Integrating Carbon and Financial Reporting: Accurately Assessing the Financial Implications of Greenhouse Gas Emissions in the European Oil and Gas Industry

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This thesis concludes my six-year-long university journey, a transformative period that has left an indelible trace. Looking back at the person I was six years ago and comparing it with the person I am now, I am amazed by how this experience has shaped my personal and academic growth.

This period was far from easy, testing the depths of my resilience and determination. The emergence of a global pandemic and accompanying changes in the world and my personal life presented unforeseen obstacles. Despite these trials, several factors were pivotal in keeping me steadfast and resolute during these challenging times.

Most importantly, I thank my family, who have always supported me and believed in my abilities. They have been the bedrock of my strength, encouraging me to persevere through the most trying moments and wholeheartedly celebrating my achievements. To my parents, sister, and extended family, I owe an immeasurable debt of gratitude.

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This document represents hours of work and dedication. I hope its contents will provide valuable insights, inspire further exploration, and contribute to the field. Above all, I sincerely hope that you will enjoy reading this research.

EXECUTIVE SUMMARY

This master thesis presents the results of a research study that focuses on integrating financial and carbon reporting within the European Union (EU) oil and gas industry. The objective was to investigate suitable approaches to carbon reporting, explore integration methods, design and evaluate a reference architecture and example integrated report, and provide recommendations for improving integrated reporting practices. To achieve this objective, this master thesis adopted a research process inspired by the Design Science Research Methodology (DSRM) of Peffers et al.

The study examined various reporting standards and guidelines, including Global Reporting Initiative (GRI), Greenhouse Gas (GHG) Protocol, Sustainability Accounting Standards Board (SASB) standards, Task Force on Climate-related Financial Disclosures (TCFD), European Sustainability Reporting Standards (ESRS), and International Financial Reporting Standard (IFRS), to determine their relevance to stakeholders and coverage of reporting aspects. The research recommends incorporating all three scopes of GHG emissions, maintaining consistency and comparability. The GHG Protocol, combined with relevant topics from the GRI guidelines, is suggested as a suitable approach. Furthermore, emerging standards such as ESRS, IFRS, and SASB should be considered, focusing on addressing climate-related risks as per the TCFD guidelines.

Regarding integrating financial and carbon reporting, practical approaches using the eXtensible Business Reporting Language (XBRL) standard were explored. However, challenges such as developing a supported taxonomy, staff training, implementation costs, and stakeholder communication need to be addressed.

To establish a comprehensive reference architecture, the study highlights the importance of a structured design encompassing essential capabilities, business processes, application interactions, and data elements. The ArchiMate modeling language in combination with The Open Group Architecture Framework (TOGAF) were utilized, and the architecture was divided into Strategy, Business, and Application layers. An information structure model and Entity-Relationship Diagram (ERD) were developed to illustrate data entities and their relationships.

The research presents an example XBRL report based on publicly available data from a major company in the oil & gas sector, Shell, demonstrating the integration of financial and carbon reporting in practice. Shell follows reporting frameworks such as GRI, SASB, TCFD, the GHG protocol for carbon reporting, and IFRS for financial reporting. The European Single Electronic Format (ESEF) financial taxonomy was chosen for structuring the data in the report, although a specific taxonomy for the carbon reporting standard ESRS will be developed in the future.

The usability and value of the reference architecture and example report were assessed with the help of practitioners and by using an evaluation process based on the Universal Theory of Acceptance and Use of Technology (UTAUT) theoretical model. The practitioners found the reference architecture useful and valuable in terms of providing guidance for organizations implementing integrated reporting. Suggestions for improvements included enhancing compatibility, customization, and integration with information systems. Next, as for the example XBRL

report, the practitioners considered it to be clear and understandable, aiding comprehension and application of integrated reporting.

Based on the research findings, recommendations are provided to enhance reporting practices and support the transition toward a more sustainable future. These recommendations include continuously monitoring carbon reporting standards, exploring alternative integration methods beyond XBRL, incorporating additional aspects of sustainability reporting, expanding the scope to include Scope 3 emissions, and actively participating in standard and taxonomy development, automation opportunities, and industry forums and initiatives.

The study acknowledges several limitations that may impact the generalizability and completeness of the findings. These limitations include the availability of published standards, limited literature on integrated carbon reporting, lack of widely adopted carbon reporting taxonomies, and sample size limitations in the evaluation process.

Future research and work opportunities are identified to address these limitations and further advance the understanding and implementation of integrated reporting. These include (1) continuously investigating upcoming carbon reporting standards and taxonomies, (2) exploring alternative integration approaches beyond XBRL, (3) incorporating Scope 3 emissions, other greenhouse gases, and broader sustainability reporting aspects, and (4) improving the reporting process's architectural design, data convergence, and automation along with (5) the development of the documentation.

The research contributes to both theory and practice. The theoretical contribution lies in the analysis of EU standards, the exploration of theoretical approaches for integration, and the design of a reference architecture. The practical contribution is demonstrated through creating an XBRL-based integrated carbon and financial report, evaluating the proposed approach by industry practitioners, and providing practical recommendations for enhancing integrated reporting practices.

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ACRONYMS

ADM	Architecture Development Method
API	Application Programming Interface
BCM	Business Capability Map
CSRD	Corporate Sustainability Reporting Directive
DSRM	Design Science Research Methodology
EA	Enterprise Architecture
EFRAG	European Financial Reporting Advisory Group
ERD	Entity-Relationship Diagram
ERP	Enterprise Resource Planning
ESEF	European Single Electronic Format
ESMA	European Securities and Market Authority
ESRS	European Sustainability Reporting Standards
EU	European Union
FSB	Financial Stability Board
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
IFRS	International Financial Reporting Standard
IIRC	International Integrated Reporting Council
ISSB	International Sustainability Standards Board
IR	Integrated Reporting
KPI	Key Performance Indicator
LEI	Legal Identity Identifier
PK	Primary Key
RQ	Research Question
SASB	Sustainability Accounting Standards Board

SSI	Semi-Structured Interview
TCFD	Task Force on Climate-related Financial Disclosures
TOGAF	The Open Group Architecture Framework
UNFCCC	United Nations Framework Convention on Climate Change
UTAUT	Universal Theory of Acceptance and Use of Technology
XBRL	eXtensible Business Reporting Language

1 INTRODUCTION

Climate change poses significant risks to the environment and our planet. It is a phenomenon primarily driven by the accumulation of GHG in the Earth's atmosphere, mainly carbon dioxide from burning fossil fuels. These emissions are a direct outcome of diverse human activities, encompassing the production and consumption of energy in sectors like oil and gas [72].

The impacts of climate change extend extensively and have adverse effects. Rising global temperatures lead to more frequent and intense heatwaves, droughts, and extreme weather events like hurricanes and floods [16]. Melting glaciers and ice caps contribute to rising sea levels, threatening coastal areas and island nations [15]. Changes in precipitation patterns affect agricultural productivity, leading to food shortages and impacting ecosystems [65].

Reducing GHG emissions and mitigating climate change's effects is crucial to address this pressing issue. One essential aspect of this effort is the systematic reporting of emissions. By monitoring and reporting emissions data, companies comprehensively understand their environmental impact. This information allows them to identify areas of improvement, set reduction targets, and develop strategies to transition to more sustainable practices [92].

Systematic reporting also contributes to solving the problem on a larger scale. It enables policymakers, researchers, and the public to assess the magnitude of emissions, track progress in emission reductions, and evaluate the effectiveness of climate change mitigation initiatives [95]. Furthermore, it facilitates transparency and accountability, providing stakeholders with the necessary information to hold companies accountable for their environmental performance [6].

By integrating carbon reporting into financial reporting, companies can track their environmental impact and translate it into financial metrics. This integration allows for a better understanding of the economic implications associated with emissions [44]. It provides investors with crucial data to make informed decisions, encourages companies to improve their environmental performance, and helps governments implement appropriate taxation mechanisms to internalize emissions costs [6, 95].

Through systematic reporting, companies can actively contribute to addressing climate change. They play a vital role in transitioning to a low-carbon economy by measuring, managing, and reducing their carbon footprints [92]. Additionally, transparent reporting fosters collaboration, knowledge sharing, and the adoption of best practices, accelerating the development and implementation of sustainable solutions across industries [90].

In this research, we propose an approach to integrate carbon and financial reporting within the European oil and gas industry. By designing a reference architecture and developing an example integrated report, we aim to facilitate compliance with existing regulations, provide stakeholders with valuable insights into the monetary implications of GHG emissions, and contribute to the collective efforts in mitigating climate change.

1.1 Background

This section provides the necessary background information to develop an understanding of the context in which this research takes place and the scope of work in the present master thesis. Specifically, it includes several sections that define key terms and concepts related to our research project.

Section 1.1.1 defines the greenhouse gases and lists what can be considered a GHG. Next, in Section 1.1.2, the net zero therm is defined, which is often used by companies in the context of limiting carbon dioxide emissions. Then, Section 1.1.3 explains different corporate reporting types, including financial, social, environmental, and sustainability reporting.

Furthermore, Section 1.1.4 provides the definition of the reference architecture, which will be designed further. Finally, Section 1.1.5 introduces the XBRL standard used to implement the designed architecture.

1.1.1 Greenhouse Gases

It is crucial to understand the composition and impact of GHG because they are directly linked to climate change and global warming. *Greenhouse gases* are gases that absorb and trap infrared radiation in the form of heat in the atmosphere, causing the *greenhouse effect*. It works as follows: solar energy heats the surface of the Earth; the surface reflects some of it to the atmosphere where it is absorbed and trapped by GHG, while the rest becomes heat [22].

The list of what can be considered greenhouse gas was introduced in Kyoto Protocol in 1997 [86]. The Kyoto Protocol was developed as part of the United Nations Framework Convention on Climate Change (UNFCCC) established in 1992 [63]. It aimed to limit and reduce GHG emissions of 37 industrialized countries concerning set targets [86].

The Kyoto Protocol entered into force in 2005 with two commitment periods: 2008-2012 and 2013-2020, and preceded the Paris Agreement [62]. According to the protocol, there are the following greenhouse gases:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

This research primarily focuses on carbon dioxide as the most common GHG, representing 76.7% of emissions from man-made sources [49].

1.1.2 Net Zero

It is also important to provide a clear definition and understanding of the concept of *net zero* for comprehending the motivations behind companies' efforts to reduce their carbon footprint and integrate carbon and financial reporting. *Net zero* is the concept coming from the adoption of the Paris Agreement [62]. The agreement was introduced in 2015 and entered into force in

2016 with the goal of limiting global warming by 1.5°C. This should be done by hitting the peak of GHG emissions before 2025 and reducing them by 43% by 2030 to become *net zero* in 2050 [62]. There are no defined metrics or goals for countries on how to achieve these milestones; however, the process will be constantly monitored.

Additionally, the European Green Deal was introduced in 2019 to meet the goals of the Paris Agreement, providing a set of policy initiatives for reducing GHG emissions by at least 55% by 2030 and reaching *net zero* state by 2050 in the EU [17]. Thus, *net zero* refers to the aim of the companies to reduce their absolute emissions across their whole value chain along with the compensating emissions released into the atmosphere with the emissions removed from the atmosphere making the overall impact neutral [26].

It is essential to distinguish between *net zero* and *net zero carbon* to understand which emissions are aimed to be reduced. This research focuses on the *net zero carbon* target and the related metrics, such as carbon intensity and absolute carbon emissions [54]. The comparison between current and net zero carbon flow is presented in Figure 1.1.

Figure 1.1a shows that the current emissions from fossil fuels, industrial processes, and land-use change significantly exceed the carbon emissions removal sinks. In contrast, *net zero* carbon flow (Figure 1.1b) implies a balance between flows to and from the atmosphere, including reducing fossil fuels and land-use emissions and increasing carbon removal sinks.

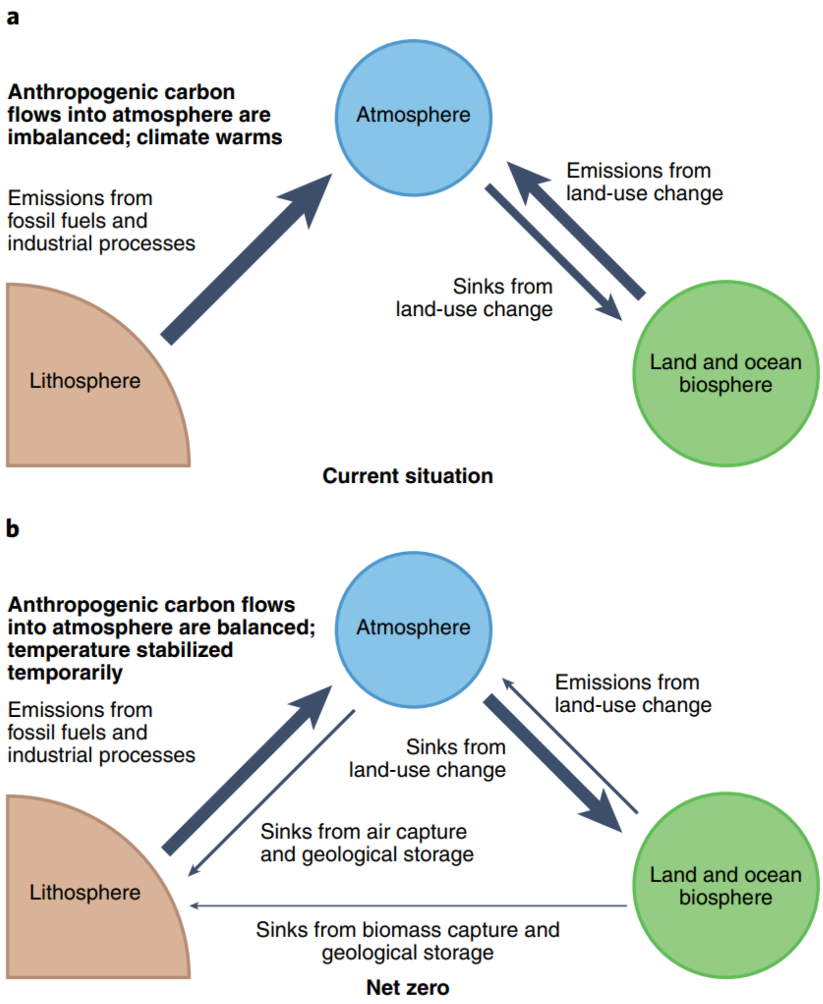


Figure 1.1: a - Current Carbon Flow, b - Net Zero Carbon Flow [26]

1.1.3 Reporting Types

Companies are obliged to report various information throughout their activity. It is important to provide an overview and comprehension of different types of reporting to understand the challenges and complexities associated with integrating carbon and financial reporting. The overview of different types of reporting is presented in Figure 1.2.

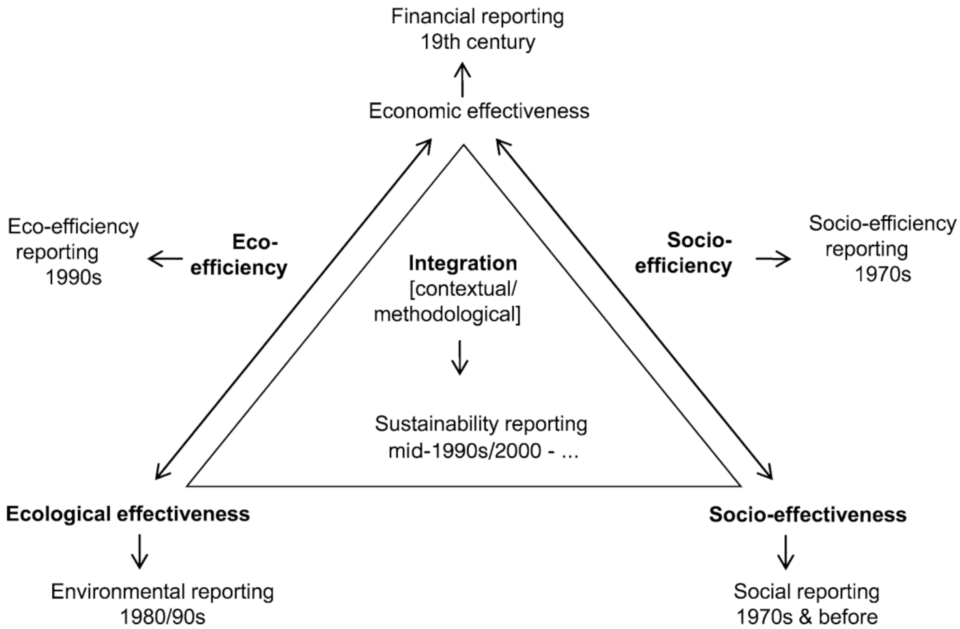


Figure 1.2: Development of Different Types of Reporting [45]

The first form of reporting was *financial reporting* focusing on the monetary metrics reflecting the economic performance of the company [45]. With the rise of income levels and the growing importance of quality of life, certain companies began publishing *social reports* with a focus on the social impact of the companies' activity (socio-effectiveness). This type of reporting, however, is not very common nowadays due to the reduced credibility, complicated integration with financial reporting, and the overall improving working environment. The *environmental reporting* developed with a focus on the ecological effectiveness to reflect the environmental impact of the companies, including emissions, wastes, etc. Additionally, links exist between different reporting types, such as eco-efficiency (between financial and environmental reporting) or socio-efficiency (between financial and social reporting).

