to identify what type of information is needed for impact reporting but also to demonstrate a reliable contribution to the goals of an institution.

This can also be helpful for organisations that are not considered financial intermediaries in the classical sense. NGOs or extraterritorial organisations that are dedicated to *just transition* and sustainable development do not only provide capital for their projects, but also personnel and training. They already have their own explicit or implicit ToC but depend on donations and state funding. To that end, they must demonstrate that the projects they manage *make a difference* and therefore already collect data for some form of KPIs. The ESG-LM methodology developed here, as well as the process of epistemic justification, could build on already existing ToCs of these organisations and help to focus their evaluation efforts.

7.3 ESG-LM methodology for academic research

All of the tools discussed in this study are designed to facilitate quick assessments of desired sustainable effects and provide some information on the robustness of the results. Although they are grounded in a consistent epistemology, they do not provide a comprehensive framework for academic studies. However, they can be used for that purpose if adjusted or integrated into other frameworks. I identify four types of academic studies for which the ESG-LM and its tools might be helpful: statistical studies on the basis of Causal-Diagrams, evaluation methodologies, transition experiments, and empirical studies on the Additionality of Financing.

CDs go back to Judea Pearl and have already been briefly discussed in Chapter 5.5.3 (Pearl, 2009; Pearl & Mackenzie, 2019). Pearl labels such diagrams as a form of "'provisional causality', that is, causality contingent upon the set of assumptions that our causal diagram advertises" (Pearl & Mackenzie, 2019, p. 150). They can be used if randomised trials are impossible or unethical, and can describe causal pathways and predict confounding variables in a study. The ESG-LM already provides some of these causal assumptions in its ToC, especially if pre-conditions and target conflicts have been identified. It also has tools to justify or prioritise certain causal hypotheses over others. It could thus be used as a basis or first CD that is then further refined with the help of statistical tests. Case Study C on the relationship between funding personnel, personnel education, and providing facilities for early childhood development could be an example of such a study.

The second type of academic studies for which the ESG-LM could be useful are **evaluation methodologies**. ToCs have long been established as practices for this type of assessment in the social sciences. In fact, ToCs here are usually a lot more complex and account for both feedback loops and the capacities of actors. However, the causal inferences here are usually only measured with the help of qualitative indicators or auxiliary metrics. Some of the tools developed in this dissertation could thus facilitate the identification of useful metrics, the justification of CMs (especially in conjunction with BR), the interpretation of results, and the refinement of the ToCs.

Transition experiments (the third ESG-LM application for academic research) on the other hand are an emerging research area for questions of sustainable development that have, as of yet, no established assessment methodology. They are designed to test or co-create interventions for sufficiency or behavioural change on small scales (e.g., in a district of a city). As such, they can be difficult to evaluate with conventional statistical methods due to their asymmetric causal relationships, open research-design, and intentional interactions with the stakeholders. An ESG-LM in general, but also its integration of PrT, CA and CoA could facilitate impact assessments in this type of small-N within-case studies. More importantly, the development of an ESG-LM could indicate to the researchers which type of evidence or empirical fingerprints they ought to look for in first place, but also help to confirm the *ex ante* hypotheses.

My set-theoretic considerations of Additionality might be also helpful for **empirical studies** in the area of SF. Despite my inability to make a conclusive case for Additionality from financing conditions alone, I demonstrated a probability relationship between such Financing and the Additionality of desired outcomes. An empirical study could therefore test these assumptions (additional or consequential outcomes being more likely when such conditions are present) if sufficient data on these outcomes is available or collected. Moreover, I also discussed what type of other conditions need to be present for a convincing chain of causal conditions for Additionality. Surveys of stakeholders in the market could thus be a tool to investigate these additional conditions and compare them to cases where private equity, grants or favourable loan conditions are either provided or not.

7.4 Conclusion

My ongoing research on earmarked SF greatly benefited from the methodology developed in this study. I have also already integrated its core mechanics into other types of studies (e.g., a current EU project on the co-benefits of sufficiency). However, my main contribution to academia is not my operationalisation of *measuring* desired changes, but rather, the integration of concepts from philosophy and the social sciences into studies that are usually only modelled according to linear relationships or at best looked at from a strict empirical perspective. I hope I could convey the value of identifying what we *ought* to measure before such models are developed and that incomplete empirical information should not prevent us from finding the most plausible causal inferences.

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ANNEX

A-1 Definitions of terms

Annex Table a: definitions used throughout this study

Term	Definition	Source
Activity (ESG-LM)	Activities are tasks performed by Main Actors in support of specific objectives.	own adaptation from Social Impact Investment Taskforce (2014)
additional consequential Financing (ESG-LM)	Consequential Financing is the provision of private equity or grants for ESG measures or projects. Doing so makes it more likely that desired sustainable Outcomes occurred that would not have occurred otherwise.	own definition
additional favourable Financing (ESG-LM)	Favourable Financing is the provision of capital for ESG measures or projects at conditions that lower the capital costs for the borrower. Doing so makes it more likely that additional desired Outcomes occur.	own definition
Additionality	(1) An outcome is additional if it is different from what would happen without an input. (2) An input is additional if it is different from what would happen without an intervention.	adaptation from Gillenwater (2012)
attributable Financing (ESG-LM)	(1) Let N be a set of necessary causes for an outcome from contribution O in the ESG-LM such that $O \subseteq N$. (2) Let F_{att} and N_0 be exhaustive subsets of N and O_{att} be a subset of O so that $O_{att} \subseteq F_{att}$. Then the general base-case for attributable Financing is defined as: "The non-presence of attributed Financing is sufficient for the non-presence of attributed outcomes" ($F_{att} \wedge N_0 = O_{att}$ and $\neg O_{att} = \neg F_{att} \vee \neg N_0$).	own definition
Attribution (ESG-LM)	Initiators in the ESG-LM (Main Actors, Other Actors, Financing Actors) attribute to specific desired changes, if their contribution up to this point is the main cause of the effect. The degree to which Attribution is ascertained is described by the ratio (%) of an Actor's financial commitment compared to the overall investments necessary for this effect.	own definition
Contribution (ESG-LM)	Actors in the ESG-LM (Main Actors, Other Actors, Initiators) contribute directly to at least one of its desired changes (Outputs, Intermediate Outcomes, Long-Term Outcomes, Impacts) if, all other things being equal, their actions are either necessary or sufficient. They contribute indirectly if their actions precede such necessary or sufficient conditions.	own definition
Contribution (ESG-LM)	Actors in the ESG-LM (Main Actors, Other Actors, Initiators) contribute to desired changes (Outputs, Intermediate Outcomes, Long-Term Outcomes, Impacts) if, all other things being equal, their actions are either necessary, partially necessary, sufficient, or partially sufficient for this change.	own definition
Credence (in ESG-LMs)	Credence in a ESG-LM is the degree of belief a reader of the impact assessment is warranted to have in particular results.	own defintion
deadweight Financing (ESG-LM)	The presence or non-presence of deadweight Financing is irrelevant for attributed Outcomes" ($F_D \vee \neg F_D = O_{att}$ but $N_{CH} = O_{CH}$).	own definition
Earmarking	Earmarking means that capital providers restrict resources or financial instruments to specific purposes, usually in terms of geographic and thematic scope.	adaptation from Weinlich et al., (2020, p. 26)
ESG rating	ESG rating means an opinion, a score or a combination of both, regarding an entity, a financial instrument, a financial product, or an undertaking's ESG profile or characteristics or exposure to ESG risks or the impact on people, society and the environment, that are based on an established methodology and defined ranking system of rating categories and that are provided to third parties, irrespective of whether such ESG rating is explicitly labelled as rating or ESG score.	European Commission, 2023c Art 3.1
ESG-LM method	(1) The ESG-LM is an ex post evaluation method open to ex ante predictions that explicates testable hypotheses for the presumed causality and measurability of outcome constructs on the basis of implicit stakeholder ToCs.	own definition