Sustainability reporting aimed to integrate all three types of reporting to reflect the companies' sustainability activities and development for the stakeholders. However, in practice, the integration turned out to be problematic, as all three perspectives (economic, social, and environmental) need to be present and consistent, resulting in a contextual integration challenge. Moreover, reports from different perspectives have different types and forms that must be combined, resulting in a methodological integration challenge. This research is focused on sustainability and financial reporting, the scope of which is explained later in this chapter.

1.1.4 Reference Architecture

A clear definition of the *reference architecture* is essential for developing a framework to integrate carbon and financial reporting and creating an example report. The literature has multiple definitions for this term. From a software perspective, it is "a predefined architectural pattern, or set of patterns, possible partially or completely instantiated, designed, and proven for use in particular business and technical contexts, together with supporting artifacts to enable their use. Often, these artifacts are harvested from previous projects" [14].

A reference architecture is also defined in the literature as "a reference model mapped onto software elements (that cooperatively implement the functionality defined in the reference model) and the data flows between them" [5]. This definition was chosen as the most suitable for the current research as it accurately reflects its implementation objectives, including the usage of the software elements and the existing data exchange between them.

1.1.5 XBRL Standard

It is crucial to introduce and understand the concept of *XBRL*, as this research utilizes the XBRL standard to generate an integrated carbon and financial report aligned with the designed referenced architecture. *XBRL* is a widely-adopted open international standard designed to facilitate business reporting by providing a definitive language that authoritatively defines reporting terms. This standardized approach enhances the representability of financial statements, as it tags the data in reports, simplifying its usage and analysis [97].

One of the key features of XBRL is its use of reusable authoritative definitions, known as *taxonomies*, which capture the meaning and interrelationships of reporting terms. This approach enhances the quality of business reporting by enabling the creation of business rules that constrain what can be reported, thus improving the overall quality of financial statements [97]. Examples of XBRL taxonomies that are relevant to this research are SASB, European Financial Reporting Advisory Group (EFRAG), and ESEF taxonomies [24, 75, 82].

1.2 Research Design

This section presents an overview of the research design used in this master project. It begins by stating the problem in Section 1.2.1, followed by the description of the research objectives in Section 1.2.2.

The research scope is defined in Section 1.2.3, and the research questions are listed in Section 1.2.4. Finally, the research relevance is discussed in Section 1.2.5, and the research structure is presented in Section 1.2.6.

1.2.1 Problem Statement

Integrating carbon and financial reporting in the European oil and gas industry faces significant challenges, including the lack of standardized methodologies, disparate regulations, and the complex mapping of carbon and financial data. These challenges hinder the accurate measurement, monitoring, and reporting of GHG emissions and their financial implications.

As a result, stakeholders cannot understand the financial implications of emissions and make informed decisions toward achieving net zero carbon goals. Therefore, there is a need to develop an approach that addresses these challenges and enables the effective integration of carbon and financial reporting, ensuring the reliable quantification and disclosure of emissions-related financial information in compliance with relevant European regulations and standards.

1.2.2 Research Objectives

Based on the formulated problem statement, the overall goal of this research is to develop an approach for integrating carbon and financial reporting in the European oil and gas industry. By achieving this goal, the research aims to enhance the understanding of the financial implications of emissions, support informed decision-making by stakeholders, and contribute to the industry's efforts in achieving net zero carbon goals.

To achieve the overall goal, we set out the following objectives for this work:

1. Analyze the relevant EU standards that regulate carbon reporting in the oil & gas industry;
2. Explore approaches to implement integrated carbon and financial reporting in the EU oil and gas industry;
3. Design a reference architecture that outlines the approach for integrating carbon and financial reporting in the EU oil and gas industry;
4. Create an example XBRL integrated carbon and financial report based on the designed reference architecture;
5. Evaluate the effectiveness and usability of the proposed integrated reporting approach;
6. Propose recommendations for enhancing the integration of carbon and financial reporting in the European oil and gas industry.

1.2.3 Research Scope

The research in this master thesis proposes the approach of integrating carbon and financial reporting to gain a better understanding of the financial implications of carbon emissions. Therefore, the scope is limited to focusing solely on CO_2 emissions as the most significant ones out of other GHG emissions [49].

Moreover, our research efforts specifically focus on the oil and gas industry, a crucial sector for achieving the net zero goal established in the Paris Agreement [62]. In addition, the present research only examines the EU carbon and financial reporting regulations in the oil and gas industry due to the significant differences in regulations across different countries.

The primary focus of research has been directed towards the reporting format and potential data consolidation methods rather than the accounting and computation of emissions, carbon, and financial Key Performance Indicator (KPI)s. More specific architecture scope can be found in Section 4.2.4.

1.2.4 Research Questions

To accomplish the research objectives, we formulated several research questions.

The main Research Question (RQ) is the following:

- *How can carbon and financial reporting be effectively integrated in the European oil and gas industry to accurately measure, monitor, and disclose the financial implications of greenhouse gas emissions?*

Moreover, this thesis investigates the following **sub-questions**:

RQ1: *What should be a suitable approach to carbon reporting in the oil and gas industry in the EU?*

(a) What are the standards for regulating carbon reporting, and how are they (mis)aligned?

(b) What kind of data does an oil and gas company need to report for carbon reporting?

RQ2: *How to combine financial and carbon reporting in the oil and gas industry in the EU?*

(a) What are the potential approaches to do that?

(b) What are the implementation challenges of each approach?

RQ3: *How can a reference architecture be designed to facilitate the integration of carbon and financial reporting?*

(a) What essential capabilities should an integrated carbon and financial reporting system possess?

(b) Which business processes should be depicted in the reference architecture?

(c) How can the interactions between the different applications within an integrated carbon and financial reporting system be designed?

(d) What data should be included in the reference architecture to ensure comprehensive reporting and compliance with regulatory requirements and XBRL standard?

RQ4: *How can the reference architecture be demonstrated through an example XBRL report?*

(a) What type of report would be suitable to showcase the reference architecture effectively?

(b) Which regulations and standards should be considered when producing the example report?

(c) Which specific XBRL taxonomy should be used to structure the data in the report?

RQ5: *To what extent do the reference architecture and the example XBRL report contribute to the implementation and adoption of integrated reporting?*

(a) Are the reference architecture models usable and useful in the perceptions of practitioners in the field?

(b) In what ways did the practitioners in the field find the example XBRL report helpful or limiting in their understanding and application of integrated reporting?

RQ6: *What recommendations can be proposed to enhance the integration of carbon and financial reporting in the European oil and gas industry?*

1.2.5 Research Relevance

The research is highly relevant to the companies in the European oil and gas industry, offering significant contributions in several key areas. First, the study provides a detailed analysis of the relevant EU standards governing carbon accounting within the oil and gas industry. This analysis is critical in understanding the regulatory framework governing carbon accounting and how it impacts the industry.

Then, the research analyses integrated carbon and financial reporting trends and investigates potential approaches for implementing such reporting in the EU oil and gas industry. This examination is important for industry stakeholders seeking to improve transparency and accountability in their reporting practices.

Next, the research proposes a reference architecture for an XBRL-based integrated carbon and financial reporting system. This architecture offers a framework for developing more efficient and effective reporting systems, which is critical in enhancing reporting practices in the oil and gas industry.

Additionally, the research demonstrates the reference architecture as an example XBRL integrated carbon and financial report. This prototype enables stakeholders to understand better the financial implications of CO_2 emissions, thereby contributing to more informed decision-making and improved environmental performance. The research's relevance lies in its potential to improve reporting practices, enhance transparency and accountability, and facilitate better environmental management within the oil and gas industry.

The research also assesses the practicality and effectiveness of the integrated reporting approach within the industry. By evaluating the proposed approach and analyzing its impact on reporting accuracy, decision-making processes, and stakeholder engagement, this research provides insights into the benefits and challenges associated with integrated carbon and financial reporting.

Finally, the research provides actionable recommendations for companies in the industry and practitioners. These recommendations address the identified challenges and support continuous improvement in integrating carbon and financial reporting.

1.2.6 Research Structure

This master thesis is organized into eight chapters. Chapter 1 serves as an introduction to the thesis, presenting the background information necessary for a clear understanding of the subject matter.

Chapter 2 reports the results of a systematic literature review. It provides a comprehensive overview of existing literature on carbon and financial reporting in the European oil and gas industry to answer the first two research questions. Chapter 3 outlines the methodology employed in the research.

Chapter 4 introduces the designed reference architecture and answers the third research question. Chapter 5 addresses the fourth research question and implements the designed reference architecture by creating an example XBRL integrated report. Chapter 6 presents the results of interviews conducted to evaluate the effectiveness and usability of the integrated reporting approach and answers the fifth research question.

Chapter 7 engages in a comprehensive discussion of the conducted research, discussing the limitations of the research, identifying opportunities for future work and research, and providing recommendations for enhancing the integration of carbon and financial reporting, answering the sixth research question. Finally, Chapter 8 concludes the thesis by summarizing the main findings, theoretical contributions, and practical implications.

2 LITERATURE REVIEW

This chapter answers **RQ1** and **RQ2** by conducting a systematic literature review to provide insights into suitable approaches to carbon reporting in the oil and gas industry in the EU and the integration of financial and carbon reporting within the same industry:

- *What should be a suitable approach to carbon reporting in the oil and gas industry in the EU?*
  - What are the standards for regulating carbon reporting, and how are they (mis)aligned?
  - What kind of data does an oil and gas company need to report for carbon reporting?
- *How to combine financial and carbon reporting in the oil and gas industry in the EU?*
  - What are the potential approaches to do that?
  - What are the implementation challenges of each approach?

Section 2.1 provides an overview of the methodology employed in the review, while Section 2.2 outlines the search process followed. The findings of the systematic literature review are presented in Section 2.3, and Section 2.4 examines and interprets them. Finally, Section 2.5 concludes the review by summarizing the main findings and highlighting their significance.

2.1 Methodology

Based on the stated research questions, this systematic literature review aimed to examine carbon reporting practices and regulations within EU oil and gas industry and subsequently explore possible strategies to align carbon and financial reporting.

The review followed Barbara Kitchenham's methodological guidelines to achieve this objective, which involved generating search queries using relevant keywords and filtering the results based on inclusion and exclusion criteria [52]. The goal was to comprehensively evaluate the research topic by examining all published research.

2.1.1 Data Sources & Search Strategy

The studies were collected primarily from the digital library Scopus, where multiple search queries were executed based on the keywords. Various trial searches using different combinations of search terms were made. The keywords were chosen based on the discussion and preliminary investigation of the research questions. Several interviews with experts in the field helped shape the research area and develop a list of keywords for the search.

From the test searches, it was clear that just carbon reporting is rarely observed in the literature. Therefore, it was decided to expand the search area to sustainability and non-financial reporting.

Additionally, the search of the literature discussing the approaches for integrating carbon and financial reporting was expanded to other industries and countries due to the lack of a research base because of the novelty of the research topic.

Finally, the grey literature from the Internet was scanned based on the keywords, which mostly covered regulations and standards in the field of sustainability reporting, along with the reference lists of the chosen studies for additional sources.

2.1.2 Study Selection

The papers found with the search queries were subjected to a set of inclusion and exclusion criteria outlined in Table A.1 in Appendix A. These criteria were established based on the research question and were designed to ensure that only relevant papers were included in the analysis.

An additional search was conducted to explore the potential solution further using the XBRL standard. This subsequent search aimed to gather more information specifically related to the XBRL standard and its applicability in the context of the research question. New inclusion and exclusion criteria were introduced for this additional search to refine the selection process.

2.1.3 Study Quality Assessment

To assess the quality of each of the chosen studies, the following checklist was created based on the one described by Barbara Kitchenham [52].

1. Does the study include a case study or any other validation method?
2. How many samples (companies) were investigated to validate the study?
3. Is it clear how and why the samples were chosen?
4. Were the used tools and methods properly described?

2.1.4 Data Extraction

All the metrics needed for quality assessment and data synthesis were extracted from each study, including case study presence, number of samples, reasons for choosing samples, and description of used tools and methods.

2.1.5 Data Synthesis

Studies researching the same topic were compared for potential similarities and differences in the tabular form, where the most relevant for the review metrics were extracted from each of the studies. Additionally, grey literature was compared to see the (mis)alignments. Overall, some general trends were visible after examining all included studies.

2.2 Search Process

This section describes the conducted search process, including search queries, their results, and the study selection process.

2.2.1 Search Queries

The final search queries for each RQ are presented in Table 2.1:

RQ	Queries
1	• (TITLE-ABS-KEY (”carbon reporting”) OR TITLE-ABS-KEY (”carbon accounting”) OR TITLE-ABS-KEY (”sustainability reporting”) OR TITLE-ABS-KEY (”sustainability accounting”) OR TITLE-ABS-KEY (”non-financial accounting”) OR TITLE-ABS-KEY (”non-financial reporting”) AND TITLE-ABS-KEY (”oil & gas” OR ”oil and gas”)) AND (LIMIT-TO (LANGUAGE , ”English”)) • (TITLE-ABS-KEY (ifrs OR issb OR efrag OR tcfd OR csrd OR esrs OR gri OR nrfd OR sasb OR esg OR ”ghg protocol”) AND TITLE-ABS-KEY (carbon OR sustainability) AND TITLE-ABS-KEY (”oil & gas” OR ”oil and gas”)) AND (LIMIT-TO (LANGUAGE , ”English”))
2	• (TITLE-ABS-KEY (”integrated reporting”) AND TITLE-ABS-KEY (carbon OR sustainability OR non-financial) AND TITLE-ABS-KEY (”financial reporting”)) AND (LIMIT-TO (LANGUAGE , ”English”)) • (TITLE-ABS-KEY (xbrl) AND TITLE-ABS-KEY (carbon OR sustainability OR non-financial)) AND (LIMIT-TO (LANGUAGE , ”English”))

Table 2.1: Search Queries

2.2.2 Study Selection Process

Overall, 308 studies were overviewed, of which 31 were chosen for deeper investigation after the filtering based on inclusion and exclusion criteria. In the end, 19 studies were analyzed. Additionally, 12 grey literature sources were observed, where one was excluded due to the lack of access. The overall search process can be seen in Figure 2.1.

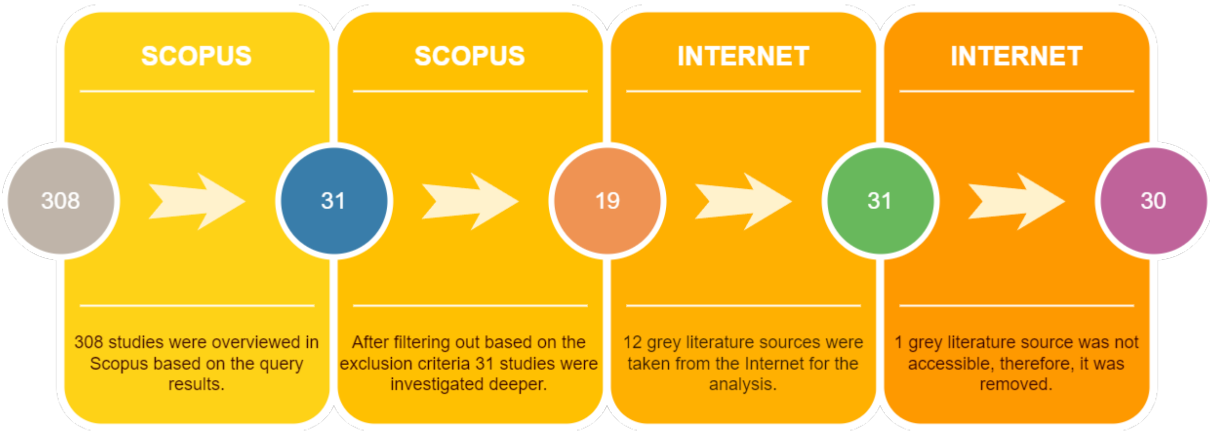


Figure 2.1: The Search Process

For RQ1, the first query returned 93 studies, and the second returned 54. Based on the chosen inclusion and exclusion criteria, after a preliminary overview of the results, 15 studies were selected, where 7 were excluded after a deeper investigation. Apart from that, 6 relevant standards were observed from the grey literature.

For RQ2, the first query returned 125 results, and the second returned 36. Based on the chosen inclusion and exclusion criteria, after a preliminary overview of the results, 16 studies were selected, of which 4 were excluded after a deeper investigation. Apart from that, 5 relevant sources were taken from the grey literature, where one was not accessible anymore.

The included and excluded studies list with the reasons for that is presented in Appendix A.2.

2.3 Findings

The subsequent section provides the outcomes of a systematic literature review conducted, divided into two sections for each RQ. Section 2.3.1 categorizes the findings based on the standard that governs carbon reporting in the EU, the mandatory reporting metrics, and the related studies. On the other hand, Section 2.3.2 organizes the findings according to the various approaches for integrating carbon and financial reporting.

2.3.1 Carbon Reporting in Oil & Gas Industry in EU

In response to the growing importance of sustainability reporting, multiple organizations have taken the initiative to develop standards and guidelines in this area. These efforts aim to provide organizations with consistent frameworks and criteria for reporting their sustainability performance and impacts.

GHG Protocol

One of the essential standards is GHG Protocol. It contains standards for reporting GHG emissions for companies, organizations, countries, and cities. For companies, the primary standard is Corporate Standard [70]. It covers the reporting on 7 greenhouse gases, including carbon dioxide and methane. It helps companies to prepare a GHG inventory, resulting in consistent and transparent GHG accounting, lower costs, and a more effective business strategy.

This standard describes reporting of Scope 1 and Scope 2 emissions, where Scope 1 includes the organization's direct GHG emissions from company facilities and vehicles, and Scope 2 includes indirect GHG emissions related to electricity generation, heating, cooling, or steam consumption.

Another GHG protocol standard describes Scope 3 emissions, which include all other indirect GHG emissions, - Corporate Value Chain (Scope 3) Standard [71]. It helps the companies to assess their entire value chain emissions impact to find possible reduction opportunities. Scope 3 emissions include purchased goods and services, capital goods, transportation and distribution, and business travel. The overview of all 3 scopes and their emissions is presented in Figure 2.2.

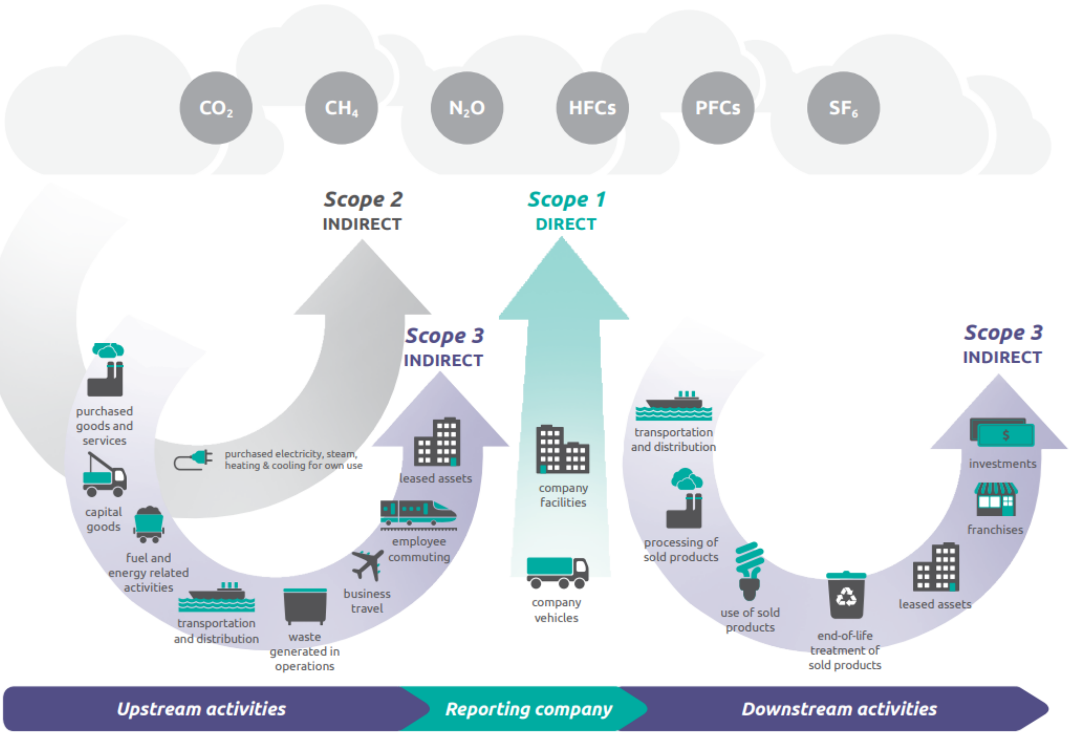


Figure 2.2: Overview of GHG Protocol Emission Scopes [71]

Voicu D. Dragomir [20] analyzed 5 oil and gas companies to compare their reports concerning GHG protocol. All companies reported Scope 1 and 2 emissions, but only two companies (BP and Shell) reported Scope 3 emissions and used the GHG protocol to collect activity data.

GRI

Another important organization in the field of sustainability reporting is GRI [47]. It is a non-profit organization based in Europe that focuses on creating guidelines for sustainability reporting to measure the organization's impact on the people, economy, and environment. There are three series of standards: the GRI Universal Standards, the GRI Sector Standards, and the GRI Topic Standards, all containing disclosures with the requirements and recommendations. Universal Standards apply to all organizations and include general purpose, disclosures, and material topics. Sector Standards describe 40 sectors (including oil and gas) and the relevant disclosures. Topic Standards define disclosures for reporting information on various topics, such as health and safety, tax, and waste.

Following the research questions, Oil and Gas GRI standard (GRI 11) was examined to identify valuable metrics. It first briefly overviews the sector in general and its activities (exploration, development, production. refining, and others) and business relationships (joint ventures, state-owned enterprises (SOEs), suppliers, contractors, and customers). The standard then provides 22 possible material topics suitable for reporting in the industry, including GHG and air emissions, climate adaptation, resilience, transition, biodiversity, etc. For each of the topics, the impacts and disclosures are described. The main topic is GHG emissions, which includes disclosures on direct (Scope 1) and indirect (Scope 2 and 3) emissions, along with energy and emissions intensity and consumption.

The GRI 305 (Emissions) standard was also analyzed to investigate the disclosures needed for carbon reporting [47]. The standards contain 7 general disclosures regarding GHG emissions of all 3 scopes along with the GHG emissions intensity, reduction, emissions of ozone-depleting substances (ODS), nitrogen oxides (NOx), sulfur oxides (SOx), and other significant air emissions.

Multiple papers assess how well oil and gas companies comply with GRI guidelines. Cardoni et al. analyze the problem of reporting comparability among oil and gas companies by checking 68 sustainability reports and mapping them with GRI standards [12]. In the end, only 41 reports were suitable for the analysis, where only 16 were comparable. The most reported topics proved to be Emissions, Occupational Health and Safety, Effluent and Waste, and Economic Performance.

Avram et al. analyzed the integrated reports of the 49 companies (including other industries apart from oil and gas) to investigate their consistency and comparability [8]. The results showed that companies that affect the environment the most report more information, and the oil and gas industry has a high consistency level. The most disclosed metrics are Emissions and Energy indicators, Compliance, Materials and Effluents and Waste. The authors point out that organizations can use different measurement units and names for the same indicator, and a company can suddenly stop or start reporting a specific indicator.

Gill et al. analyzed 30 oil and gas websites from 3 geographical regions: North America, Europe, and Asia, to compare what concept systems they report [29]. The authors compared not only environmental indicators but also economic and social ones. The most reported environmental GRI indicators were the Organisation's consumption of direct primary energy sources, the Environmental impacts of transporting products, goods, and materials used in the organization's operations as well as transporting members of the workforce, and the Significant impacts of organizations on biodiversity in protected areas and high biodiversity value outside protected areas.

Alazzani et al. investigated the data reporting level needed to assess their environmental performance properly [2]. They selected 8 oil and gas companies concerned about the environment and assessed their reporting about GRI guidelines. The most reported indicators were: Habitats protected or restored, Initiatives to reduce greenhouse gas emissions and reductions achieved, and the Total number and volume of significant spills. None of the companies, however, disclosed information about the Percentage of products sold and their packaging materials that are reclaimed by category indicator, which might be just not applicable to them.

Comyns et al. took 232 reports issued by 45 oil and gas companies to check their GHG reporting quality and quantity with regards to GHG protocol and GRI guidelines [18]. The results showed that the overall quality of the reports is way below the required level according to observed standards. Companies that used GRI guidelines produced reports of higher quality, and larger companies tend to report a higher quantity of information on GHG emissions, but the quality is not usually higher.

SASB & IFRS

SASB is another set of standards identifying environmental, social, and governance issues with a focus on financial performance and enterprise value [10]. They contain specific disclosure topics, relevant accounting metrics for 77 industries, and the activity metrics used for normalization and technical protocol to compile data. For the research, Oil & Gas Standards were analyzed, which are divided into 4 industries: Services, Midstream, Refining & Marketing, and Exploration & Production. The last three industries need to report GHG emissions (which include only Scope 1 emissions) and Air Quality metrics, along with the Water Management for the last two.

Homayoun et al. proposed a model to use a sustainability reporting framework to guide the disclosure of metrics concerning SASB standards for Maersk Oil Company [46]. The model was developed for only Exploration & Production and Midstream sectors. The authors also state that although GRI is more widely used and easier to implement, it is too general and not business-applicable. Therefore, SASB-based reports might be a better option.

SASB standards have now become a part of IFRS standards developed by the International Sustainability Standards Board (ISSB) [81]. The board is currently developing its sustainability reporting standard containing climate-related and general sustainability disclosures, which has yet to be released.

ESRS & TCFD

Another set of standards currently in progress is ESRS, developed by the EFRAG [41]. The standards come from the Corporate Sustainability Reporting Directive (CSRD) regulating what EU companies must report. The draft set of ESRS was published in November 2022 and contained Environment, Social, and Governance standards. Environment standards are divided into 5 topics containing related disclosures: Climate change, Pollution, Water and marine resources, Biodiversity and Ecosystems, and Resource use and circular economy. The final version is expected to be published in June 2023 (along with sector-specific standards), and the first companies will have to apply starting in 2024.

ESRS is built on TCFD standard, created by The Financial Stability Board (FSB) to develop recommendations on disclosures for supporting companies' investors and other stakeholders in assessing climate change risks [13]. The recommendations are divided into 4 areas: Governance, Strategy, Risk Management, and Metrics and Targets. They are adoptable by all organizations with possible supplemental guidance for specific sectors (including Energy). Governance disclosures are built around climate-related risks and opportunities, while Strategy ones disclose their actual and potential impacts. The Risk Management area discloses the method of identifying climate-related risks, and Metrics and Targets describe the metrics and targets for assessing and managing them, including GHG emissions.

Dye et al. analyzed the sustainability reports of 30 oil and gas companies to check their compliance with TCFD, GRI, and SASB, where companies were divided into three groups based on their capitalization [21]. The results show that the GRI framework is often mentioned in the reports (by more than half of the companies) but often without full compliance. SASB is cited only by 3 companies from the smaller market, and TCFD is mentioned by 12 of 15 larger market firms. There is a lack of consistency and standardization regarding environmental performance metrics. Companies use different time scales, units of measurement, and metrics in general, making it harder to comply with SASB and TCFD, which require the disclosure of financial and environmental risks.

2.3.2 Integrated Carbon & Financial Reporting Approaches

The convergence of financial and carbon reporting is a relatively new research area, and as a result, the academic literature on this topic is still emerging. However, some scholarly sources provide insights into possible approaches for integrating financial and sustainability reporting.

The IR Framework

One of the popular trends in this field is IR. It comes from The IR Framework developed by the International Integrated Reporting Council (IIRC) [73]. Firstly introduced in 2010, the IIRC merged with SASB and ISSB in 2021 to provide a higher-quality reporting framework covering most enterprise values and drivers.

The framework proposes the reporting in the form of an integrated report which explains the value creation process to the financial capital providers. It is developed with a principles-based approach, which does not include any specific performance indicators or measurement methods. Still, it does have some preliminary requirements needed to be applied to the report. The framework is mainly written for the private sector but can potentially be adapted for the public sector too.

The most recent version of the framework is divided into three parts: Fundamental Concepts, Guiding Principles, and Content Elements. The Fundamental Concepts explain the reasons for producing an integrated report. The created and preserved value of the organization is linked to the value created and preserved by others. To create value, organizations rely on certain critical resources and relationships (capitals), and the process of value creation is influenced by certain factors represented by the Content Elements.

The Guiding Principles explain how the integrated report should be prepared, including Strategic focus and future orientation, Connectivity of information, Stakeholder relationships, Materiality, Conciseness, Reliability and completeness, Consistency and comparability.

The Content Elements state what should be included in the integrated report: Organizational overview and external environment, Governance, Business model, Risks and opportunities, Strategy and resource allocation, Performance, Outlook, and Basis of preparation and presentation.

Staszkiewics et al. discuss one way to possibly implement integrated reporting [83]. They introduce a solution that, instead of the classic double recording of transactions with one value (Dr.-Cr., currently used in financial accounting), records the transaction as two double records with two different values. The first record remains to be the classic Dr.-Cr. one, and the second represents the transaction's environmental impact (SDr.-SCr.). Therefore, each transaction will have at least four records with two financial and two environmental values. The limitation of such a solution is that the financial reporting rules comply with specific legal standards. Therefore, it is impossible to implement this concept until the law is changed. For now, it can only be applicable in management accounting.

XBRL Reporting

Additionally, Lubin and Esti demand "a new approach for sustainability reporting" by analyzing the growing "sustainability gap" [55]. More and more companies have begun to understand the importance of sustainability strategies leading to increasing competitive advantage and financial gains. However, investors are not entirely convinced that the sustainability aspect is that critical when it comes to profit and position on the market. One reason for this is that sustainability reporting uses language unfamiliar to investors, and the used metrics do not explain the business value of sustainability. Therefore, a linkage is needed to see the monetary outcomes of proper sustainability reporting.

Peter Seele addresses the call for the new approach and proposes a concept of ”digitally unified reporting” [76]. He unifies the concept of integrated reporting for sustainability and XBRL-based reports for finance and introduces XBRL-based sustainability reporting, which enables 24/7/365 digital transparency.

The limitation of Seele’s approach is too much information being disclosed, for which global governance and standardization are needed. Another limitation is that XBRL-standardized data repositories are more complex than usual indicators, such as GRI. To solve that, a feasible standard should be introduced to reduce the complexity and establish comparability. It is unclear who should play the role of supervising authority. It could be a certified management system or a public authority based on a regulatory framework. There are no proper XBRL taxonomies for sustainability reporting, and upcoming ones could also have limitations. Regulatory commitment is needed to experience the benefits of the addressed concept fully.

Additionally, the vulnerability of the data should be addressed. XBRL data can be a subject of cyber attacks. Therefore, strong security measures are needed. Another limitation is the high cost of developing data standards, which all the benefits of XBRL-based reporting can compensate for. Finally, this concept came from the literature rather than from the corporate world, which might result in different priorities and points of view.

Efimova et al. support Seele and propose the usage of XBRL as a tool for integrating financial and non-financial reporting [23]. Such an application would ensure effective management and meet stakeholder information requests. However, the authors say that the training of professionals in this field is needed along with developing proper standards.

Bartolacci et al. review the studies investigating the implementation of XBRL published in the past twenty years [9]. After analyzing 142 articles, five research areas were identified: adoption issues, financial reporting, decision-making/market efficiency/corporate governance, audit and assurance, and non-financial reporting.

Only the last cluster is interesting for this research, consisting of seven articles. The advantages of using XBRL in sustainability and environmental reporting are more precise metrics that would increase comparability and reduce costs, improved data management, and real-time reporting to stakeholders. However, the studies do not assess such implementation’s real and effective consequences due to recency and lack of standards.

Therefore, it is worth looking at existing and upcoming XBRL taxonomies and regulations in sustainability reporting. One of the first published XBRL taxonomies was based on GRI guidelines, which is currently non-accessible [48].

Madlberger et al. used ontology-based data integration to propose a mechanism for automatically generating a domain-specific ontology, proved by querying and linking actual data [56]. The ontology is based on GRI taxonomy and modeled using the Web Ontology Language (OWL). Potentially, this could be done on a larger scale with XBRL-based sustainability reports.

Another approach is described by Arndt et al. [7]. To visualize them better, the researchers use XBRL to transform sustainability reports into Topic Maps (XTM). The reports will be published separately by topics, which can be displayed based on a user group. Additional information can be presented, such as paragraphs or dictionary descriptions.

In September 2021, another XBRL taxonomy was published, based on SASB standards for 77 industries based on 11 sectors [82]. The taxonomy requires companies to provide general information (name, country, etc.). It covers the TCFD framework and its four pillars (Governance, Strategy, Risk Management, and Metrics & Targets) along with the industry and sector-specific disclosure topics and accounting and activity metrics. It is possible to add a narrative on the disclosure topic, additional dimension, and additional (jurisdiction-specific) disclosure for metrics.

EFRAG published a limited first draft of an XBRL taxonomy for the ESRS on climate change [24]. Adopting the related CSRD will require European companies to tag their sustainability reports according to the developed taxonomy. The taxonomy focuses on the GHG emissions, divided by segment and country, including the CO2 emissions equivalent, the target/base year share, and the annual target/base year (only for Scope 1).

Regarding the upcoming taxonomies, IFRS is developing IFRS Sustainability Disclosure Taxonomy for the IFRS Sustainability Disclosure Standards [81]. It is expected to be published in 2023.

Daria Miscikowska investigated the perception of adopting XBRL for financial reporting needed for compliance with IFRS based on the evidence of 25 Polish companies [60]. Most respondents noted the benefit of increased comparability, usefulness, and accessibility of financial information. However, the drawbacks of increased preparation time and additional training and implementation costs were also seen. Additionally, companies did not see the need for extending the XBRL implementation for non-financial reporting, which is currently being planned according to CSRD. Therefore, further explanation of the business rationale of such a proposal is needed for stakeholders.

Faccia et al. proposed an XBRL-based model of an additional income statement for non-financial reporting about IFRS, which would ensure the comparability of financial statements and encourage additional mandatory disclosures [25]. The model is built from the perspective of added value. The customized input weighing should make the proposed income statement suitable for a company of any size and industry. The proposed model, however, has not yet been tested and implemented.

Additionally, several researchers proposed their own XBRL taxonomies for sustainability reporting. Fumiko Satoh defined the core XBRL taxonomy for GHG emissions reporting based on GHG protocol [74]. The taxonomy is structured as a document, divided into Required information and Optional information. Required information contains Scope 1 and 2 emissions data along with the total emissions and base year information, and Optional information includes Scope 3 emissions data and information on purchased and transferred offsets. For the further improvement of the taxonomy, a real scheme for emissions reduction is needed as well as potential complexity reduction (e.g., currently, the tuples are used, and later can be replaced with dimensions).