Term	Definition	Source
	(2) Its linear cause-effect logic addresses multiple agencies and multiple simultaneous causal strands and can have different CMs. (3) It is used to qualify and quantify indicators for the attribution and contribution of economic entities towards sustainability objectives, including the direct or indirect financing of such interventions (in line with a maximation of common good value).	
Financing	The term Financing relates to all financial mechanisms that result in capital provision for actors in the economy used for the realisation of tangible Outputs. This specifically includes direct or indirect lending, non-refundable grants, and ex post allocations of previously financed economic activities and projects in Bonds.	own definition
Generic Hazard (ESG-LM)	Generic Hazards are risks of reduced Outputs caused by Actors with different intentions or competing for the same resources.	own definition
Generic Rebound (ESG-LM)	Generic Rebounds are caused by insufficient or unintended interactions of the system with the explicated outcome pathways in the ESG-LM. They either represent (i) risks of partial compensation or overcompensation of desired outcomes or (ii) risks of negative contributions to other overarching goals.	own definition
Impact (ESG-LM)	Impacts are the ultimate, societal level changes that occur as a result of the sum of the processes that happen within the system.	Corlet Walker et al., (2018)
Initiator (ESG-LM)	The Initiator is any institution responsible for providing capital towards desired changes.	own definition
Input (ESG-LM)	Inputs are resources — such as capital, personnel, or physical assets — deployed in the service of certain activities.	own adaptation from Social Impact Investment Taskforce, (2014)
Intermediate Outcome (ESG-LM)	Intermediate Outcomes are direct and desired changes for individuals, groups or regions that follow from the successful delivery of Outputs.	own definition
Justified belief (ESG-LM)	A belief in the claims of causal strands in the ESG-LM is justified if its propositions are probabilistically conditioned on evidence, the credence of actors in these propositions can be shown to be above a reasonable threshold, and no additional evidence lowers this probability below this threshold.	own definition
Long-Term Outcome (ESG-LM)	Long-Term Outcomes are persistent desired changes for groups or regions that contribute to overarching goals.	own definition
Main Actor (ESG-LM)	The Main Actor is directly causally linked to desired Outputs in the ESG-LM.	own definition
Materiality	We define materiality as the measurement of tangible real-world parameters in the social and/or environmental realm. This measurement pertains to significant improvements based on sustainability performance indicators, such as greenhouse gas (GHG) emissions or gender representation on corporate boards of directors.	Busch et al., 2021, p. 33
Measuribility	The criterion of Measurability is tested with help of all identified potential best-available or best-needed indicators for an ESG-LM. The highest Measurability is achieved if all Outcomes can be associated with best-available rather than best-needed indicators. By contrast, if not all Outputs can be associated with either best-needed or best-available indicators, the ESG-LM is likely inadequate for impact measurement.	own definition
Other Actors (ESG-LM)	Other Actors are all Actors that (i) are not the Main Actor but contribute to desired Outputs in the ESG-LM.	own definition
Output (ESG-LM)	Outputs are tangible desired results from Activities by the Main Actor.	own adaptation from Social Impact Investment Taskforce, (2014)
Sufficient Likelihood Justification	S is justified in believing that p if and only if S believes that p in a way that makes it sufficiently likely that her belief is true	Steup & Neta (2020)
Sustainable Finance	All financing (investing and lending) can have impacts on social and environmental systems. These financial services are considered SF if they interact with the surrounding systems in a way that either avoids negative impacts to these dimensions and or results in desired changes in line with global and societal sustainability goals.	own definition

Source: see Table

A-2 PoC: Development and Evaluation

The ESG-LM for the PoC was developed in five steps.

(1) Define the desired change

I selected the European *Sustainable and Smart Mobility Strategy* (European Commission, 2020d) for the PoC because it covers more than one sustainability dimension on a well-researched issue (sustainable mobility) that can be directly connected to broader sustainability goals. For achieving the EU's goal of reducing GHG emissions by 55% until 2030, the transport sector has to reduce its emissions by 15 to 18% over the course of 15 years (European Commission, 2020c, p. 52). The objectives are pursued by 82 policies spread over 10 flagships included in the annex of the strategy. As a first step, the goals of the strategy are translated into Long-Term Outcomes (such as "smarter mobility in Europe") and then the milestones for 2030 into Intermediate Outcomes that are connected to these desired changes (such as "O2.1: seamless multi-modal passenger transport").

(2) Introduce the Actors

The second step consists of the definition of economic activities in form of NACE asset classes aligned with the purposes of the strategies (such as "G.45.1: sale of motor vehicles") as well as the definition of a set of Actors. Apart from Initiators that finance these sectors (K.64 & K.66), any company in any of the selected sectors can be considered an Actor in the contribution. The total set of Actors (Main Actors and Other Actors) can broadly be categorised into manufacturers, energy providers, civil construction providers, retailers, transport service providers (including rental/leasing), digital service providers, and consultants (architects, engineers, researchers, etc.).

(3) Define the tasks

In step (3), the defined economic activities and their matching to Outcomes is used as a basis to identify relevant categories and sub-categories of physical objects that are affected by the ToC. These are in turn aligned with the intentions of Main Actors in the outcome pathway as depicted in Annex Table b.

Annex Table b: suggested intentions for PoC

Intention	Long-Term Outcome(s)	Physical Objects
climate-friendly	3: internalised external costs of transport 4: more sustainable transport modes 5: reduced dependency on fossil fuels	motor vehicles | rail vehicles | vessels | air crafts | transport infrastructures
well-connected	1: more resilient mobility in Europe 2: smarter mobility in Europe	transport infrastructures | information infrastructures

Intention	Long-Term Outcome(s)	Physical Objects
well-accessible	2: smarter mobility in Europe 4: more sustainable transport modes	motor vehicles | vessels | transport infrastructures | information infrastructures
well-priced	3: internalised external costs of transport	information infrastructures

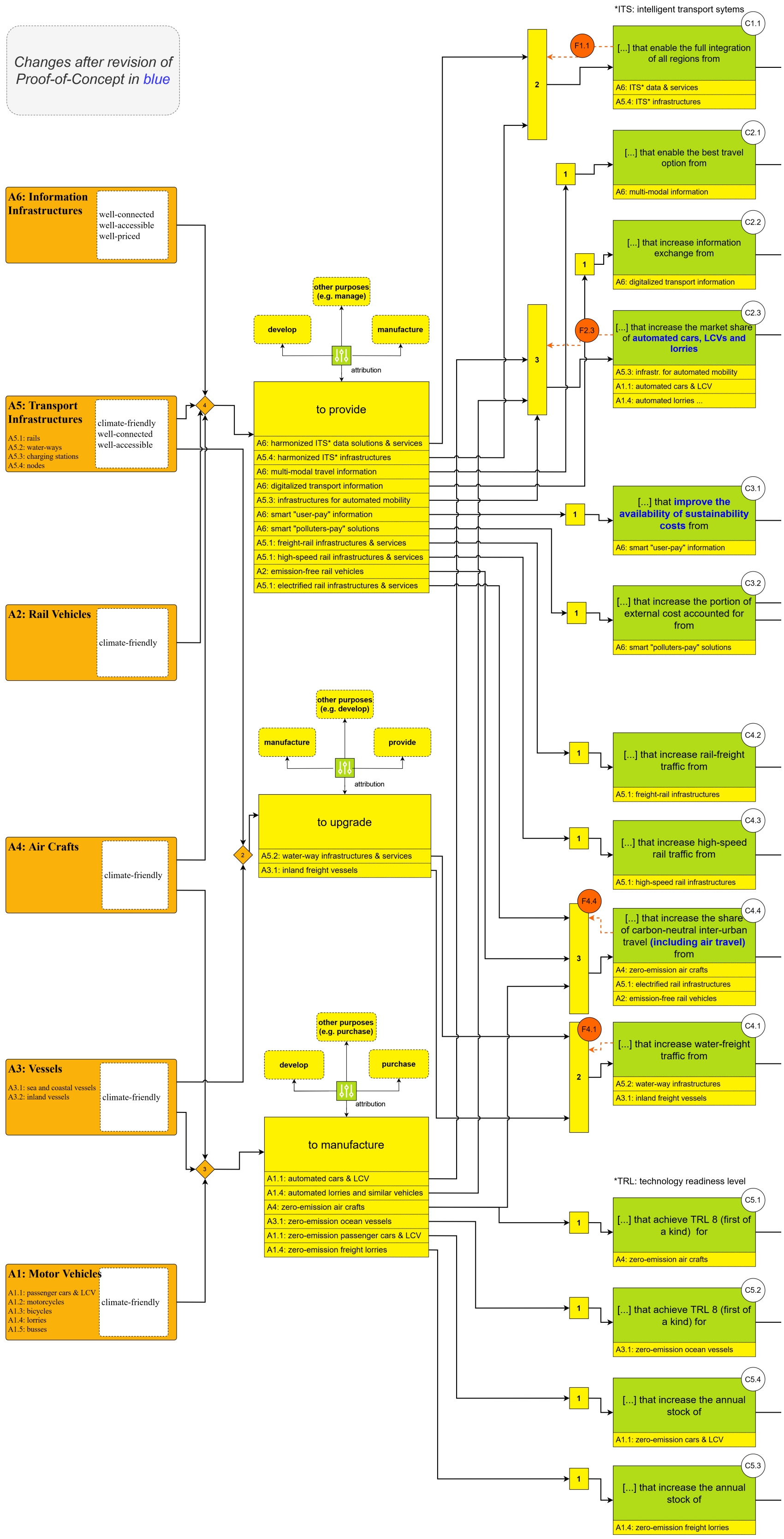
Source: own compilation

To finalise the identification of Activities, the interactions of Actors with the objects are described as purposes (such as “develop”, “manage”, “purchase”, etc.).

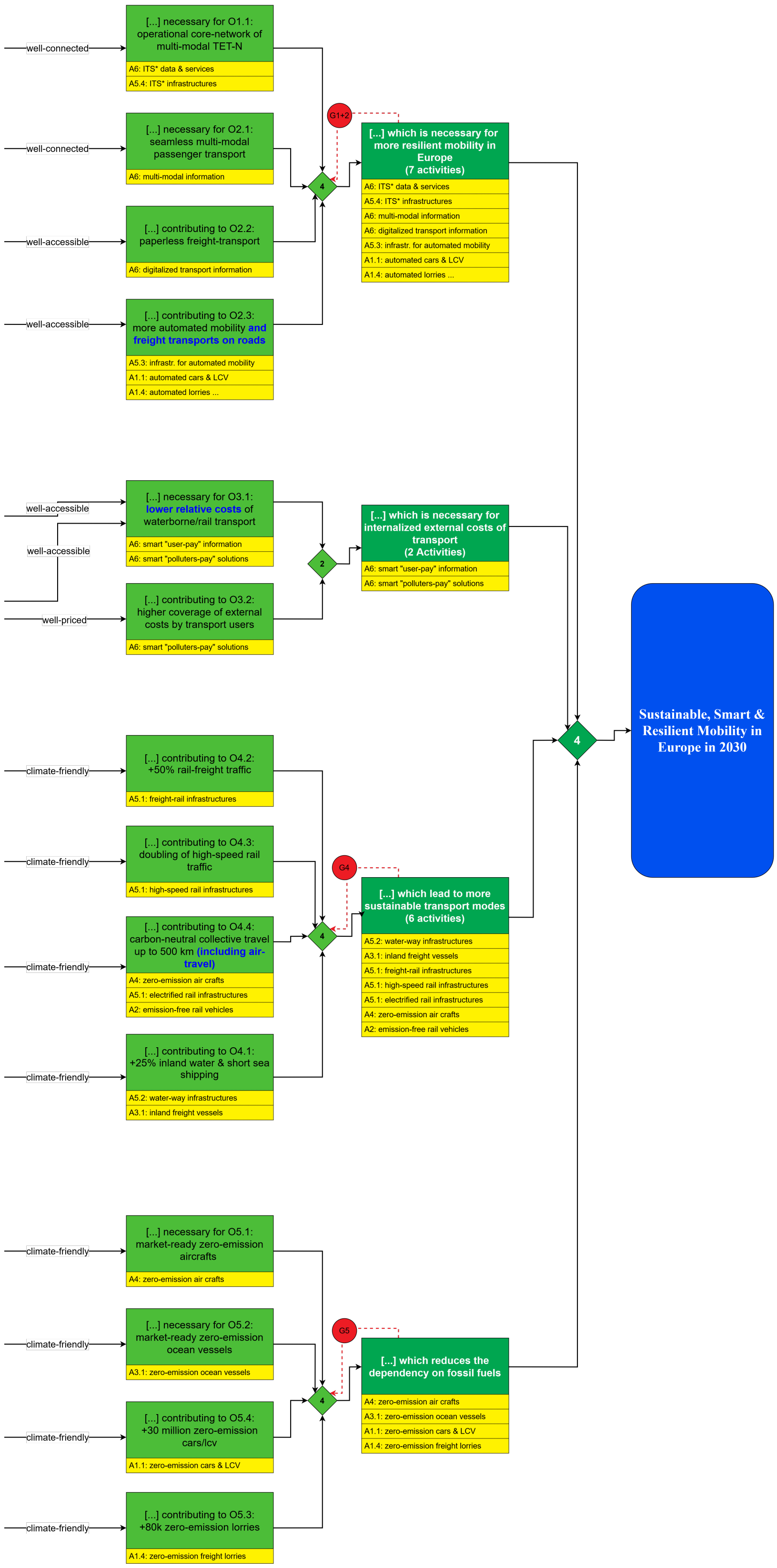
(4) Map the intervention

The next step consists of mapping out the entire ToC for the PoC. It first identifies the Outputs. These Outputs are then connected to the Activities to complete the intervention model and then to the identified outcome pathways to complete the ESG-LM. This results in a graphical presentation of the ESG-LM, as shown in Annex Figure a (the figure depicted here already includes the location of additional entities such as identified indicators and target conflicts).

Annex Figure a: ESG-LM for the PoC



Annex



Source: own development

(5) Set-up the assessment

Step 5 consists of the identification of potential indicators and the identification of target conflicts. Although all 14 Outputs could be associated with “measurable” output-indicators, five Outputs were limited to the assignment of best-needed indicators as shown in Annex Table c.

Annex Table c: list of potential output-indicators for PoC

No	Indicator Suggestion	Indicator Type
C1.1	number of additional carbotage operations [1]	$\text{available}_{\text{best}}$
C2.1	availability of best travel options [true/false]	$\text{needed}_{\text{best}}$
C2.2	number of paperless freight transport operations [1]	$\text{needed}_{\text{best}}$
C2.3	net turnover for automated mobility/transport [EUR]	$\text{needed}_{\text{best}}$
C3.1	availability of user-pay information [true/false]	$\text{needed}_{\text{best}}$
C3.2	share of internalised external costs of transport users [%]	$\text{needed}_{\text{best}}$
C4.1	additional water traffic capacity [tonnes]	$\text{available}_{\text{best}}$
C4.2	additional or upgraded rail-freight capacity [tonnes]	$\text{available}_{\text{best}}$
C4.3	additional or upgraded high-speed rail travel capacity [persons/year]	$\text{available}_{\text{best}}$
C4.4	additional or upgraded emission-free travel capacity [persons/year]	$\text{available}_{\text{best}}$
C5.1	prototype tested and demonstrated [true/false]	$\text{available}_{\text{best}}$
C5.2	prototype tested and demonstrated [true/false]	$\text{available}_{\text{best}}$
C5.3	number of additional zero-emission lorries [1]	$\text{available}_{\text{best}}$
C5.4	number of additional zero-emission cars & LCV [1]	$\text{available}_{\text{best}}$

Source: own compilation

The next step aims to identify the Generic Hazards and Generic Rebounds of the ESG-LM. All four Outputs that require more than one Activity can be associated with Generic Hazards (indicated by the letter F) and three out of four of the Long-Term Outcomes (indicated by the letter G). The following Annex Table d shows these risks and the reasoning for them.

Annex Table d: identified generic target conflicts for PoC

No	Identified generic target conflicts	Risk type
F1.1	Output can only be achieved if physical ITS systems are standardised alongside ITS data solutions and across regions	Generic Hazard
F2.3	Output can only be achieved if the additional infrastructures (e.g., charging stations) are sufficient for a growth in automated vehicles	Generic Hazard
F4.1	Output is severely reduced if increase in water-way capacity is not matched by the rate of which vessels are upgraded	Generic Hazard
F4.4	Output is severely reduced if no emission-free aircrafts can be developed in time	Generic Hazard
G1+2	Long-term outcome is conditioned on market-based solutions that have not been developed yet (e.g., automatisation of lorries)	Generic Rebound
G4	Long-term outcome is reduced if travel and freight capacities compete for the same resources	Generic Rebound
G5	Long-term outcome is reduced if emission-free vehicles depend on fossil fuels for electricity	Generic Rebound

Source: own compilation

The quality of the PoC model as a generic ESG-LM is assessed with help of my criteria-based evaluation scheme. Three criteria are assessed: Goal Certainty, Sufficiency, and Measurability.

An adequate model regarding *Goal Certainty* requires a positive response to the following control question:

Are Inputs, Activities, Outputs, Intermediate Outcomes, and Long-Term Outcomes necessary or sufficient for a contribution to at least one of their descendants in the ESG-LM?

The following table lists all the Outputs as they appear to be required for Intermediate Outcomes as well as the Activities leading up to them. It is assessed whether these Outputs are necessary at all, sufficient but not necessary, or necessary only under additional conditions with the latter being a limitation of the model.

Annex Table e: Goal Certainty evaluation of PoC

(Note: AND indicates a conjunct of two independent conditions)

intermediate outcomes	outputs as antecedents and Goal Certainty evaluation of causal condition(s)		Reasoning
O1.1: operational core-network of multi-modal TET-N	enabling full integration of all regions from providing ITS data solution & services AND infrastructures	N	must be present
O2.1: seamless multi-modal passenger transport	enabling best travel option from providing multi-modal ticket & travel information	N	must be present
O2.2: paperless freight transport	increased information exchange from providing digitalised transport information	N	must be present
O2.3: more automated mobility	increased market share of automated vehicles from providing infrastructures for automated mobility AND manufacturing automated cars AND automated lorries	N ∨ C	automated lorries are not necessary for Outcome
O3.1: higher share of waterborne/rail transport	enabling sustainable choices from providing smart “user-pay” information AND increased portion of external costs accounting from smart “polluters pay” information	C	outcome can be realised without the outputs
O3.2: higher coverage of external costs by transport users	increased portion of external costs accounting from providing smart “polluters pay” information	N	must be present
O4.1: +25% inland water & short sea shipping	increased water-freight traffic from upgrading water-freight infrastructures & services AND upgraded inland freight vessels	N	must be present
O4.2: +50% rail-freight traffic	increased rail-freight traffic from providing rail-freight infrastructures & services	N	must be present
O4.3: doubling of high-speed rail traffic	increased high-speed rail traffic from high-speed rail infrastructures and services	N	must be present

intermediate outcomes	outputs as antecedents and Goal Certainty evaluation of causal condition(s)		Reasoning
O4.4: carbon-neutral collective travel up to 500 km	increased share of carbon-neutral travel from providing emission-free rail vehicles AND rail infrastructures & services AND manufacturing of zero-emission air crafts	N ∨ C	air crafts are not necessary for Outcome
O5.1: market-ready zero-emission aircrafts	achieving TRL-8 from manufacturing zero-emission aircrafts	N	must be present
O5.2: market-ready zero-emission ocean vessels	achieving TRL-8 from manufacturing zero-emission ocean vessels	N	must be present
O5.3: +80k zero-emission lorries	increasing annual stock of zero-emission freight lorries from manufacturing	N	must be present
O5.4: +30 million zero-emission cars/LCVs	increasing annual stock of zero-emission cars & LCV from manufacturing	N	must be present