La Torre et al. modeled an artifact of a bi-dimensional XBRL taxonomy based on the IR Framework to be used for integrated reporting [53]. The model was based on two dimensions described in the framework: Content elements and Capitals. The third dimension represents the Type of information (financial/non-financial, quantitative/non-quantitative). This structure allows users to navigate disclosure from two perspectives, show only particular topics of interest, and drill down to get additional information. The model was then tested using integrated reports of 19 companies from 6 different sectors. It can also be potentially integrated with existing financial reporting taxonomies or upcoming sustainability ones. However, the authors point out the need to embed different social actors' perspectives and the theoretical background of the proposed model, which still needs to be transformed into a real XBRL taxonomy and later applied in practice.

Mora also proposed an XBRL taxonomy based on the IR Framework [61]. It consists of several KPIs along with the tested XBRL architecture in the software called Formulae. The indicators are divided into basic (expressed in absolute value), composed (described in relative terms), and complex (described in relation drivers from different areas). KPIs are built based on four areas: profit (financial), people (social), planet (environmental), and pilots (governance). The created architecture allows for the extension of the taxonomy by adding new dimensions or validation rules along with the other relationships, however, it has not been validated.

2.4 Interpretation

The following section interprets the findings from the systematic literature review, focusing on the addressed RQs. Section 2.4.1 examines and compares the European standards employed in the field of carbon reporting, along with the associated reporting metrics.

Section 2.4.2 presents an overview of the main areas covered by the papers reviewed and compares the approaches to integrated reporting. Furthermore, a detailed comparison of XBRL taxonomies is provided.

2.4.1 Carbon Reporting in Oil & Gas Industry in EU

For **RQ1**, it was clear that the sustainability reporting standards are still being developed. Most companies use GRI guidelines in their sustainability reporting [2, 8, 12, 18, 21, 29]. However, not all GRI indicators are reported by companies. After comparing the studies presented in Table 2.2, the most reported indicators were related to Emissions, Energy, Compliance, and Effluents and Waste. Additionally, the companies tend to use different names, periods, and measurement units for the same indicator, affecting reports' comparability and overall quality [8, 21].

The other common standard is GHG protocol which is mainly related to carbon accounting, including direct (Scope 1) and indirect (Scope 2 and 3) emissions [70]. Although the majority of emissions belong to Scope 3, the companies tend to report mainly Scope 1 and 2 emissions [20], and the quality of the reports is still not very high [18].

SASB standards are also widely used, covering 77 industries, where oil and gas are divided into four industries. However, emissions reporting covers only Scope 1 for three of them. The standards are aimed to be more specific and business-applicable, unlike widely spread GRI [46].

Upcoming standards include ESRS and IFRS, which still leave some space for new, more specific disclosure requirements. They will be built on TCFD, which requires the disclosure of financial environmental risks and are mandatory to use for EU companies [21].

Study	Samples analysed	The most reported GRI indicators
Cardoni et al. [12]	68 oil and gas companies, where only 41 obtained GRI requirements, and 16 were comparable	Emissions (EN15, EN16, EN21) Occupational Health and Safety (LA6) Effluents and Waste (EN22-EN24) Economic Performance (EC1)
Avram et al. [8]	99 organizations (not only oil and gas), out of which 49 were selected, where 10 companies are environmentally sensitive	Emissions (EN15-EN21) Energy (EN3-EN7) Compliance (EN29) Effluents and Waste (EN22-EN26) Materials (EN1, EN2)
Gill et al. [29]	30 oil and gas websites	Organisation's consumption of direct primary energy sources (EN3) Environmental impacts of transporting products, goods, and materials used in the organization's operations as well as transporting members of the workforce (EN29) Significant impacts of organizations on biodiversity in protected areas and high biodiversity value outside protected areas (EN12)
Alazzani et al. [2]	8 oil and gas companies	Habitats protected or restored (EN13) Initiatives to reduce greenhouse gas emissions and reductions achieved (EN18) Total number and volume of significant spills (EN23)

Table 2.2: Comparison of GRI Studies

Overall, the standards often target different groups and serve different purposes. TCFD, IFRS, and SASB are aimed at investors, while GRI, GHG protocol, and ESRS are aimed at all stakeholders. GRI, SASB, and ESRS are general standards, and TCFD and GHG protocol are climate-related. Upcoming IFRS will be both general and climate-related. Only GRI and SASB have industry-specific standards. The majority of standards (apart from SASB and potentially IFRS) require reporting all three scopes of emissions. The overview of standards and related studies is presented in Table 2.3.

Standard	Published	Industry-specific	Matter	Aimed towards	GHG emissions	Related research
GRI	Yes	Yes (40 sectors)	General	All stake-holders	Scope 1, 2, 3	[2, 8, 12, 18, 21, 29, 46]
GHG protocol	Yes	No	Climate	Companies and organisations, countries and cities	Scope 1, 2, 3	[18, 20]
SASB	Yes	Yes (77 industries)	General	Investors and capital providers	Scope 1	[21, 46]
ESRS (CSRD)	Yes (draft)	No (in progress)	General	Companies	Scope 1, 2, 3	-
IFRS	No	No	General & Climate	Investors	Unknown	-
TCFD	Yes	No (only supplemental for certain sectors)	Climate	Investors, lenders, and insurance underwriters	Scope 1, 2, 3	[21]

Table 2.3: Comparison of Standards in Carbon Reporting

2.4.2 Integrated Carbon & Financial Reporting Approaches

Regarding **RQ2**, the studies mostly observed the potential benefits of integrating financial and non-financial reporting. The researchers address the problem organizations the linkage between sustainability and finance [55] and propose theoretical solutions for filling the gap [76, 83]. Still, the practical implementations remain to be not properly validated [7, 25, 56, 60, 83].

After analysis of the relevant literature (the overall comparison can be found in Table 2.4), several conclusions were made. One major trend in the literature is integrated reporting from the IR Framework by IIRC [73], proposing that organizations deliver an integrated report containing both financial and non-financial data. This framework is often combined with the other trend - XBRL-based reports, requiring data to be tagged to represent financial statements better [9, 23, 76].

Overall topic	Studies
Sustainability reporting	[9, 55, 60]
Integrated reporting	[9, 23, 76, 83]
Practical implementation	[7, 25, 56, 61, 83]
XBRL taxonomy development	[53, 61, 74]

Table 2.4: Overall Comparison of IR Studies

However, XBRL-based reports are not currently used for sustainability or integrated reporting. One reason for that is a lack of proper taxonomies supported by legal standards needed for the creation of a high-quality report [9, 23, 76]. The current taxonomies are either not accessible anymore (GRI), limited (SASB, EFRAG), or still in progress (EFRAG, IFRS). Several researchers attempted to propose their own taxonomies, but none were actually validated with a real case study [53, 61, 74].

The overview of the analyzed taxonomies is presented in Table 2.5.

XBRL Taxonomy	Accessible	Based on	Related research
GRI taxonomy	No	GRI guidelines	[7, 56]
SASB taxonomy	Yes	SASB standards, TCFD	-
EFRAG taxonomy	Yes (draft)	ESRS/CSRD	-
IFRS taxonomy	No (in progress)	IFRS	[25, 60]
Satoh taxonomy	Yes	GHG protocol	[74]
La Torre taxonomy	Yes (artifact)	The IR Framework	[53]
Mora taxonomy	Yes	The IR Framework	[61]

Table 2.5: Comparison of XBRL Taxonomies

Additionally, the stakeholders need a business rationale for the XBRL implementation, which can be costly and needs additional employee training [23, 60, 76]. Nevertheless, XBRL-based reports will establish improved data management and analysis possibilities and real-time reporting to the stakeholders [9, 23, 76].

2.5 Summary

The following section summarizes the findings and interpretations from the systematic literature review in response to our two RQs.

2.5.1 Carbon Reporting in Oil & Gas Industry in EU (RQ1)

The primary standards regulating sustainability (specifically carbon) reporting were analyzed along with the studies observing the quality of sustainability reporting in the oil and gas industry in the EU. The results show that the existing standards are still under development. However, most require reporting all three scopes of GHG emissions. Most companies try to comply with GRI guidelines, GHG protocol, SASB standards, and TCFD. The standards aim at different stakeholder groups and can have general or climate matters, with some of them having industry-specific standards.

Furthermore, compliance with standards still needs to improve across the companies in the oil & gas industry. The reports need more consistency and comparability, often using different names, periods, and measurement units.

Therefore, the primary data source for carbon reporting would be GHG protocol, including Scope 1-3 emissions and their intensities. Additionally, related topics from GRI guidelines should be reported, particularly those related to Emissions (EN15-E21). Once the ESRS and IFRS (merged with SASB, which only includes Scope 1 emissions) reach their final publication stage, their carbon-related disclosures should also be considered, knowing that ESRS reporting will be mandatory for EU companies starting in 2024. Moreover, ESRS will be based on TCFD, which guidelines should also be considered (especially the risks from the emissions from all three scopes).

2.5.2 Integrated Carbon & Financial Reporting Approaches (RQ2)

The trends in integrated reporting were investigated, along with the studies discussing the potential implementation of XBRL in sustainability and integrated reporting and the analysis of existing and upcoming XBRL taxonomies. Few literature sources propose a practical approach for integrated sustainability and financial reporting.

The IR Framework sets a theoretical base for companies to deliver integrated reports, leaving space for practical implementation. However, the current double-entry accounting system may be hard to change because of the need to change the laws.

Therefore, the most promising practical implementation proposals are related to using the XBRL standard. The language is already used for financial reporting, making it easier to integrate with sustainability and improving the report's usefulness and comparability. Moreover, there is currently no validated case of such a solution, opening the gap in the research area.

However, to build an XBRL-based solution, a taxonomy supported by a legal standard is needed, which is currently in progress or covers only part of the sustainability domain. Such a solution also requires additional staff training, has high implementation costs, and is needed to be explained to stakeholders.

3 RESEARCH METHODOLOGY

This chapter focuses on the research methodology employed in this thesis, describing a systematic approach to address each part of our research process. This approach lays the foundation for the subsequent chapters, guiding the reader through the research process and showcasing the development and evaluation of the research artifact.

The chapter begins by introducing Design Science [66] as our methodology of choice for this work in Section 3.1. Next, the problem statement and research relevance methodology are discussed in Section 3.2, along with outlining the methodology of formulating research objectives, questions, and scope of the study in Section 3.3.

Then, the methodology of the design and development of the research artifact is described in Section 3.4. Section 3.5 showcases how the artifact of the research will be demonstrated in the real-world context, while Section 3.6 describes the evaluation procedure of the research artifact and its demonstration.

Finally, Section 3.7 describes how research findings will be publicly shared with other researchers and practitioners. Section 3.8 summarizes and overviews the methodology with regard to each stage.

3.1 Design Science Research Methodology

The research is based on the methodology described by Peffers et al. called *DSRM*, presented in Figure 3.1 [66]. We chose it because of its suitability to our research context. According to this methodology, a research project consists of six stages:

1. *Problem identification and motivation*, that defines the specific research problem and explains the value of the solution;
2. *Defining the objectives for a solution*, that comes up with the solution goals and scope based on the defined problem;
3. *Design and development*, that focuses on creating the design research artifact (construct, model, method, etc.) and determining its functionality and architecture;
4. *Demonstration*, that solves the problem by demonstrating the usage of the designed artifact with a case study, simulation, or other activity;
5. *Evaluation*, that observes and measures how well the artifact solves the problem with satisfaction surveys, quantifiable performance measures, or other empirical evidence or logical proof;
6. *Communication*, that includes publishing the conducted research to discuss it with other researchers and practicing professionals.

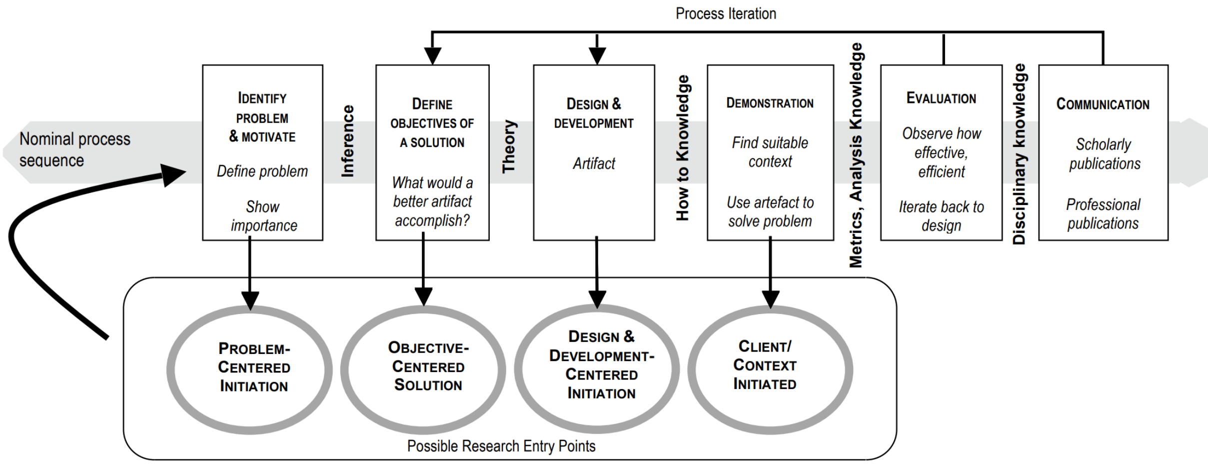


Figure 3.1: Design Science Research Methodology Process Model [66]

Additionally, a research project has four entry points corresponding with the first four stages of the methodology. They are briefly explained below:

1. *Problem-Centered Initiation*, when the research idea came from a problem observation or suggested future research in a paper;
2. *Objective-Centered Solution*, when a research need can be addressed by artifact development;
3. *Design and Development-Centered Initiation*, when an existing artifact has not yet been supported by a solution for the problem domain in which it can be used;
4. *Client/Context Initiation*, when the observation of a practical working solution is needed to apply it retroactively.

The current research has adopted the *Problem-Centered Initiation* entry point. This choice was made based on the findings of a systematic literature review conducted in Chapter 2, which identified the pressing need for an integrated carbon and financial reporting approach. The next sub-sections describe how each step of the DSRM of Peffers et al. [66] was performed in the present research project.

3.2 Problem Identification & Motivation

The first stage of DSRM was demonstrated by formulating the problem statement in Section 1.2.1 and explaining the research relevance in Section 1.2.5. In Section 1.2.1, the problem statement was formulated, highlighting the existing gap in the literature concerning the need for an integrated carbon and financial reporting approach. The problem statement concisely articulated the specific issue the research aimed to address. It provided clarity and context to the research endeavor, outlining the significance and urgency of finding a solution to the identified gap.

Section 1.2.5 further emphasized the research relevance by discussing the broader implications and importance of addressing the identified gap. It explained the significance of integrating carbon and financial reporting, highlighting the potential benefits for organizations, investors, and other stakeholders. This section provided a comprehensive understanding of the relevance and potential impact of the research in the field of carbon and financial reporting and decision-making.

3.3 Solution Objectives Definition

The second stage of DSRM was addressed by formulating research objectives in Section 1.2.2, defining research questions in Section 1.2.4, and establishing the scope of the study in Section 1.2.3. In Section 1.2.2, the research objectives were listed to guide the investigation and development of an integrated carbon and financial reporting artifact. These objectives were shaped by the identified gap in the literature and aimed to fill that gap by providing a comprehensive solution. The objectives served as a road map, outlining the specific goals that the research aimed to achieve.

Section 1.2.4 focused on formulating RQs that aligned with the research objectives. These questions were designed to delve into specific aspects of integrated reporting, enabling a thorough exploration of the topic. By formulating RQs, the study aimed to address key areas of inquiry and provide insights into the development, implementation, and potential challenges associated with the proposed solution.

Furthermore, in Section 1.2.3, the scope of the research was defined. This involved setting boundaries and determining the extent of the study. The scope encompassed various dimensions, such as the industry sector and geographical location that the research would focus on. By defining the scope, the research project ensured a clear and focused approach, enabling a comprehensive investigation within the identified parameters.

3.4 Design & Development

The third stage of DSRM for this research project will be executed by designing the artifact, which is the reference architecture for integrated carbon and financial reporting. This design will utilize the ArchiMate and TOGAF frameworks.

The *ArchiMate Modeling Language* of The Open Group is a widely used modeling language for Enterprise Architecture (EA) [42]. ArchiMate provides a comprehensive set of concepts and notations for representing various organizational components' structure, behavior, and relationships. The core of it includes concepts from three layers at which the architecture can be modeled from different viewpoints depending on the stakeholders' concerns:

- *Business Layer* for modeling the enterprise operational organization independent from the technology;
- *Application Layer* to describe the structure, behavior, and interaction of the enterprise applications;
- *Technology & Physical Layer* to describe the behavior and structure of the enterprise technology infrastructure.

The ArchiMate Core Framework also includes the following aspects:

- *Active Structure Aspect* representing the activity elements such as business actors and application components;

- *Behavior Aspect* representing the actors' behavior: processes, functions, events, and services;

- *Passive Structure Aspect* representing the objects at which the behavior is aimed, such as information or data objects.

For the purpose of this research, *the ArchiMate Full Framework* was considered, which includes additional elements presented in Figure 3.2:

- *Strategy layer* representing strategic direction and choices;

- *Implementation & Migration layer* supporting the corresponding processes;

- *Motivation aspect* for modeling motivations and reasons guiding the change.