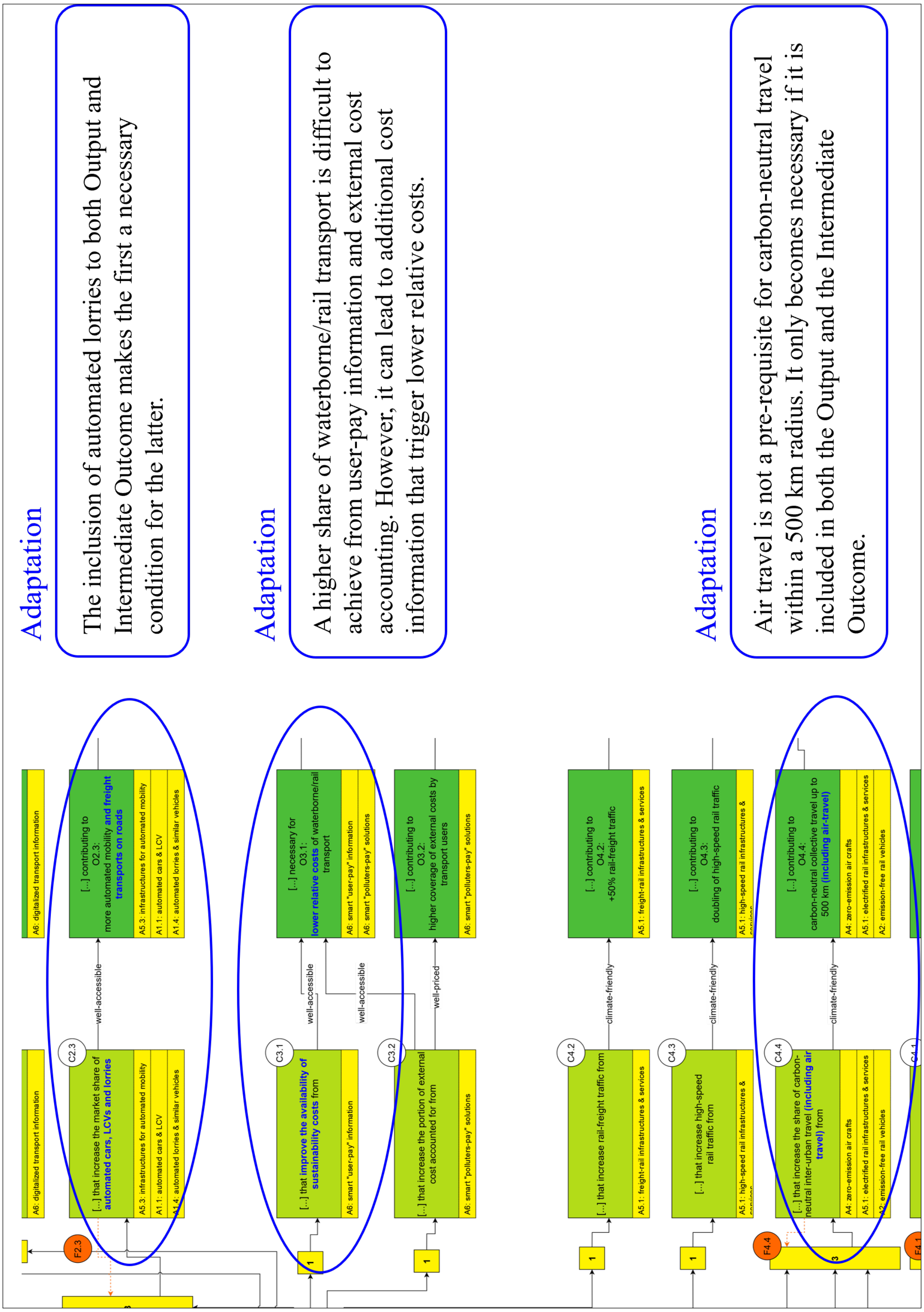
Source: own compilation

These Intermediate Outcomes are, for the most part, directly conditioned on previous realisations of Outputs. Outputs such as “increasing the annual stock” from manufacturing vehicles is sufficient for some contribution but only necessary for achieving an absolute number of vehicles in the market (e.g., O5.3). Other causal propositions are more complex, because they postulate an entire package of causes to be present. Some of these are clearly jointly needed for a desired change (e.g., building infrastructures and providing services), while others are not.

There are two Outputs in Annex Table e for which not all activities are required for the desired change (necessary or contributory: N ∨ C). There is also one output for which the outcome could entirely be realised without the intervention (contributory: C). The related activities therefore currently prevent the adequacy of the ESG-LM as required for the criterion of Goal Certainty. Thus, the ESG-LM of the PoC must be revised.

The following Annex Figure b shows the revised parts of the ESG-LM and highlights these changes.

Annex Figure b: revision of ESG-LM for PoC after evaluation



Source: own development

As such an ESG-LM can be considered adequate, the two additional criteria of Sufficiency and Measurability can be assessed. Sufficiency investigates whether parts of the ESG-LM describe sufficient causal conditions for desired changes with the following control question:

Is Goal Certainty achieved for the entire ESG-LM (1)? If so, are all Inputs fully or partially sufficient for their designated Outputs (2) and all Outputs fully or partially sufficient for their designated Long-Term Outcomes (3)?

Since the answer to the first part of the question has been ensured, it should now be assessed whether all inputs are sufficient for their designated outputs to achieve a scoring of 2. Almost all pathways between Inputs and Outputs focus on Actors from industries related to economic activities in the transport sector by either providing services or manufacturing the necessary products. However, most Outputs would not be achieved without additional Actors from other sectors. The Sufficiency is therefore evaluated to correspond only to the minimum requirement (score 1).

The third criterion of Measurability compares the identified potential indicators along the outcome pathways:

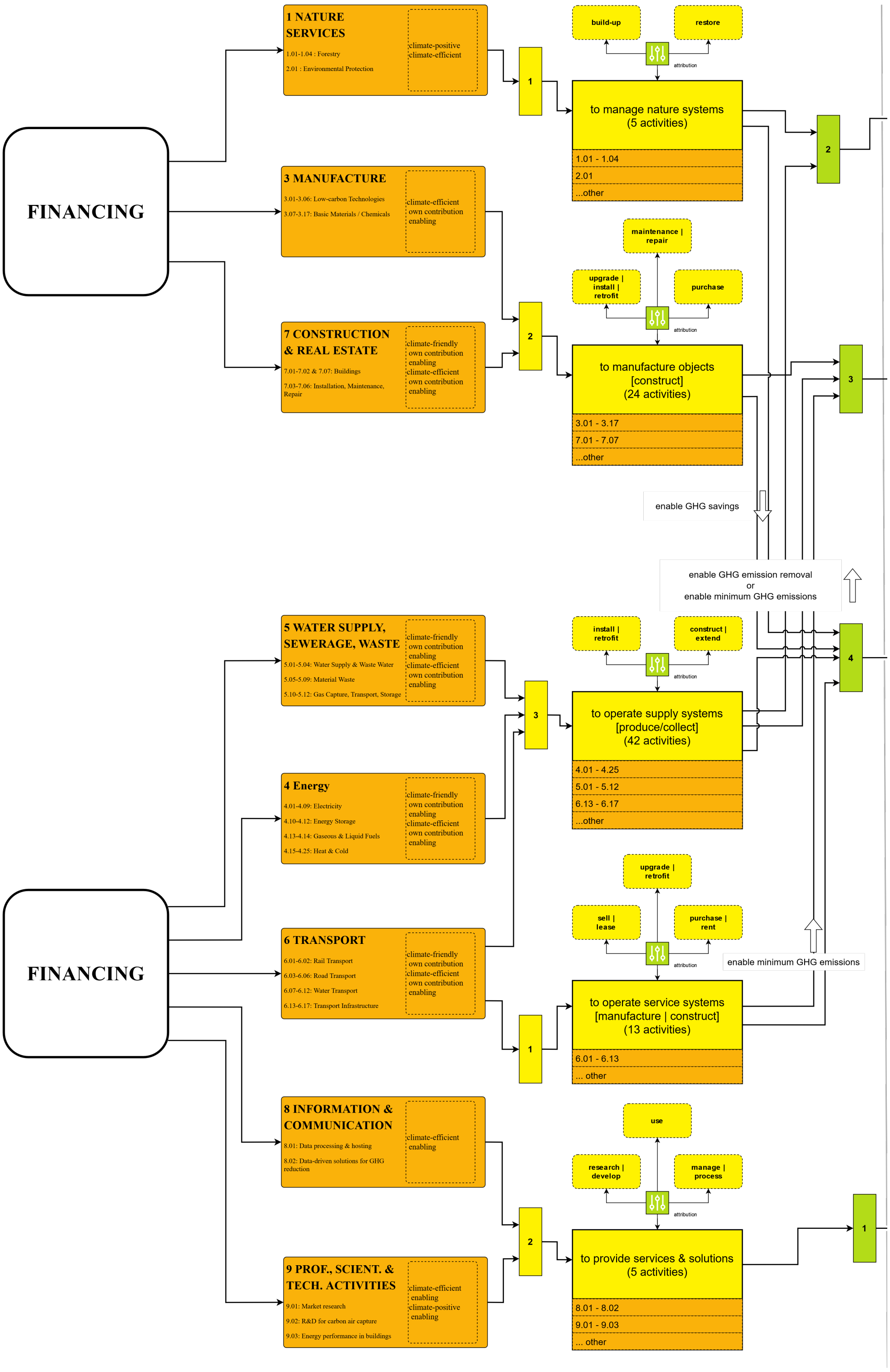
Can all Outputs be measured with either best-available or best-needed indicators (1)? If so, are there best-available indicators for all Outputs and at least best-needed indicators for Intermediate Outcomes (2) or even best-available indicators for each Outcome (3)?

The minimum requirement could already be established during development. However, since it cannot be ensured that best-available indicators exist for all Outputs, a score of 1 is assigned here as well. Overall, a score of 2 was assigned to the entire PoC. This is expected, given that the PoC covers many and rather different types of outcome pathways.