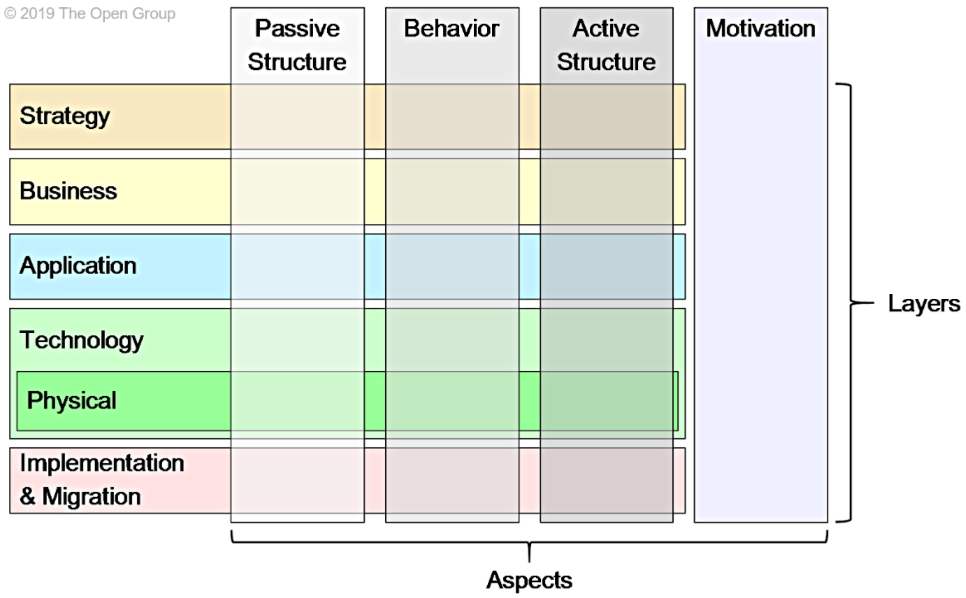


Figure 3.2: ArchiMate Full Framework [42]

The ArchiMate Language is often combined with TOGAF [43]. This framework proposes an ADM for a tested and repeatable process for developing EA:

- *Preliminary Phase* prepares and initiates activities for creating architecture capabilities and principles;

- *Phase A: Architecture Vision* defines the scope and the stakeholders of the architecture and creates the Architecture Vision;

- *Phase B: Business Architecture* develops Business Architecture to support the Architecture Vision;

- *Phase C: Information Systems Architecture* develops the Information Systems Architecture to support the Architecture Vision;

- *Phase D: Technology Architecture* develops the Technology Architecture for the Architecture Vision;

- *Phase E: Opportunities & Solutions* manages the implementation planning;
- *Phase F: Migration Planning* produces the detailed Implementation and Migration plan;
- *Phase G: Implementation Governance* supervises the implementation;
- *Phase H: Architecture Change Management* manages changes to the new architecture;
- *Requirements Management* manages architecture requirements during ADM.

The architecture stages of TOGAF (B, C, and D) correspond with the layers of the ArchiMate Core Language. The remaining stages of the framework map onto the Strategy & Motivation and Implementation & Migration layers of the ArchiMate Full Language. The correspondence between the ArchiMate Language and the TOGAF ADM is reflected in Figure 3.3.

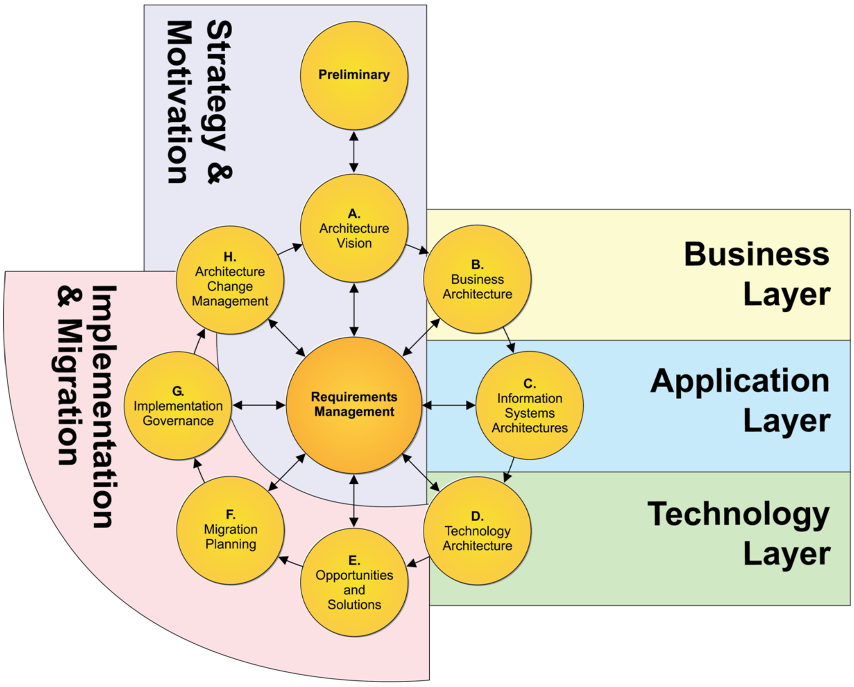


Figure 3.3: Correspondence between the ArchiMate Language and the TOGAF ADM [42]

It is important to note that not all ArchiMate layers will be considered when modeling a reference architecture for this research. Only models containing elements from Strategy, Business, and Application layers will be created due to the complexity of modeling the Technology layer. Similarly, only corresponding TOGAF phases will be executed when modeling architecture, including Preliminary Phase, Phases A, B, and C, and Requirements Management.

3.5 Demonstration

The fourth stage of DSRM will be showcased by producing an example XBRL integrated carbon and financial report in the form of a *case study* featuring Shell, a multinational energy company. This demonstration will apply the developed reference architecture and showcase its effectiveness in integrating carbon and financial reporting within a real-world context.

A *case study* thoroughly examines an individual unit to gain insights into a broader category of similar units [28]. In the case of this research, one oil and gas company that operates in EU

(Shell) is taken as an example to test the applicability of the artifact for other European oil and gas companies.

Vanwynsberghe and Khan suggest seven common features of a *case study* [88]:

Feature 1 *Small N*: using a small sample size on which the artifact is applied;

Feature 2 *Contextual detail*: providing a highly detailed analysis of the usage of the artifact in a real-world context;

Feature 3 *Natural settings*: taking the situation with little control over behavior or events;

Feature 4 *Boundedness*: providing a detailed description of boundaries:

Feature 5 *Working hypotheses and lessons learned*: making conclusions out of the collected and analysed data:

Feature 6 *Multiple data sources*: using multiple sources of data;

Feature 7 *Extendability*: extending the gained knowledge from the sample unit to other similar units.

Therefore, the *case study* will utilize these features by:

Feature 1 *Small N*: focusing on Shell as a representative organization;

Feature 2 *Contextual detail*: providing a highly detailed analysis of how the reference architecture can be applied within Shell carbon and financial reporting practices;

Feature 3 *Natural settings*: taking into account natural settings of Shell, considering operations related to carbon and financial reporting;

Feature 4 *Boundedness*: providing a detailed description of the boundaries within which the report will be constructed;

Feature 5 *Working hypotheses and lessons learned*: drawing conclusions about the effectiveness and implications of the developed reference architecture for Shell and potentially other organizations;

Feature 6 *Multiple data sources*: incorporating multiple data sources during the report construction process, both related to carbon and financial reporting;

Feature 7 *Extendability*: extending the gained knowledge from Shell to other European oil and gas companies seeking to implement integrated carbon and financial reporting practices.

3.6 Evaluation

The baseline methodology for the fifth stage of DSRM is the UTAUT, reflected in Figure 3.4 [89]. This theory is used to assess the probability of success of the new technology (system) introduction and to see the drivers for its acceptance. The theory is based on four constructs:

- *Performance Expectancy*: the extent to which a person believes that the usage of a system will help achieve their personal goals and improve their job performance;
- *Effort Expectancy*: the extent of ease of the use of the system;

- *Social Influence*: the extent to which a person sees that the people important to them think they should use the new system;
- *Facilitating Conditions*: the extent to which a person believes there is sufficient infrastructure (both organizational and technical) to support the system usage.

The model suggests that these constructs, in turn, impact two key determinants of technology adoption: *Behavioral Intention* and *Use Behavior*. *Behavioral Intention* refers to the degree to which an individual intends to use the technology, while *Use Behavior* reflects the actual usage of the technology.

UTAUT also includes four key moderators that can influence the relationship between the constructs and the determinants of technology adoption: *Gender*, *Age*, *Experience*, *Voluntariness of Use*. These moderators can affect how individuals perceive and respond to the various constructs and, consequently, their likelihood of adopting the new technology.

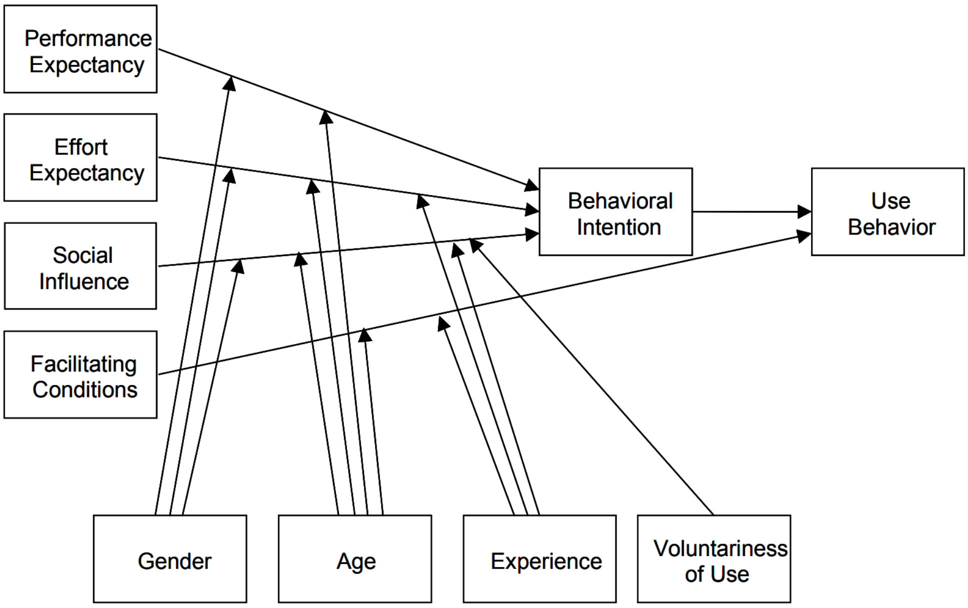


Figure 3.4: Unified Theory of Acceptance and Use of Technology Model [89]

3.6.1 Data Collection

The data collection method chosen for the research is conducting *SSI* [51, 59] with employees from various departments and job functions from the oil and gas company. A *SSI* is a method used to gather subjective responses from individuals about a specific situation or phenomenon. It is used when there is sufficient objective knowledge about the situation or phenomenon but a lack of subjective understanding [59].

During the SSI, interviewees are asked open-ended questions about the artifact and are free to respond as they wish and share their thoughts and experiences. The researcher may ask follow-up questions to explore their responses further [59].

The main advantage of this approach is that it allows the interviewer to focus on key areas and explore relevant ideas that may arise during the interview. This increased flexibility can provide a more comprehensive understanding of the assessed artifact [1]. By interviewing a diverse group of employees, it is possible to gain insights into the specific challenges and benefits of using the artifact in various roles and contexts.

The SSI method implies creating an interview guide, developed based on the framework proposed by Kallio et al., presented in Figure 3.5 [51]. It consists of the following stages:

Stage 1 *Identifying the prerequisites to use a SSI* to assess whether SSI is a suitable data collection method for the research;

Stage 2 *Retrieving and utilizing the previous knowledge* to get a deeper understanding of the topic by conducting a literature review or consulting experts in the field;

Stage 3 *Formulating the preliminary preview guide* which covers the main content of the interview and the possible follow-up questions;

Stage 4 *Pilot testing* to validate the content of the preliminary guide by experts and reformulate the biased or unnecessary questions;

Stage 5 *Presenting the complete interview guide* used for the final data collection.

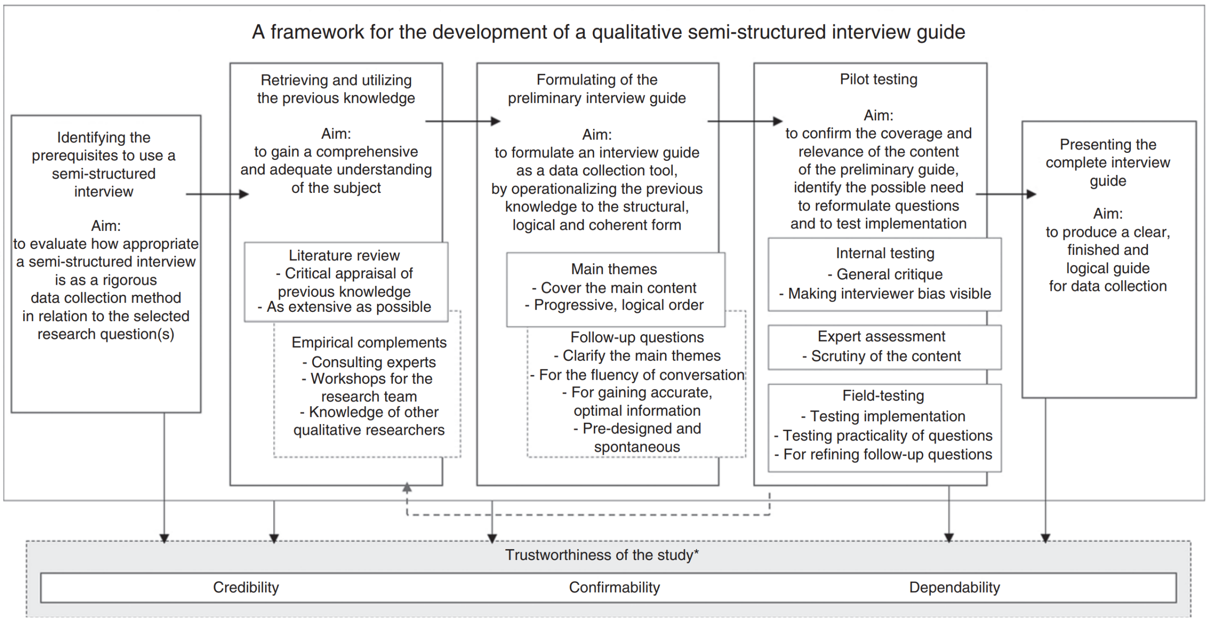


Figure 3.5: The Phases of a SSI Guide Development [51]

3.6.2 Data Analysis

Once the interviews have been conducted and the responses have been gathered, it is necessary to analyze the data to evaluate the effectiveness and usability of the designed artifact. Since all participants were asked the same set of questions in a specific order, a systematic comparison of their responses can be carried out to provide an objective and clear analysis of the results [59].

The data collected from the interviews can be analyzed using an analysis technique called *content analysis*. The objective of content analysis is to organize and condense the informational content of the collected data. This is achieved by categorizing the data by item and identifying common characteristics among the responses [59].

According to McIntosh and Morse, the analysis involves the following steps [59]:

Step 1 *Data preparation*, which involves transcription of audio recorded during the interview to text for further analysis;

Step 2 *Analysis conduction*, which involves reading all interviewees' responses to the same question and highlighting important phrases and words, and then sorting the data into broad categories based on similar characteristics, which are later subdivided into smaller categories;

Step 3 *Data transformation*, which involves presenting responses as percentages, frequencies, or non-parametric statistics to identify patterns.

3.7 Communication

The sixth stage of DSRM for this research project will be demonstrated by disseminating the thesis on a publicly accessible platform. To ensure wide accessibility and visibility, the thesis will be uploaded to the University of Twente repository [85].

The University of Twente repository is a central hub for sharing scholarly works and research outputs, providing a platform for spreading knowledge and fostering collaboration. The repository follows open-access principles, allowing anyone with internet access to freely download and utilize the thesis. This ensures that the research findings, insights, and recommendations will be accessible to a global audience, including researchers, academics, and practitioners interested in integrated carbon and financial reporting.

3.8 Summary

The research process adopted in this research project is grounded in the application of DSRM as the guiding framework with a *Problem-Centered Initiation* entry point [66]. In summary, the research stages based on DSRM will be executed as follows:

1. *Problem identification and motivation* stage was demonstrated in the Chapter 1 by formulating the problem statement in Section 1.2.1 and explaining the research relevance in Section 1.2.5;
2. *Defining the objectives for a solution* stage was also addressed in Chapter 1 by formulating research objectives in Section 1.2.2 and research questions in Section 1.2.4 and describing the scope in Section 1.2.3;
3. *Design and development* stage will be executed by designing the artifact - the reference architecture for integrated carbon and financial reporting using ArchiMate and TOGAF frameworks [42, 43];
4. *Demonstration* stage will be shown by producing an example XBRL integrated carbon and financial report in the form of a case study with Shell;
5. *Evaluation* stage will be conducted by having semi-structured interviews with experts in the field through a constructed questionnaire based on the UTAUT and then analyzing the results to evaluate the usefulness of the designed artifact [89];
6. *Communication* stage will be demonstrated by uploading the thesis to the University of Twente repository for public access [85].

The DSRM adapted for this research is shown in Figure 3.6.

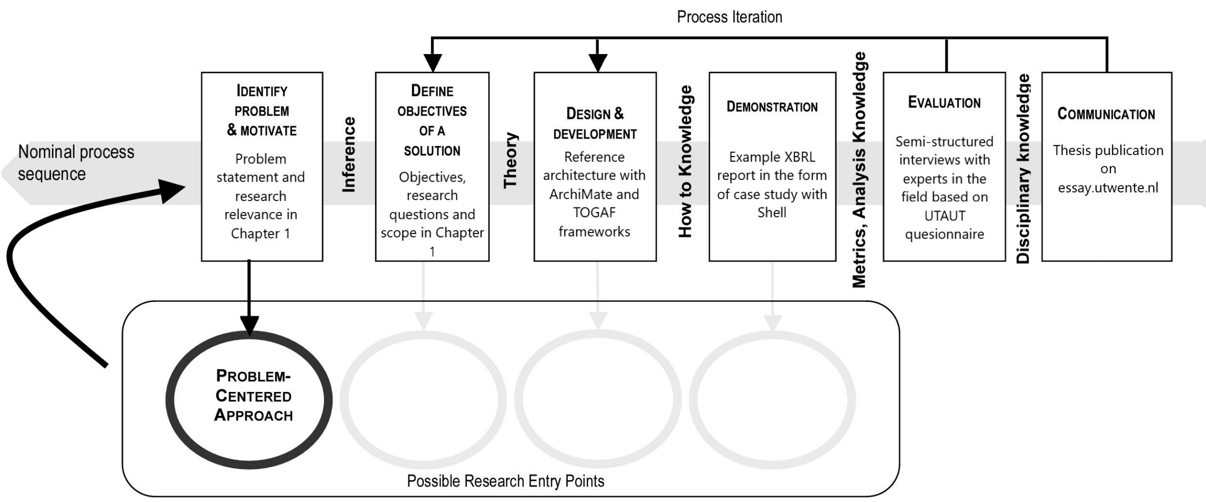


Figure 3.6: The Research Stages of the Present Research Project Mapped to DSRM Process

4 DESIGN AND DEVELOPMENT

This chapter describes the artifact design part of the research. The design process follows TOGAF ADM to ensure the process is thorough and considers all necessary aspects of the integrated carbon and financial reporting system. It aims to answer the **RQ3** and the related sub-questions:

- *How can a reference architecture be designed to facilitate the integration of carbon and financial reporting?*
  - What essential capabilities should an integrated carbon and financial reporting system possess?
  - Which business processes should be depicted in the reference architecture?
  - How can the interactions between the different applications within an integrated carbon and financial reporting system be designed?
  - What data should be included in the reference architecture to ensure comprehensive reporting and compliance with regulatory requirements and XBRL standards?

Section 4.1 describes the Preliminary phase of TOGAF ADM. It includes the definition of the scope of the impacted organizations, used governance and support frameworks, and the explanation of the adjustment of TOGAF framework.

Section 4.2 depicts Phase A of the framework and identifies stakeholders and their concerns, business goals, drivers and constraints, and the scope of the system. The Business Capability Map is also built, and the architecture value propositions and KPIs are mentioned along with the risk assessment of the designed architecture.

Section 4.3 presents Phase B of the framework. It is focused on the Business Architecture design, explaining the chosen viewpoints, their representation, and the gap analysis.

The Information Systems Architecture (Phase C) is divided into Section 4.4, dedicated to the application architecture, and Section 4.5, dedicated to the data architecture of the system, with the corresponding viewpoints and the gap analysis. In addition, the Requirements Management phase was constantly followed by conducting gap analysis for each phase and getting feedback from the stakeholders in Chapter 6.

Finally, Section 4.6 presents the overall model of the reference architecture and summarises the answers to the stated research questions. All models in enlarged sizes can be found in Appendix B.

4.1 Preliminary Phase

This section builds upon the Preliminary phase of TOGAF ADM, which serves as a foundation for the subsequent stages of the architecture modeling process.

4.1.1 Scope of Impacted Organizations

Core enterprises that are most affected by the implementation of integrated carbon and financial reporting system are European oil and gas companies such as Shell and BP. These companies and their products are significant emitters of greenhouse gases and will need to disclose more detailed information about their carbon footprint, emissions reduction targets, and the actions they are taking to transition to a low-carbon economy. This shift towards greater transparency aligns with growing investor and public pressure for companies to address the risks associated with climate change and take action to mitigate their impact.

Soft enterprises affected by the implementation of the integrated reporting system would be companies that are suppliers for oil and gas companies. These companies offer various goods and services to the oil and gas industry, including equipment, logistics, and transportation services. In light of the evolving reporting requirements for carbon emissions, these companies may need to adjust their business models and strategies to ensure alignment with the new standards.

Extended enterprises affected by the change in the reporting structure would be accounting firms that perform checks of the produced reports before publishing, such as Deloitte and PwC. These firms will need to adapt to new reporting standards and guidelines and ensure that their auditing processes are aligned with the integrated reporting system. This will require investment in new tools, training programs, and data management systems to meet the growing demand for accurate and reliable carbon data.

Additionally, *communities* like environmental groups would be affected by implementing such a system. These groups have been actively promoting greater transparency and accountability in corporate reporting. With access to this new data, they can hold companies accountable for their environmental impact. The availability of more detailed and reliable information on carbon emissions and reduction efforts could also help inform public policy and drive collective action to address climate change.

Finally, the *governance* involved in the architecture includes the organizations responsible for publishing regulations in the field of carbon reporting in the EU and worldwide. Examples of such organizations are EFRAG and ISSB. These organizations will need to work closely with industry stakeholders, regulators, and investors to develop common reporting standards and guidelines consistent with global frameworks such as TCFD [13]. This will require ongoing collaboration, feedback, and review processes to ensure that the reporting system remains relevant, reliable, and transparent over time.

4.1.2 Governance & Support Frameworks

The architecture is built on multiple frameworks to ensure coherence, consistency, and completeness. These frameworks provide a structured approach to modelling the integrated carbon and financial reporting system, which helps to reduce the project's complexity and improve its quality and effectiveness.

In particular, the TOGAF ADM provides a clear and well-defined process for developing the architecture, a critical component of the overall system [43]. This process helps to ensure that the architecture is aligned with business goals and objectives and is designed to meet the needs of different stakeholders.

The ArchiMate Full Framework is used to design the models reflecting the reference architecture [42]. The framework provides a set of concepts and notations used to model the different aspects of the architecture, such as business processes and application infrastructure. This enables to create clear and concise models that are easy to understand and communicate to different stakeholders.

Governance frameworks are also critical architecture components, as they provide the regulatory and policy context for carbon reporting in the EU. The TCFD, SASB, and GHG Protocol are some of the key governance frameworks that are considered when modelling the data architecture [10, 13, 70]. These frameworks provide the reporting standards, guidelines, and best practices for carbon reporting, which helps ensure data consistency and comparability across different companies in the industry. The XBRL taxonomy is also considered in the data architecture, as it provides a standard language for financial reporting that can be easily integrated with other reporting standards and frameworks.

Finally, *internal company frameworks* are considered when modelling the architecture, in this case, Shell. They provide the specific context and requirements for the company's operations to ensure that the architecture is integrated with the company's existing systems and processes and is designed to meet the specific needs of its stakeholders.

4.1.3 TOGAF Framework Adjustment

When designing the architecture for the integrated carbon and financial reporting system, only several stages of the framework were considered, in this case, the Preliminary Stage, Architecture Vision, Business Architecture, Information Systems Architecture, and Requirements Management.

Specifically, the Preliminary stage was included to ensure that the overall impact and used governance and support frameworks were defined and understood. The Architecture Vision stage was necessary to create a high-level description of the integrated carbon and financial reporting system, including its stakeholders and their concerns, purpose, scope, key capabilities and risks. The Business Architecture stage was important to understand the business processes and roles that need to be supported by the system. The Information Systems Architecture stage was necessary to design the technical components of the system, such as data structures, applications, and infrastructure. Finally, Requirements Management was included to ensure that the system meets the needs and expectations of the stakeholders.

Additionally, not every step was chosen for each stage based on the project's scope. For example, the step of defining the EA team and organization was left out of the Preliminary stage. This was because the architecture was designed as a research project with no budget, as opposed to an actual project within an organization with an allocated budget. In this case, the author took on the architect role, and there was no need to define a separate EA team and organization. However, in a real-world scenario, this step would be essential to ensure that the architecture is aligned with the organization's strategic goals and objectives and has the necessary resources and support to succeed.

4.2 Architecture Vision

The following sections describe the Architecture Vision stage of the TOGAF ADM, which serves as a crucial step in defining the strategic direction and goals of the built architecture.

4.2.1 Stakeholders and Their Concerns

For the purpose of stakeholder analysis in this thesis, the stakeholders mapping technique of Newcombe was used [64]. The stakeholders for the integrated carbon and financial reporting system for oil and gas companies in the EU can be categorized into *internal* and *external* stakeholders. Internal stakeholders are those who operate within the organization where the system is implemented, whereas external stakeholders are those who operate outside of the organization.

The architecture of the integrated carbon and financial reporting system for oil and gas companies may impact multiple categories of internal stakeholders, each with distinct concerns:

- *Top managers and the board of directors* would be concerned with the system's alignment with the company's strategic objectives, risk management, and accountability to shareholders.
- *Sustainability departments* would be concerned that the system provides reliable and accurate data on carbon emissions and aligns with the company's sustainability goals.
- *Financial departments* would be concerned that the system provides accurate and transparent financial data to meet relevant accounting standards.
- *Governance departments* would be concerned that the system complies with legal requirements in the carbon and financial reporting field.

Similar to internal stakeholders, the implementation of the integrated carbon and financial reporting system for oil and gas companies in the EU may also impact multiple categories of external stakeholders, each with unique concerns:

- *Investors*, both retail and institutional, are the stakeholder group that would be affected by the implementation of an integrated reporting system. They would need to understand the financial implications of carbon emissions associated with their investments and the alignment of the company's sustainability goals with their investment strategies.
- *Consumers* could also be considered stakeholders in this case, as they may be more likely to support companies taking action to mitigate their environmental impact. This could affect the demand for oil and gas products, as consumers may prefer products with a lower carbon footprint.
- *Suppliers* could be required to disclose their own carbon emissions and sustainability practices as part of their relationship with oil and gas companies to meet reporting requirements.
- *Accounting firms* are affected stakeholders as they need to adapt their standards to check the updated format of reports submitted by the companies.
- *Environmental groups and organisations* would be concerned that the reporting system provides accurate and transparent data on carbon emissions and that the oil and gas companies are taking practical steps to reduce their environmental impact.
- *Government organisations* that regulate carbon reporting would be concerned that the reporting system complies with regulatory requirements and effectively addresses climate change and environmental risks.

After analysing the stakeholders and their concerns, they should be placed on the stakeholder map to see the needed type of relationship with each category. For this, the power/interest matrix is built to reflect the power stakeholders hold concerning their level of interest in the project [64].

Stakeholders with little interest and power require minimal effort in communication. In contrast, stakeholders with high interest and little power will need to be constantly fully informed on the project's status. The stakeholders with high power and low level of interest are often the hardest to manage, leading to the constant need for their satisfaction, while the stakeholders with high power and high interest are the key players on which the project's future relies the most [64]. The adapted stakeholder matrix is shown in Figure 4.1.

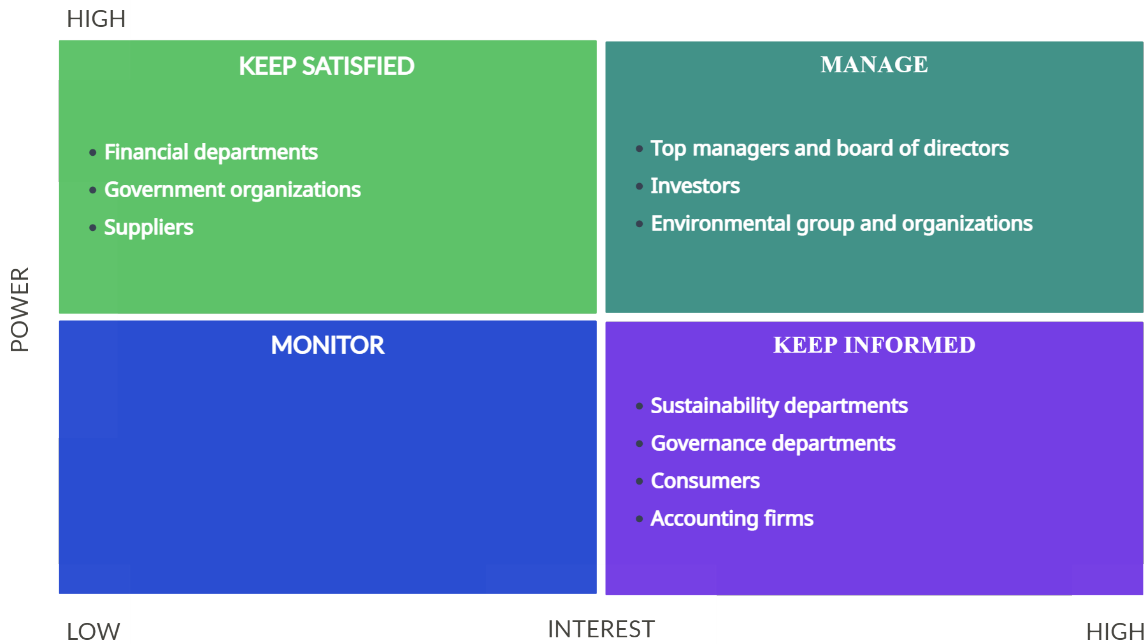


Figure 4.1: The Stakeholder Matrix

As can be seen, top managers and board of directors, investors, and environmental groups and organizations are the highest priority stakeholders that must be managed first. Then, the satisfaction of the financial departments, government organizations, and suppliers needs to be ensured along with the informing of sustainability and governance departments, consumers, and accounting firms.

4.2.2 Business Goals, Drivers and Constraints

An integrated carbon and financial reporting system for oil and gas companies in the EU is driven by various factors and aims to achieve several objectives, presented below. However, the development and implementation of such a system have certain constraints, which are also examined in this section.

First, the *business goals* of the designed architecture were identified that included the following:

- Meet the increasing demand for transparency and disclosure of carbon emissions and their financial implications by investors, regulators, and other stakeholders;
- Enhance the company's reputation and stakeholder trust by demonstrating a commitment to sustainability and carbon neutrality;
- Facilitating access to capital by providing investors with high-quality, comparable, and reliable environmental data;
- Supporting informed decision-making by providing management with a more comprehensive and integrated understanding of the company's risks and opportunities;
- Improve risk management by identifying and mitigating financial risks associated with carbon emissions;
- Optimize operations and reduce costs by identifying opportunities to improve energy efficiency and reduce emissions;
- Stay competitive in a rapidly changing energy landscape by adapting to new regulatory and market conditions.

Next, the *drivers* of such a system were summarised below:

- The Paris Agreement and the EU Green Deal, which set ambitious targets to reduce greenhouse gas emissions and promote sustainable economic growth [17, 62];
- The increasing pressure from existing investors, shareholders, and other stakeholders to disclose environmental information;
- The growing trend of sustainable investing, where investors seek companies with strong environmental performance;
- The increasing availability of data and technology to measure and track carbon emissions and financial performance;
- Increasing regulatory pressure and the emergence of international standards and frameworks for carbon reporting, such as ESRS and IFRS [41, 81], aimed at reducing carbon emissions and promoting sustainable practices;
- Growing consumer demand for sustainable products and services;
- Heightened awareness of climate change's physical and financial risks, such as extreme weather events, rising sea levels, and stranded assets;
- The potential for cost savings and operational efficiencies through more effective management of carbon emissions and resource consumption;
- The need to remain competitive in a rapidly evolving energy landscape, as technological advances and changing consumer preferences create new opportunities and challenges.

Finally, the *constraints* of the system are overviewed below:

- The cost of implementing integrated carbon and financial reporting systems may require significant investments in staff learning, data collection, analytics, and reporting infrastructure;

- The complexity of measuring and reporting carbon emissions and financial performance may require specialized expertise and resources;
- The potential impact on the company's financial performance and valuation, as investors may penalize companies with high carbon emissions;
- The regulatory uncertainty and potential for conflicting regulations across different jurisdictions;
- The need for collaboration and alignment with other stakeholders, including suppliers and other companies in the industry;
- The potential for reputational damage if a disconnect between stated goals and actual performance exists;
- The need to balance short-term financial performance with longer-term sustainability goals may require significant investment in new technologies and business models;
- The challenge of managing the risks associated with carbon-intensive assets and operations, such as the potential for stranded assets or the risk of carbon pricing.

4.2.3 Business Capability Map

A *business capability* describes a company's functional ability to perform a particular activity [11]. A *Business Capability Map (BCM)* is a structured depiction of business capabilities within a company, arranged in a specific order [4]. It facilitates communication between business and IT stakeholders by clarifying how IT outcomes align with business objectives. BCM offers a more detailed perspective on the business than strategic guidelines alone, which enables better strategic decision-making [11].

The process of designing the business capability map consisted of the following steps:

Step 1 Define a list of currently existing domains and sub-domains;

Step 2 Come up with the corresponding capabilities for each domain and sub-domain;

Step 3 Model the capability maps for the found capabilities using the Strategy layer elements of ArchiMate;

Step 4 Expand the existing capabilities with the new ones coming from the implementation of the system;

Step 5 Model the final capability map using the Strategy layer elements of ArchiMate.

The capabilities list was obtained from the literature and interviews with the experts.

First, two big domains were identified based on the existing reporting processes in oil and gas companies, which the system aims to integrate - *Financial Reporting* and *Carbon Reporting*. Each domain was then divided into smaller sub-domains.

For Financial Reporting domain, the following sub-domains were identified:

- Financial Reporting and Disclosure Management;
- Financial Data Collection and Validation;
- Financial Data Tracking.

For Carbon Reporting domain, the sub-domains were identified as follows:

- Carbon Reporting and Disclosure Management;
- Carbon Footprint Data Collection and Validation;
- Carbon Footprint Tracking.