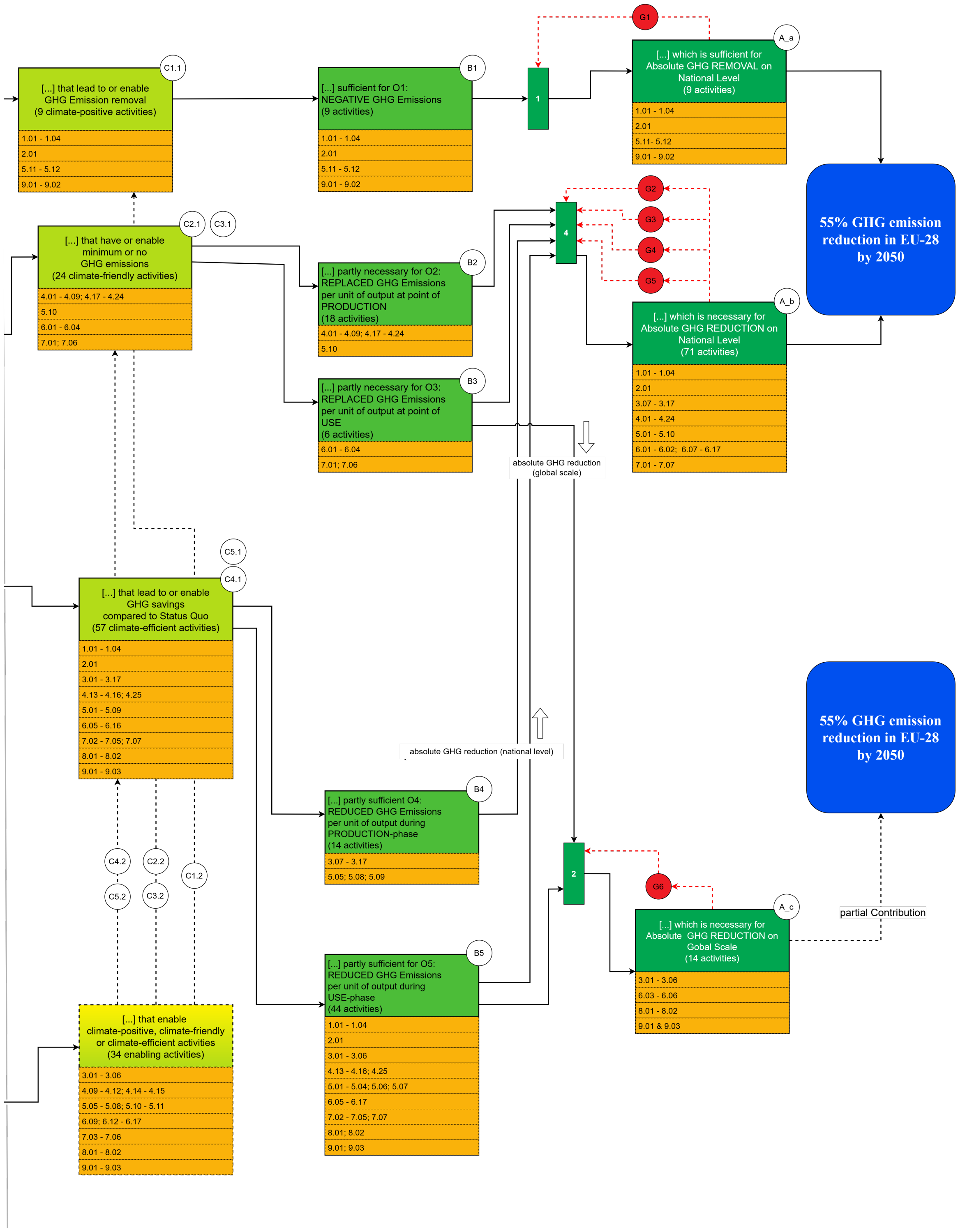
Annex

A-3 Generic ESG-LM for PT

Annex Figure c: ESG-LM for Climate Change Mitigation according to EU Taxonomy



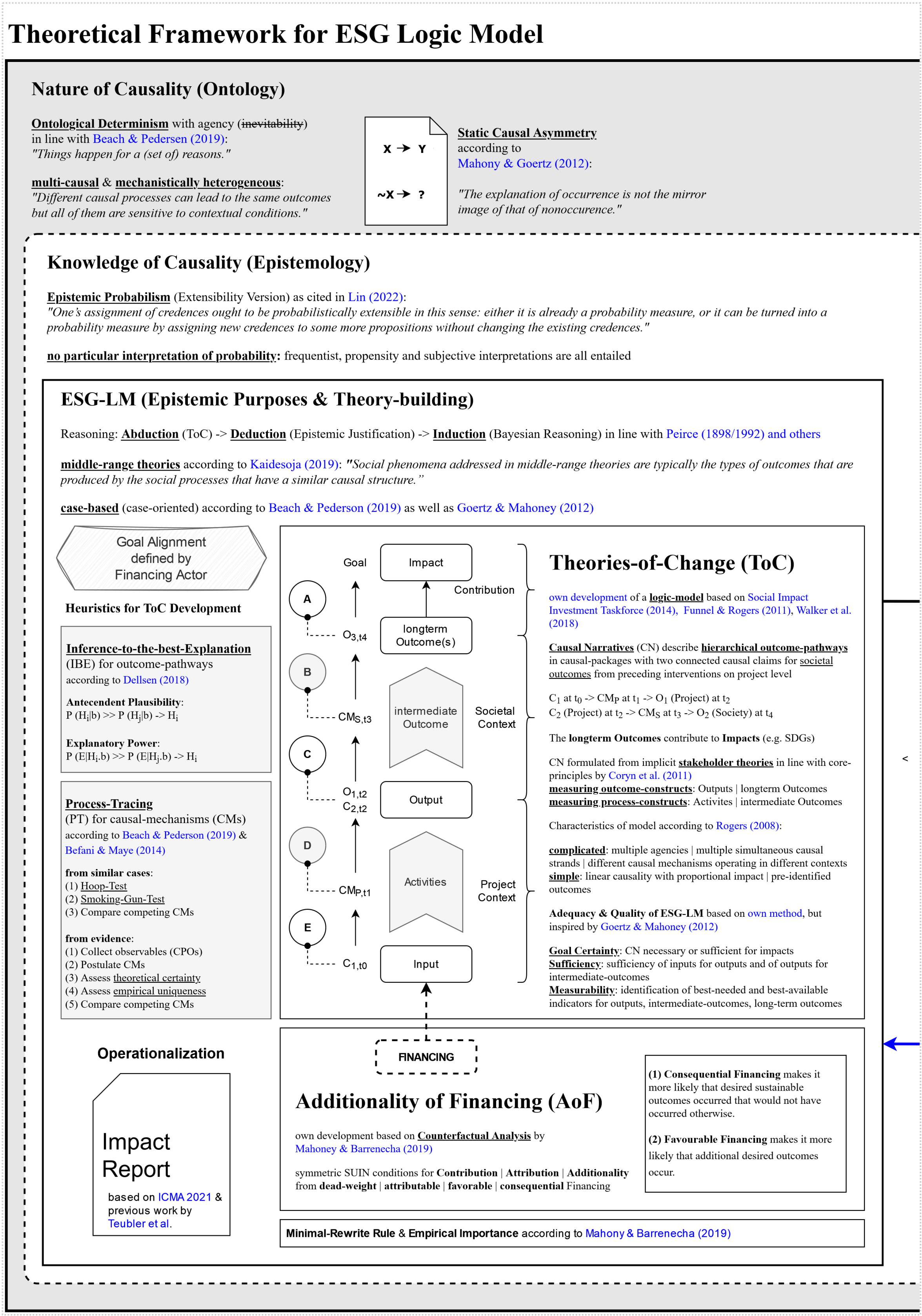
Annex



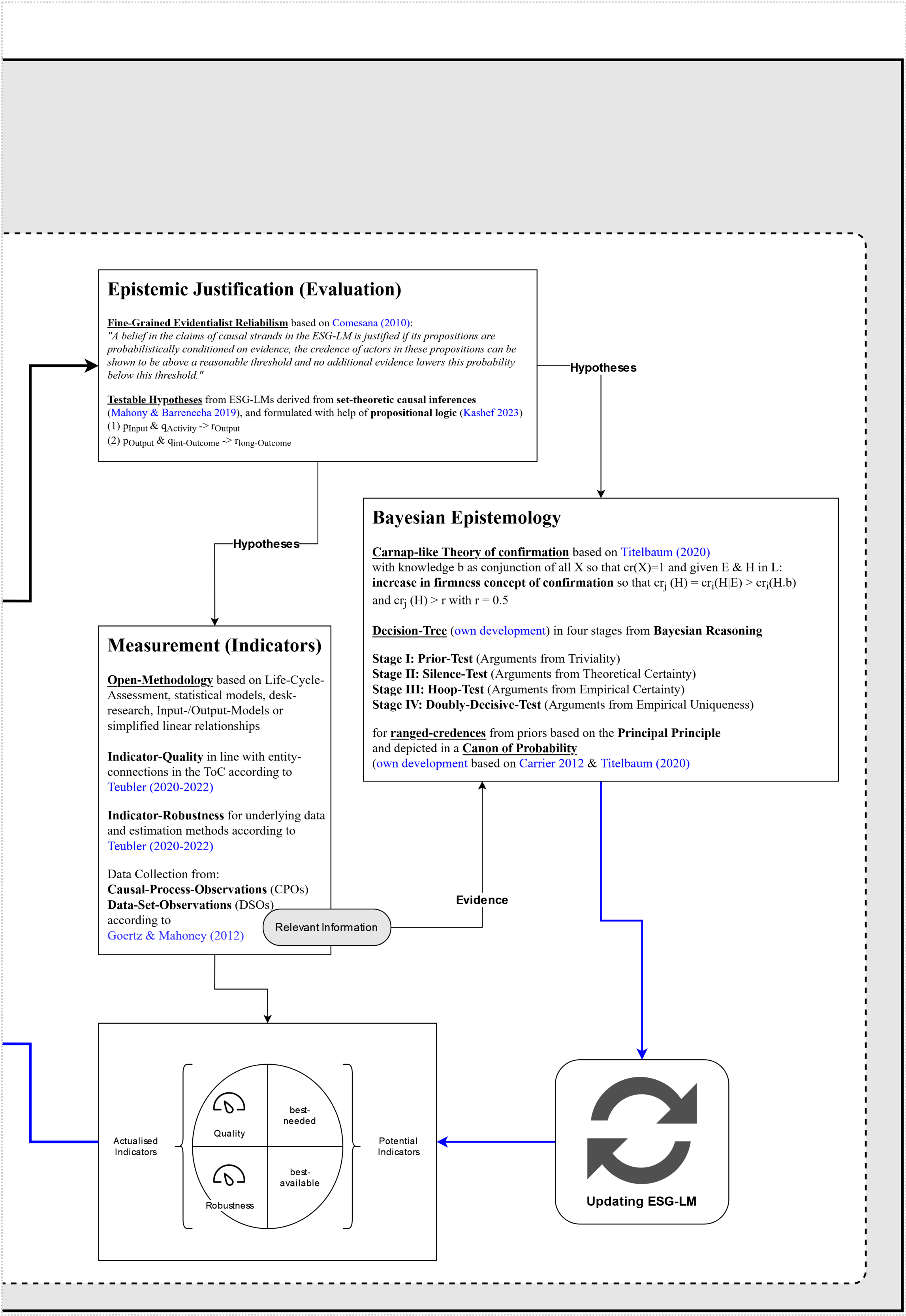
[...] that lead to or enable GHG Emission removal (9 climate-positive activities)
1.01 - 1.04
2.01
5.11 - 5.12
9.01 - 9.02
C1.1
[...] sufficient for O1: NEGATIVE GHG Emissions (9 activities)
1.01 - 1.04
2.01
5.11 - 5.12
9.01 - 9.02
B1
1
G1
A_a
[...] which is sufficient for Absolute GHG REMOVAL on National Level (9 activities)
1.01 - 1.04
2.01
5.11- 5.12
9.01 - 9.02
55% GHG emission reduction in EU-28 by 2050
C2.1
C3.1
[...] that have or enable minimum or no GHG emissions (24 climate-friendly activities)
4.01 - 4.09; 4.17 - 4.24
5.10
6.01 - 6.04
7.01; 7.06
B2
[...] partly necessary for O2: REPLACED GHG Emissions per unit of output at point of PRODUCTION (18 activities)
4.01 - 4.09; 4.17 - 4.24
5.10
4
G2
G3
G4
G5
A_b
[...] which is necessary for Absolute GHG REDUCTION on National Level (71 activities)
1.01 - 1.04
2.01
3.07 - 3.17
4.01 - 4.24
5.01 - 5.10
6.01 - 6.02; 6.07 - 6.17
7.01 - 7.07
B3
[...] partly necessary for O3: REPLACED GHG Emissions per unit of output at point of USE (6 activities)
6.01 - 6.04