Next, the list of the capabilities was produced for each of the sub-domains. For the Financial Reporting domain, the following capabilities corresponded to the sub-domains:

- Financial Reporting and Disclosure Management;
  - Development of financial report for investors and shareholders;
  - Development of financial report for stakeholders;
  - Disclosure on financial performance for regulatory reporting;
  - Development of financial report for internal decision making.
- Financial Data Collection and Validation;
  - Financial data collection;
  - Financial data validation;
- Financial Data Tracking;
  - Ability to handle ledger for different types of financial data;
  - Generation of aggregated/filtered views of financial data;
  - Full audit trail of financial data;
  - Storage of financial data;
  - Provision of auditable trusted secure financial records;
  - Access to financial data based on ownership and entitlements.

Similarly, the capabilities were introduced for each of the Carbon Reporting sub-domains:

- Carbon Reporting and Disclosure Management;
  - Development of carbon emissions report for external stakeholders (for instance, investors);
  - Delivery of carbon dashboards and reports for internal decision-making;
  - Disclosure on carbon performance for regulatory and voluntary reporting;
- Carbon Footprint Data Collection and Validation;
  - Carbon footprint data collection;
  - Carbon footprint data validation;
- Carbon Footprint Tracking;
  - Ability to handle ledger for different types of carbon footprint data;
  - Full audit trail of carbon footprint data;
  - Provision of auditable trusted secure carbon records;
  - Generation of aggregated/filtered views of carbon footprint data;

- Storage of carbon footprint data;
- Access to carbon footprint databased on ownership and entitlements.

Then, the BCM were modelled for each domain to visualise the existing capabilities. BCM for the Financial Reporting Domain can be found in Figure 4.2, and for the Carbon Reporting Domain in Figure 4.3.

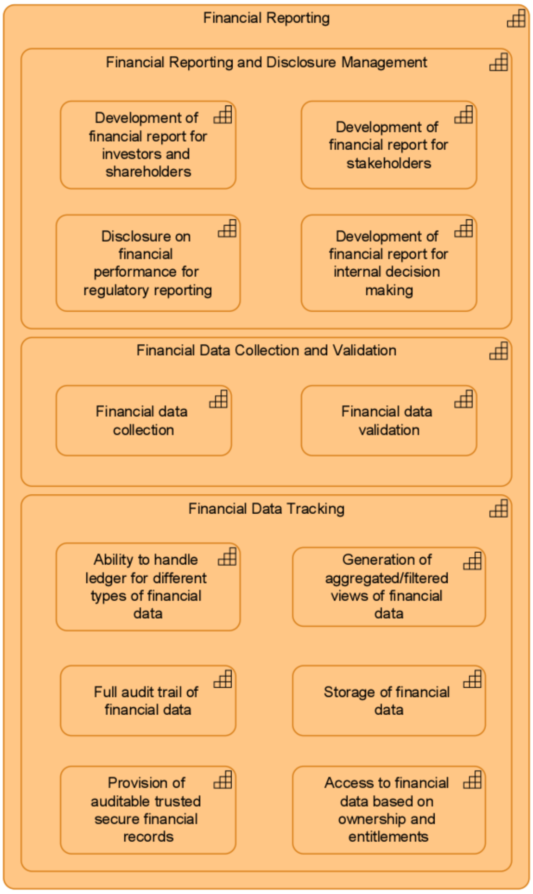


Figure 4.2: Business Capability Map for Financial Reporting

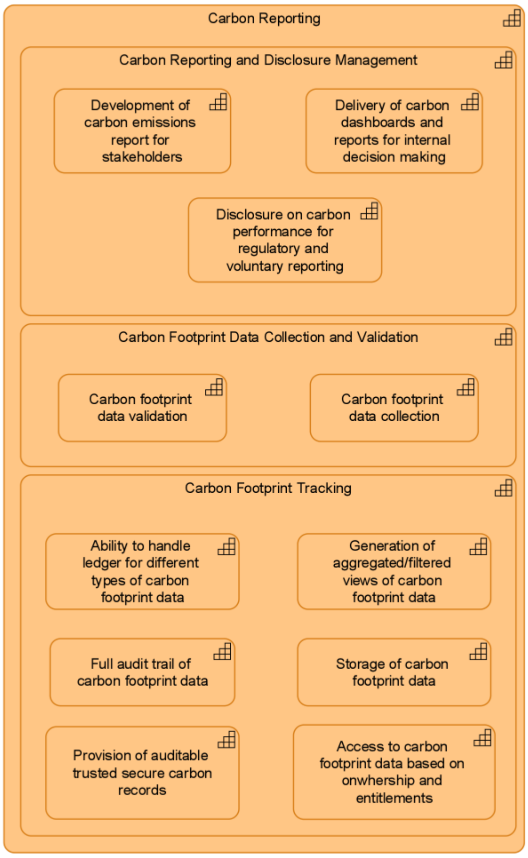


Figure 4.3: Business Capability Map for Carbon Reporting

The target architecture would need to include both domains and their capabilities, combined into the general *Integrated Reporting* domain. This domain also introduced two new capabilities, which included the consolidation of financial and carbon footprint data and the generation of integrated carbon and financial XBRL report. Then, the target BCM was modelled, reflected in Figure 4.4.

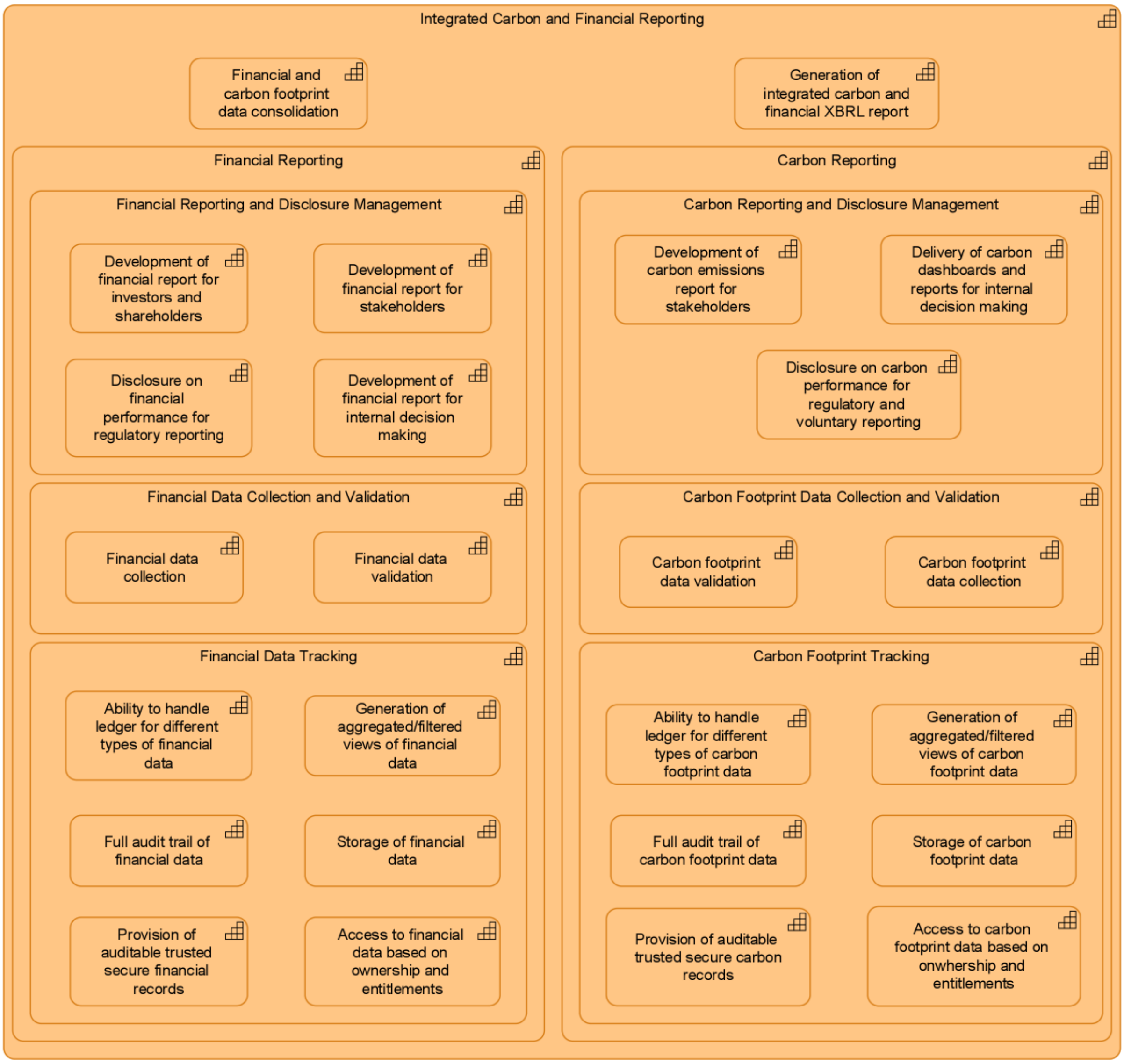


Figure 4.4: Target Business Capability Map

Figure 4.5 reflects the changes and improvements needed to be made to the existing capabilities, including creating the new united domain and the corresponding capabilities.

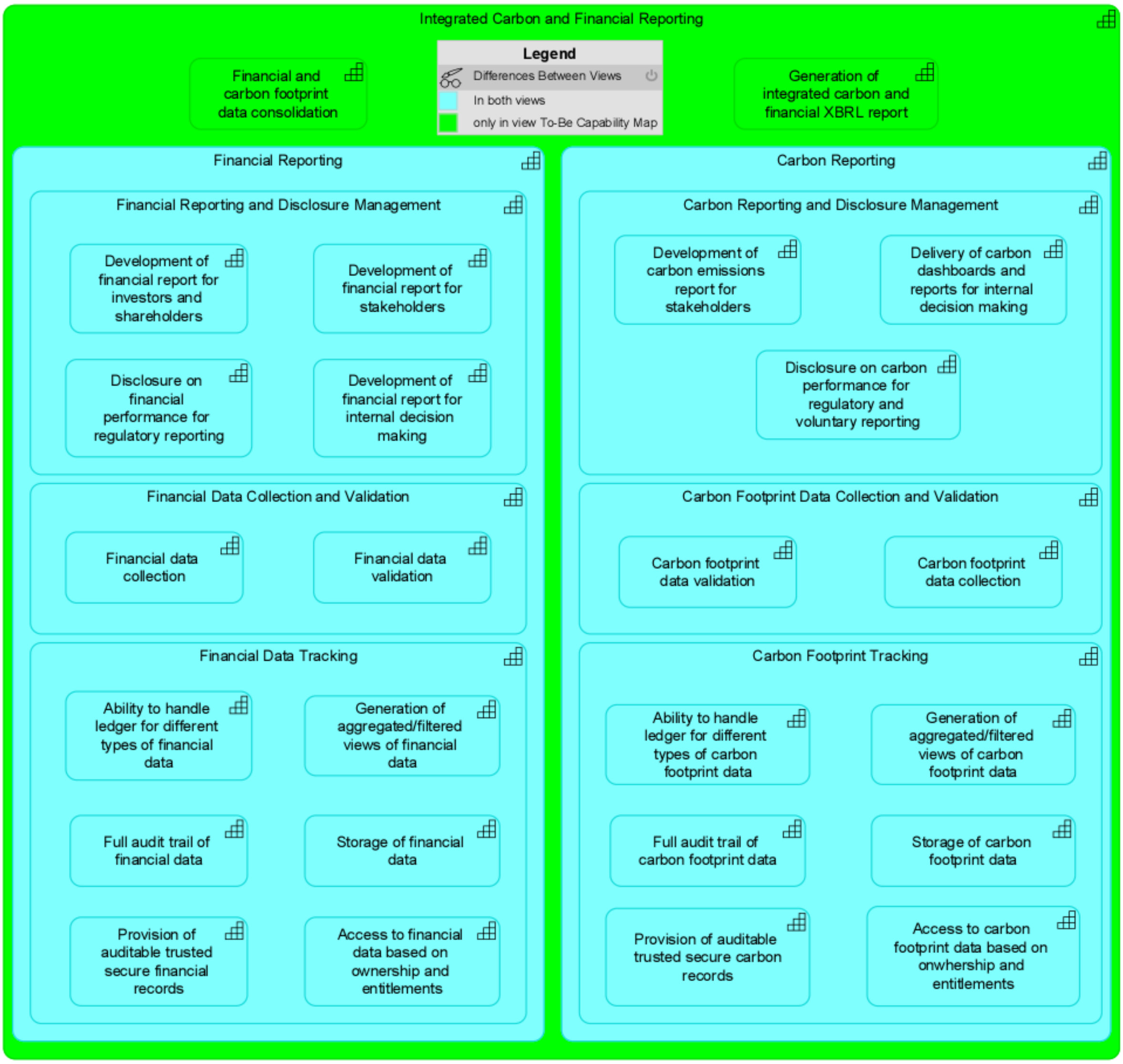


Figure 4.5: Changes Between Baseline and Target Business Capability Map

4.2.4 Architecture Scope

An integrated carbon and financial reporting system would involve reporting on both the financial performance and carbon emissions. The scope of such a system would be broad, encompassing various aspects of the companies' operations and environmental impact.

The system's primary component would be carbon reporting to ensure possible mapping with the financial component. The system reports only Scope 1 and 2 emissions as stated in GHG protocol since Scope 3 emissions are hard to map with financial metrics. Additionally, only carbon dioxide emissions are reported. Regarding the reported financial information, only the metrics that could be mapped with carbon emissions are reported in the system.

The system should allow data collection and integration from multiple sources since the financial and carbon data is stored in various systems. The system should also consider that the company has multiple assets that can report data differently. Moreover, compliance with the related carbon and financial reporting regulations within EU and adherence to a certain XBRL taxonomy should be ensured.

4.2.5 Architecture Value Propositions and KPIs

An integrated carbon and financial reporting system for oil and gas companies in the EU offers a range of value propositions, which can be measured through various KPIs. The value propositions of the designed architecture are presented below:

- *Improved transparency*: An integrated system would enable oil and gas companies to provide more transparent information on their carbon emissions and their financial implications to stakeholders;
- *Investor confidence*: An integrated carbon and financial reporting system can give investors a more comprehensive understanding of a company's risks and opportunities related to climate change, leading to increased investor confidence;
- *Cost-effectiveness*: An integrated financial and carbon reporting system could help companies identify opportunities to reduce carbon emissions, resulting in cost savings and operational efficiencies;
- *Regulations compliance*: An integrated system can help companies ensure compliance with demanding regulations related to carbon emissions;
- *Risk mitigation*: By integrating carbon and financial reporting, companies can more effectively identify and manage financial and reputational risks associated with carbon emissions;
- *Competitive advantage*: Companies that are able to demonstrate a strong commitment to reducing their carbon emissions may gain a competitive advantage in the market.

The potential KPIs for the system could include:

- *Carbon emissions reduction*: absolute reductions in emissions, reductions in carbon intensity (the amount of CO_2 emissions produced per unit of output), the cost of carbon emissions to the company, the amount of carbon emissions produced by the company's suppliers, or progress towards meeting specific carbon reduction targets;
- *Financial performance*: revenue, profit margins, return on investment (ROI), or earnings per share (EPS);
- *Reputation*: customer satisfaction, employee engagement, or brand perception;
- *Regulatory compliance*: the number of environmental violations, fines or penalties, or the percentage of assets in compliance with environmental regulations.

4.2.6 Architecture Risk Assessment

Integrating carbon and financial reporting for oil and gas companies in the EU could present various risks. Some possible risks for such a system could include:

1. *Regulatory compliance*: Regulatory compliance failure, resulting in penalties from the government;
2. *Data accuracy*: Inaccuracy or bias of the reported data, resulting in incorrect financial implications;

3. *Implementation*: Disruptions in operations and systems due to the needed changes because of the implementation of the system;

4. *Information security*: Data breaches or system failures affecting the overall value chain of the company;

5. *Reputation*: Changes in public perception after the disclosure of more data, resulting in deterioration in reputation and lower market value;

6. *Market change*: Changes in regulations or market demand for low-carbon energy affecting the financial performance of the company;

7. *Internal changes*: Changes in business processes or/and application infrastructure that would require different approaches to carbon and financial reporting.

Therefore, to minimize the potential negative outcomes associated with each risk, it is important to prioritize them. For this, the methodology by Peixoto et al. was used, which involved identifying the probability and impact of each risk and then placing this information in a matrix for prioritization [67]. The resulting risk matrix is presented in Figure 4.6, where the number corresponds to the position in the overall list of risks.

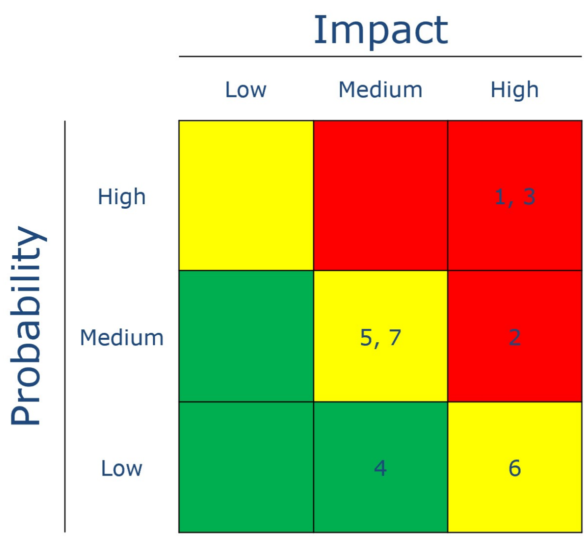


Figure 4.6: Probability-Impact Risk Matrix

The matrix shows that the most important risks with the highest priority are the risks of *regulatory compliance* and *implementation*. Medium priority risks which also need to be constantly monitored are the risks of *reputation*, *market change* and the *internal changes*, while the risk of *information security* has the lowest priority.