7.01; 7.06
absolute GHG reduction (global scale)
C5.1
C4.1
[...] that lead to or enable GHG savings compared to Status Quo (57 climate-efficient activities)
1.01 - 1.04
2.01
3.01 - 3.17
4.13 - 4.16; 4.25
5.01 - 5.09
6.05 - 6.16
7.02 - 7.05; 7.07
8.01 - 8.02
9.01 - 9.03
absolute GHG reduction (national level)
55% GHG emission reduction in EU-28 by 2050
B4
[...] partly sufficient O4: REDUCED GHG Emissions per unit of output during PRODUCTION-phase (14 activities)
3.07 - 3.17
5.05; 5.08; 5.09
C4.2
C2.2
C1.2
C5.2
C3.2
2
G6
A_c
partial Contribution
[...] which is necessary for Absolute GHG REDUCTION on Gobal Scale (14 activities)
3.01 - 3.06
6.03 - 6.06
8.01 - 8.02
9.01 & 9.03
B5
[...] partly sufficient for O5: REDUCED GHG Emissions per unit of output during USE-phase (44 activities)
1.01 - 1.04
2.01
3.01 - 3.06
4.13 - 4.16; 4.25
5.01 - 5.04; 5.06; 5.07
6.05 - 6.17
7.02 - 7.05; 7.07
8.01; 8.02
9.01; 9.03
[...] that enable climate-positive, climate-friendly or climate-efficient activities (34 enabling activities)
3.01 - 3.06
4.09 - 4.12; 4.14 - 4.15
5.05 - 5.08; 5.10 - 5.11
6.09; 6.12 - 6.17
7.03 - 7.06
8.01 - 8.02
9.01 - 9.03

A-4 Theoretical Framework of the ESG-LM

Annex Figure d: overview of theories, methods, definitions, and tools of the dissertation

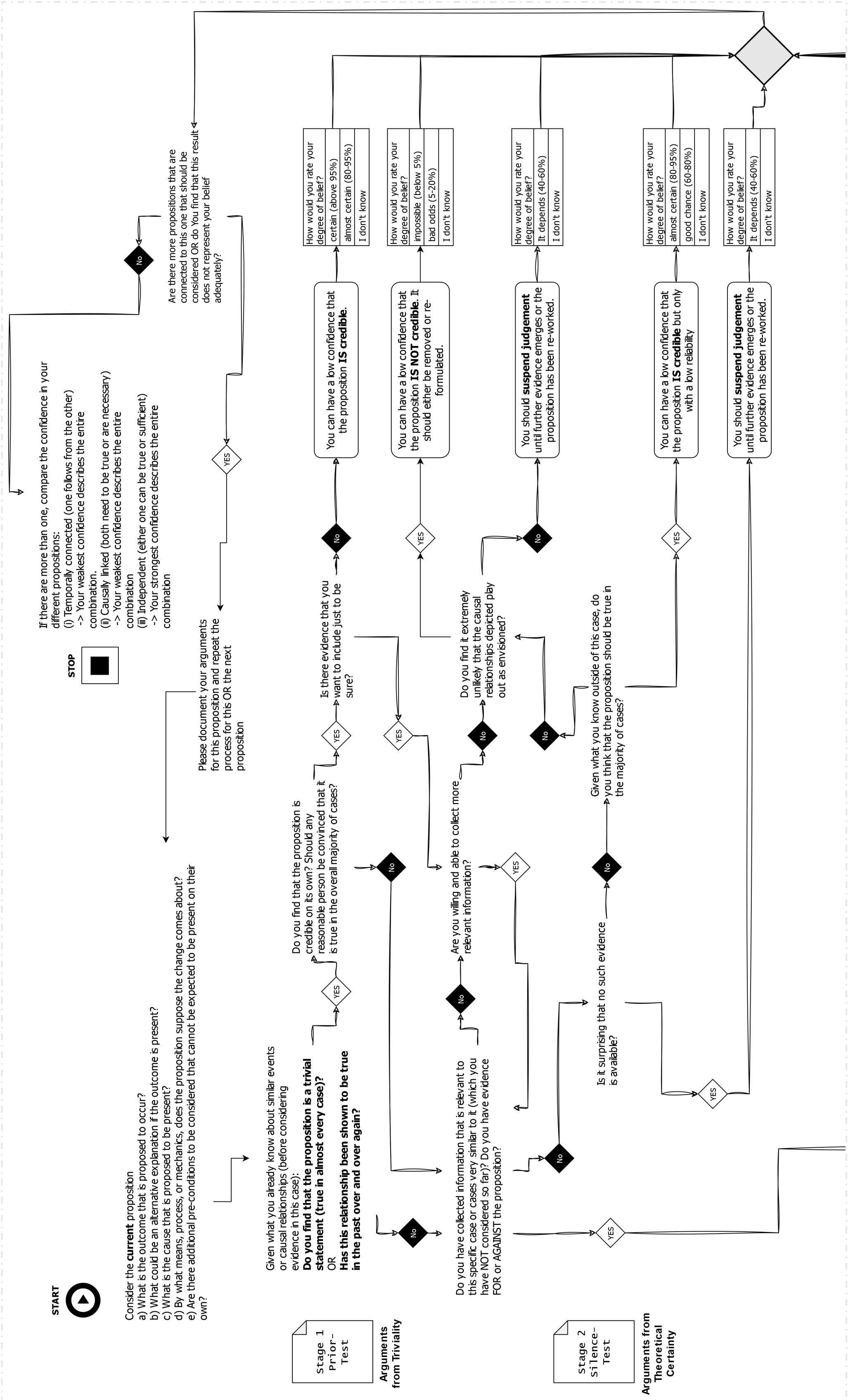


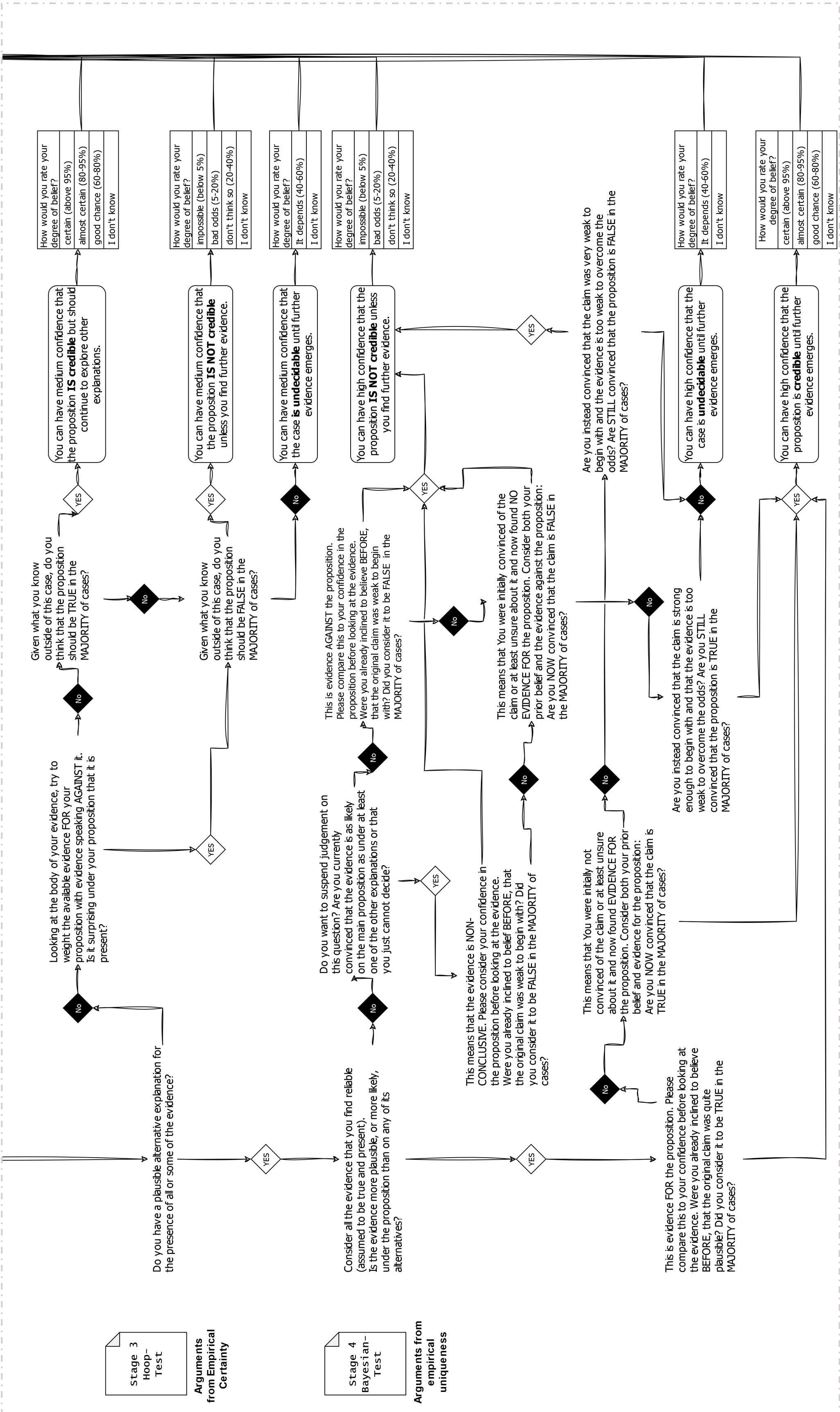
Source: own development


Epistemic Justification (Evaluation)
Fine-Grained Evidentialist Reliabilism based on Comesana (2010):
"A belief in the claims of causal strands in the ESG-LM is justified if its propositions are probabilistically conditioned on evidence, the credence of actors in these propositions can be shown to be above a reasonable threshold and no additional evidence lowers this probability below this threshold."
Testable Hypotheses from ESG-LMs derived from set-theoretic causal inferences (Mahony & Barrenecha 2019), and formulated with help of propositional logic (Kashef 2023)
(1) p_{Input} & $q_{Activity}$ -> r_{Output}
(2) p_{Output} & $q_{int-Outcome}$ -> $r_{long-Outcome}$
Hypotheses
Hypotheses
Bayesian Epistemology
Carnap-like Theory of confirmation based on Titelbaum (2020)
with knowledge b as conjunction of all X so that cr(X)=1 and given E & H in L:
increase in firmness concept of confirmation so that cr_j (H) = cr_i(H|E) > cr_i(H.b)
and cr_j (H) > r with r = 0.5
Decision-Tree (own development) in four stages from Bayesian Reasoning
Stage I: Prior-Test (Arguments from Triviality)
Stage II: Silence-Test (Arguments from Theoretical Certainty)
Stage III: Hoop-Test (Arguments from Empirical Certainty)
Stage IV: Doubly-Decisive-Test (Arguments from Empirical Uniqueness)
for ranged-credences from priors based on the Principal Principle
and depicted in a Canon of Probability
(own development based on Carrier 2012 & Titelbaum (2020)
Measurement (Indicators)
Open-Methodology based on Life-Cycle-Assessment, statistical models, desk-research, Input-/Output-Models or simplified linear relationships
Indicator-Quality in line with entity-connections in the ToC according to Teubler (2020-2022)
Indicator-Robustness for underlying data and estimation methods according to Teubler (2020-2022)
Data Collection from:
Causal-Process-Observations (CPOs)
Data-Set-Observations (DSOs)
according to
Goertz & Mahoney (2012)
Relevant Information
Evidence
Actualised Indicators
Quality
best-needed
Robustness
best-available
Potential Indicators
Updating ESG-LM

A-5 Bayesian Decision-Tree for ESG-LM Impact Assessments

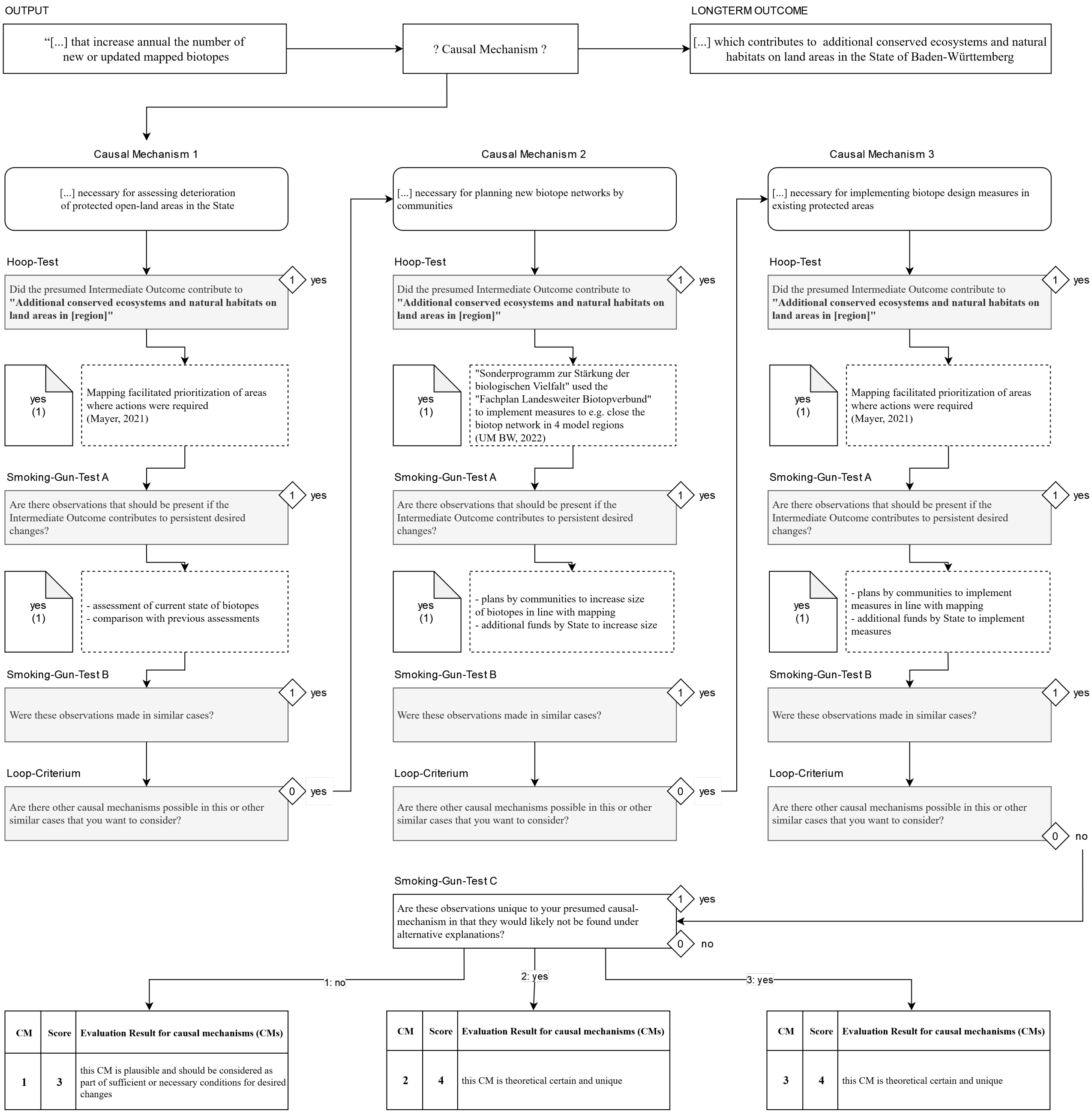
Annex Figure e: quick-guide for making Bayesian arguments for an ESG-LM




Stage 3 Hoop-Test
Arguments from Empirical Certainty
Stage 4 Bayesian-Test
Arguments from empirical uniqueness
Do you have a plausible alternative explanation for the presence of all or some of the evidence?
Looking at the body of your evidence, try to weight the available evidence FOR your proposition with evidence speaking AGAINST it. Is it surprising under your proposition that it is present?
Given what you know outside of this case, do you think that the proposition should be TRUE in the MAJORITY of cases?
Given what you know outside of this case, do you think that the proposition should be FALSE in the MAJORITY of cases?
You can have medium confidence that the proposition IS credible but should continue to explore other explanations.
You can have medium confidence that the proposition IS NOT credible unless you find further evidence.
You can have medium confidence that the case is undecidable until further evidence emerges.
You can have high confidence that the proposition IS NOT credible unless you find further evidence.
You can have high confidence that the case is undecidable until further evidence emerges.
You can have high confidence that the proposition is credible until further evidence emerges.
How would you rate your degree of belief?
certain (above 95%)
almost certain (80-95%)
good chance (60-80%)
I don't know
impossible (below 5%)
bad odds (5-20%)
don't think so (20-40%)
It depends (40-60%)
Consider all the evidence that you find reliable (assumed to be true and present). Is the evidence more plausible, or more likely, under the proposition than on any of its alternatives?
Do you want to suspend judgement on this question? Are you currently convinced that the evidence is as likely on the main proposition as under at least one of the other explanations or that you just cannot decide?
This is evidence AGAINST the proposition. Please compare this to your confidence in the proposition before looking at the evidence. Were you already inclined to believe BEFORE, that the original claim was weak to begin with? Did you consider it to be FALSE in the MAJORITY of cases?
This means that the evidence is NON-CONCLUSIVE. Please consider your confidence in the proposition before looking at the evidence. Were you already inclined to belief BEFORE, that the original claim was weak to begin with? Did you consider it to be FALSE in the MAJORITY of cases?
This means that You were initially convinced of the claim or at least unsure about it and now found NO EVIDENCE FOR the proposition. Consider both your prior belief and evidence against the proposition: Are you NOW convinced that the claim is FALSE in the MAJORITY of cases?
Are you instead convinced that the claim was very weak to begin with and the evidence is too weak to overcome the odds? Are STILL convinced that the proposition is FALSE in the MAJORITY of cases?
This is evidence FOR the proposition. Please compare this to your confidence before looking at the evidence. Were you already inclined to believe BEFORE, that the original claim was quite plausible? Did you consider it to be TRUE in the MAJORITY of cases?
This means that You were initially not convinced of the claim or at least unsure about it and now found EVIDENCE FOR the proposition. Consider both your prior belief and evidence for the proposition: Are you NOW convinced that the claim is TRUE in the MAJORITY of cases?
Are you instead convinced that the claim is strong enough to begin with and that the evidence is too weak to overcome the odds? Are you STILL convinced that the proposition is TRUE in the MAJORITY of cases?
YES
No

A-6 PrT heuristic from similar cases for "Case Study B"

Annex Figure f: example of a PT heuristic for Biotope Mapping

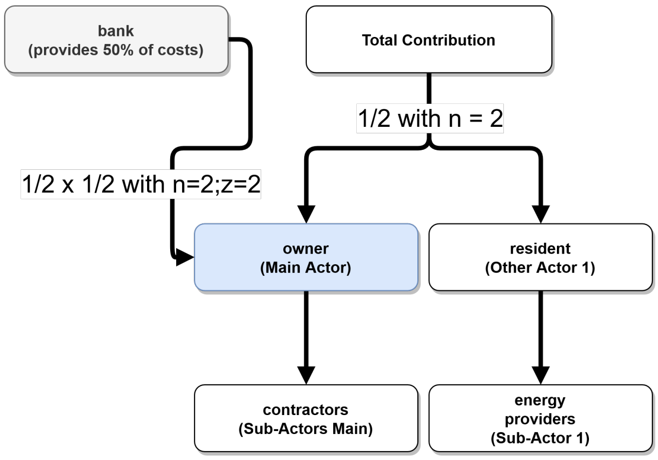


A-7 Example of Rules of Attribution and Additionality

Sections 4.2 and 4.3 describe procedures to estimate the ratio of Attribution and the capital for financing conditions that are considered favourable. The following Annex is intended to illustrate such estimates for an example.

I select the Activity of "renovating a multi-family home to increase energy efficiency" intended to "mitigate climate change". The borrower (Main Actor) is assumed to be the owner of the building with the space rented out to residents. The loan volume is assumed to cover 50% of the renovation costs of EUR 100,000. Assuming that the total energy costs for the residents are unknown or unobtainable, it seems reasonable to distribute the total contribution amongst all Activities that lead to lower GHG emissions: renovating the building by the owner (Main Actor) and reduced energy use (by the residents). All Other Actors, such as contractors and energy providers, can be considered sub-categories in the hierarchy (fully re-imbursed for their services). The following figure depicts the Rules of Attribution from a Principle of Indifference in this case.

Annex Figure g: Rules of Attribution example for "renovating multi-family home"



Source: own development

Each of the Actors responsible for the desired Outcome of "reduced GHG emissions" therefore contributes with 50%. The bank, lending 50% of the capital for the renovation thus attributes to the desired Outcome with 25%. By comparison, an equal distribution amongst all Actors would result in a Attribution ratio of only 1/8 or 12.5%.

For showing how the Rules of Additionality are applied, I further assume that the loan was provided with either one of the following options:

- Option 1: fixed annual interest rate of 3.5% over 10 years compared to a standard rate of 4.5% over 10 years
- Option 2: unscheduled repayment option for the outstanding loan in the fifth year with an annual 4.5% interest rate compared to a standard loan over 10 years without such repayments

For option 1, the expected utility U (additional interest costs) for a EUR 50,000 loan (C) over 10 years (a) at 4.5% annual effective interest rate (p) can be described by the following formular:

$$U_{max} = C \times \left(1 + \frac{p}{100}\right)^{a} - C$$

The standard capital costs (maximum contrafactual utility) can thus be predicted to be EUR 27,648. Comparing this to the actual capital costs at 3.5% (EUR 20,530) results in dispensed earnings (the additional effect of favourable financing) of EUR 7,119.

For option 2, it is assumed that the borrower pays back the remainder of the loan in the fifth year including interest. This is compared to a maximum utility at 4.5% over 10 years without any such unscheduled repayments (maximum contrafactual utility). The previously calculated interest earnings of EUR 27,648 are therefore compared to interest earnings over five years (EUR 12,309). The estimated Additionality is the difference of EUR 15,339 between the two potential outcomes.

A-8 Spot-check of locatable Activities for Case Study C

The following table lists all loans for day-care centres in Case Study C that either contained a post-code or a sufficient description to locate the new building. From a sample of 46 loans between 2019 and 2021, 18 such loans could be identified. Of this sample, six Activities could not be corroborated, because several objects in the given year could have fitted the description. Another two Activities could be corroborated but indicated that no additional places for children will be provided (either relocation of previous centre or replacement of a destroyed building). As a result, ten loans could be corroborated and provide additional places for day care for children (evidence for Hypothesis 1).

Annex Table f: investigation of evidence for additional child-care places in Case Study C

Location	E	Output-Type	Source
Bad Saluzflen	no	n.a.	no source found that could be attributed to a concrete location/institution decisively
Brüggen-Bracht	yes	new places	https://www.gwg-kreis-viersen.de/index.php/downloads-menuitem/mieterzeitung?download=211:mieze-32-2020
Engelskirchen	yes	new places	https://www.ksta.de/region/oberberg/engelskirchen-drk-kita-stellt-sich-nachtraeglich-vor-154143
Eschweiler	yes	new places	https://www.filmpost.de/aktuell/archiv/kita-neubau-in-der-krise-erster-spatenstich-gesetzt.html
Essen	no	n.a.	no source found that could be attributed to a concrete location/institution decisively
Gelsenkirchen	yes	new places	https://www.sozialwerk-st-georg.de/aktuelles/richtfest-der-kindertagesstaette-kleine-knappen.html
Gladbeck	possibly	n.a.	no source found that could be attributed to a concrete location/institution decisively
Grevenbroich	yes	replacement	https://www.kita-blumenwiese.nrw/aktuell/der-neubau-in-der-blumenwiese-schreitet-voran-1
Kaarst	yes	new places	https://www.kaarst.de/verwaltung-buergerservice-und-politik/verwaltung/presse/aktuelle-pressemitteilungen/detail/detail/News/spatenstich-fuer-kita-und-jugendeinrichtung-am-eustachiusplatz
Moers	yes	new places	https://www.bethanien-moers.de/aktuelles/aktuelles/kinderhaus-rasselbande-bethanien-eroffnet-punktlich~a393
Mönchengladbach II	yes	new places	https://mg-heute.de/awo-kita-quartierskinder-eroeffnet-im-herbst/
Mönchengladbach II	possibly	n.a.	no source found that could be attributed to a concrete location/institution decisively
Morsbach	possibly	n.a.	https://www.oberberg.drk.de/angebote/kindertageseinrichtung/standard-titel.html
Neuss	no	n.a.	no source found that could be attributed to a concrete location/institution decisively

Location	E	Output-Type	Source
Nordkirchen	yes	new places	https://www.nordkirchen.de/index.php?id=302&publish%5Bid%5D=1066713&publish%5Bstart%5D=1
Növenich	yes	new places	https://www.dueren-magazin.de/11408-noervenich-kreis-baut-neue-fuenfgruppige-kita-3-millionen-euro-baukosten
Schwerte	yes	new places	https://www.schwerte.de/politik-verwaltung-mitmachstadt/verwaltung/nachrichten-presseinfos/detailansicht/1-4-millionen-euro-fuer-kita-erweiterungen
Werne	yes	relocation	https://werne-plus.de/gesellschaftlich/2021/biberburg-kita-am-grote-dahl-weg-ist-offiziell-eroeffnet/

Source: own assessment based on data provided by NRW.BANK

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