Additionally, mitigation activities are needed for each of the identified risks. The overall table of the risks and their mitigation activities is presented in Table 4.1. To ensure compliance with regulations, the integrated reporting approach should be designed to meet all relevant regulatory requirements. Moreover, clear governance structures and procedures should be established to effectively manage compliance. Monitoring regulatory developments and engaging with relevant authorities will help companies stay informed about changes in the regulatory landscape.

Companies can mitigate the risk of data inaccuracies by implementing robust data management processes. This includes conducting regular quality control and validation checks to ensure the accuracy of reported data. Advanced analytics and data science techniques can be utilized to identify and address potential inaccuracies or biases. Providing adequate training and support to the staff responsible for reporting data is crucial for maintaining data accuracy.

To ensure a smooth implementation, companies should develop a detailed plan with clear milestones, timelines, and responsibilities. Effective communication channels should be established to engage stakeholders and manage their expectations throughout the implementation process. Thorough testing and quality assurance should be conducted to identify and address any issues before the system goes live.

Companies can establish a comprehensive information security framework to manage risks related to data and systems. This includes conducting regular vulnerability assessments and testing to identify and address potential security weaknesses. Regular training and awareness programs should be provided to staff to promote data security best practices and ensure a strong security culture within the organization.

Companies can manage reputation risks by developing a comprehensive communication strategy. This strategy should address stakeholder expectations and concerns effectively. Engaging with stakeholders and demonstrating a commitment to sustainability and environmental responsibility will help maintain a positive reputation. Monitoring and responding to social media and online sources will allow companies to identify and address potential reputation risks in a timely manner.

Companies can mitigate risks associated with market changes by conducting regular scenario planning exercises. These exercises will help identify potential risks and opportunities in the market. Diversifying the company's energy portfolio to include more low-carbon energy sources can help companies adapt to evolving market trends.

To address risks associated with internal changes, companies should engage with staff and other stakeholders to ensure their commitment to the potential changes in the system. Establishing clear performance metrics and incentives can help drive the adoption of the new system and ensure smooth internal transitions.

Risk	Priority	Probability	Impact	Mitigating Actions
Regulatory compliance	High	High	High	Proper design of the system, constant regulations monitoring
Data accuracy	High	Medium	Medium	Proper data management, staff training
Implementation	High	High	High	Detailed implementation plan, testing and quality assurance
Information security	Low	Low	Low	Staff training, proper vulnerability assessment
Reputation	Medium	Medium	Medium	Proper communication strategy, social media monitoring
Market change	Medium	Low	High	Scenario planning, portfolio diversification
Internal changes	Medium	Medium	Medium	Stakeholders engagement, transition plan

Table 4.1: Overview of Risks and Mitigating Actions

4.3 Business Architecture

For the business architecture, the following viewpoints were selected:

- The *organisation structure* viewpoint helps to identify the key business roles involved in the system's development and implementation.
- The *business process* viewpoint helps to identify the key activities and workflows involved in the development and implementation of the system.

These particular viewpoints were chosen for the business architecture because they provide a comprehensive understanding of the system's development and implementation from both a structural and process-oriented perspective. The baseline and target architecture was modeled for each viewpoint, and the gap analysis was made.

4.3.1 Organisation Structure Model

The Baseline Organisation Structure model reflects the current state of the reporting process. There are separate *Financial Reporting* and *Carbon Reporting* departments with similar business roles. Each department should have a person who is responsible for collecting data for a report and calculating relevant metrics (*Collector*), building and producing a report (*Reporter*), checking and validating the data in a report (*Approver*), and submitting it (*Submitter*). In addition, there should be an *IT Specialist* responsible for the IT side of the process, such as maintaining the system. The reporting teams work closely with the *Legal Department*, where *Advisors* check the report for complying with all required regulations and then send the final report to the *Executive Committee*, consisting of higher management, shareholders and investors. The Baseline Organization Structure is shown in Figure 4.7.

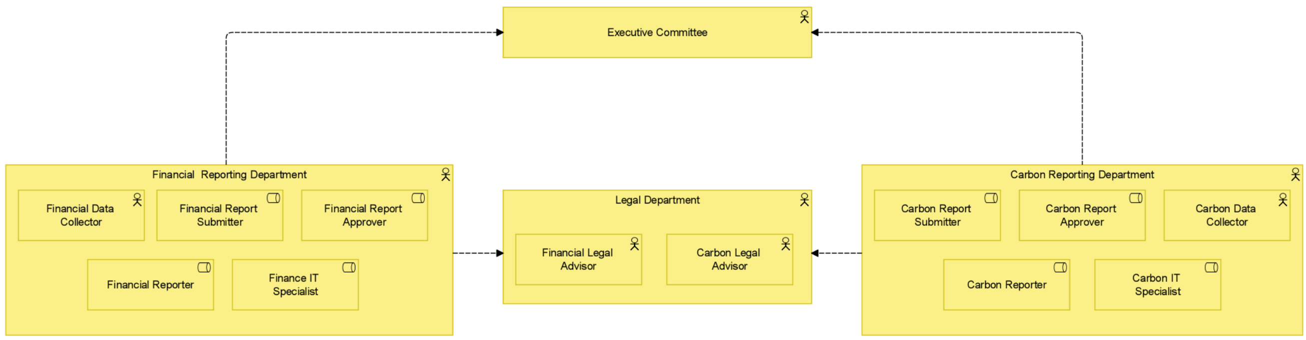


Figure 4.7: Baseline Organisation Structure Model

The Target Organization Structure Model is shown in Figure 4.8. It reflects the creation of the new *Integrated Reporting* department that introduces new business roles. *XBRL Tagger* is responsible for the XBRL tagging of the report after getting all needed data from *Financial Reporting* and *Carbon Reporting* departments, *XBRL Report Approver* then checks the report and validates the data in it to be then submitted by *XBRL Report Submitter*. The new department also works with the *Legal Department* to comply with necessary XBRL-related regulations and sends the final result to the *Executive Committee*.

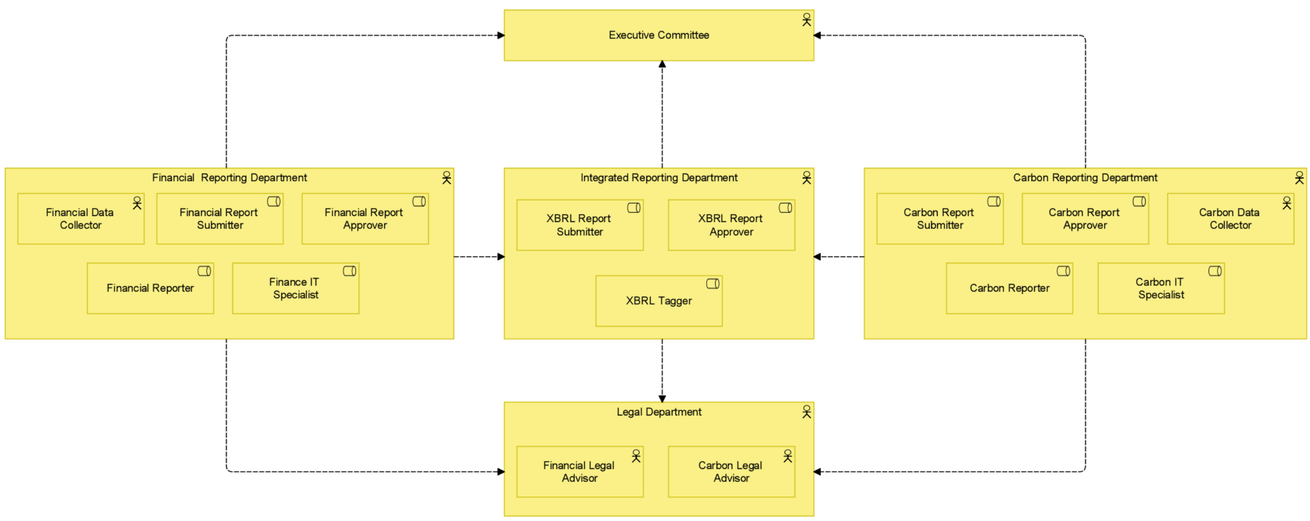


Figure 4.8: Target Organisation Structure Model

Figure 4.9 shows the gaps between the target and the baseline models and reflects the need to create a new department with the corresponding business roles and the connection to the existing departments.

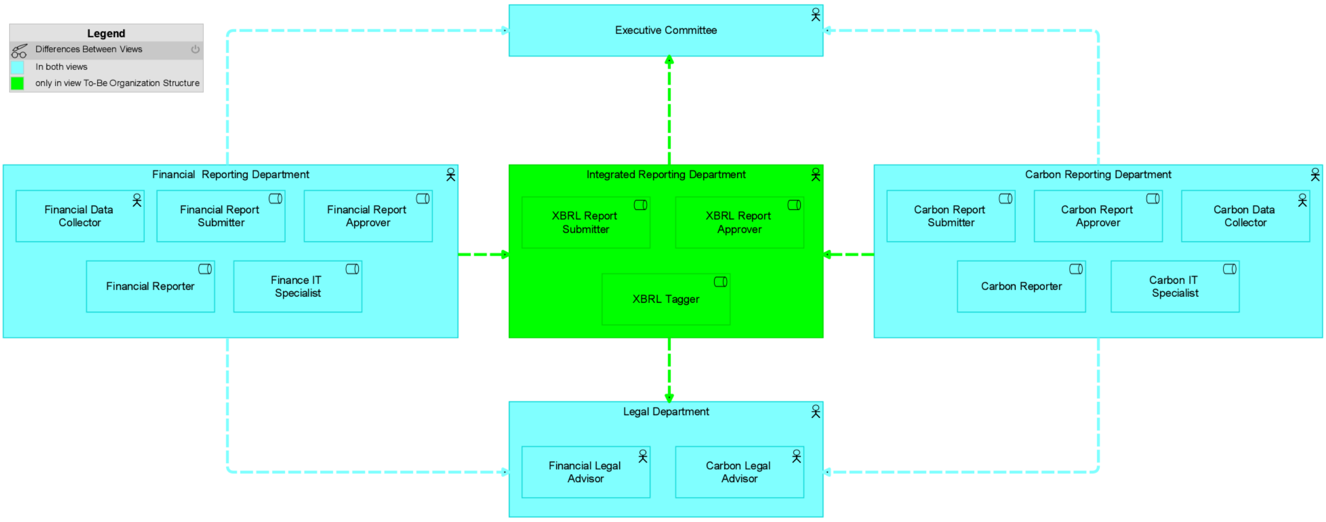


Figure 4.9: Gap Analysis for Organisation Structure Model

4.3.2 Business Process Model

To reflect the baseline architecture, the models showing the *Financial Reporting* and *Carbon Reporting* business process were first designed, which can be seen in Figure 4.10 and 4.11. Each process included similar stages, starting with the opening of the reported period (for example, quarter), collecting the needed data and validating it, calculating relevant metrics, validating the calculated metrics to detect any existing anomalies, and submitting and consolidating the data for further result preparation.

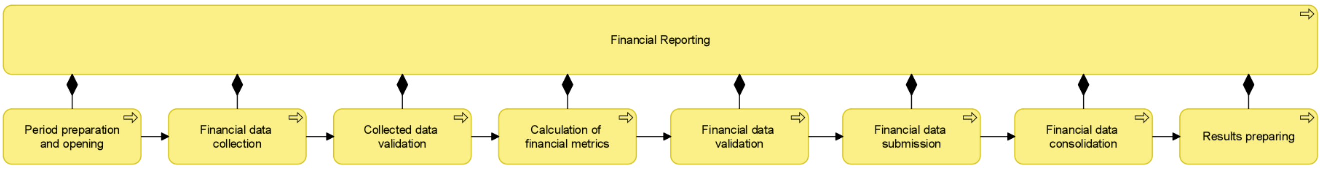


Figure 4.10: Baseline Financial Reporting Business Process Model

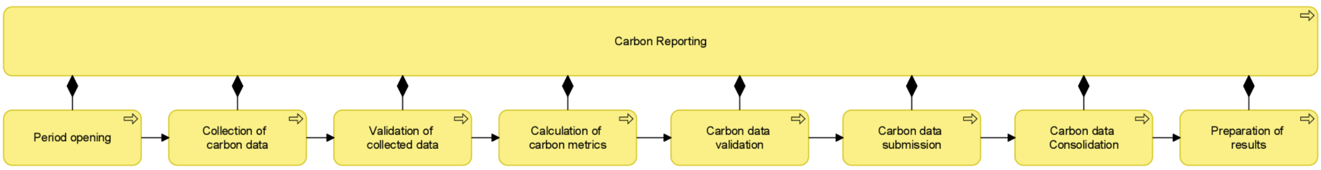


Figure 4.11: Baseline Carbon Reporting Business Process Model

For the target architecture, the flows of previously designed processes were combined into the

Integrated Reporting business process, which included newly added stages, such as consolidation of financial and carbon data, XBRL tagging and producing of an integrated report. This process is reflected in Figure 4.12.

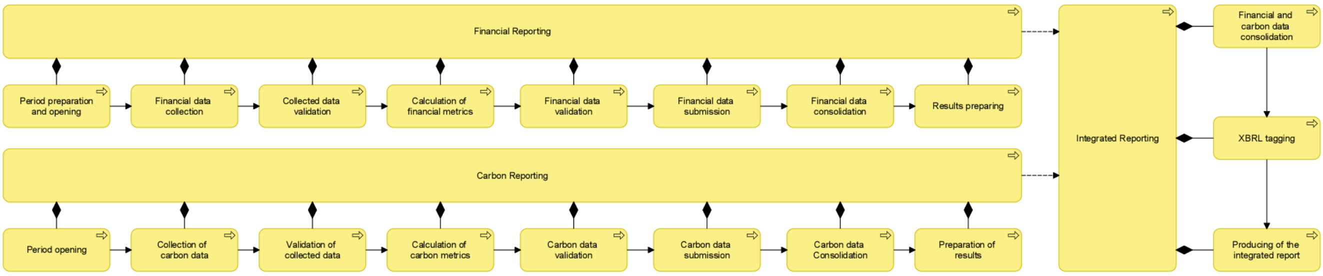


Figure 4.12: Target Business Process Model

Finally, the gap analysis was conducted that showed the new outgoing flows from the existing business processes to the newly added *Integrated Reporting* process and the related subprocesses. The analysis can be found in Figure 4.13.

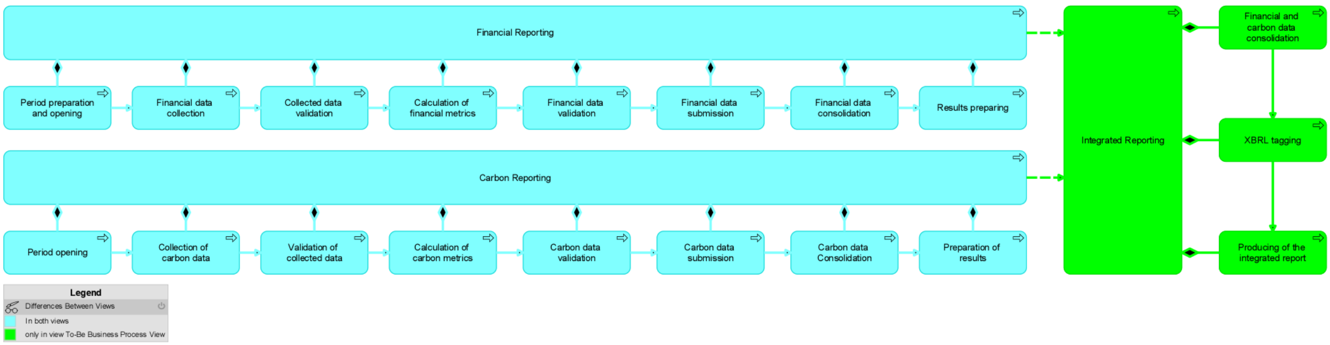


Figure 4.13: Gap Analysis for Business Process Model

4.4 Application Architecture

During the application architecture development, the *application behaviour* viewpoint was chosen to model the baseline and target architecture. This viewpoint was selected because it helps to describe the way different applications interact with each other to perform specific tasks and to reflect the data exchange process.

For the baseline architecture, two separate models reflecting the application interaction were first built for financial and carbon reporting. The application components do not have the exact software names as these vary based on the organisation apart from *Wdesk* and *Wdata*, which are critical for the implementation part of the research.

The *Financial Reporting* application behaviour model is presented in Figure 4.14. A main software consolidates all financial data in the organization called *Consolidated financial information reporting solution*. It receives the data from multiple sources, such as *Data Warehouse Platform*, which stores and manages data, *Enterprise Resource Planning (ERP) Software*, which manages all business processes within an organization, and the *Data Services Platform* which is responsible for the integration and transformation of data.

The consolidated financial data in the form of datasets is then going to the *Collaboration Platform*, which stores and manages the documents, from where it is imported to *Wdesk*. *Wdesk* is a reporting software by Workiva used to create structured reports, including the transformation of the reports in the required format such as XBRL [96]. Additionally, this software is expanded with the *Access Manager*, responsible for user authentication and authorisation, and *Key Manager*, responsible for managing encryption keys for secure data storage. Currently, in *Wdesk* mostly financial reports are produced, some formatted in XBRL.

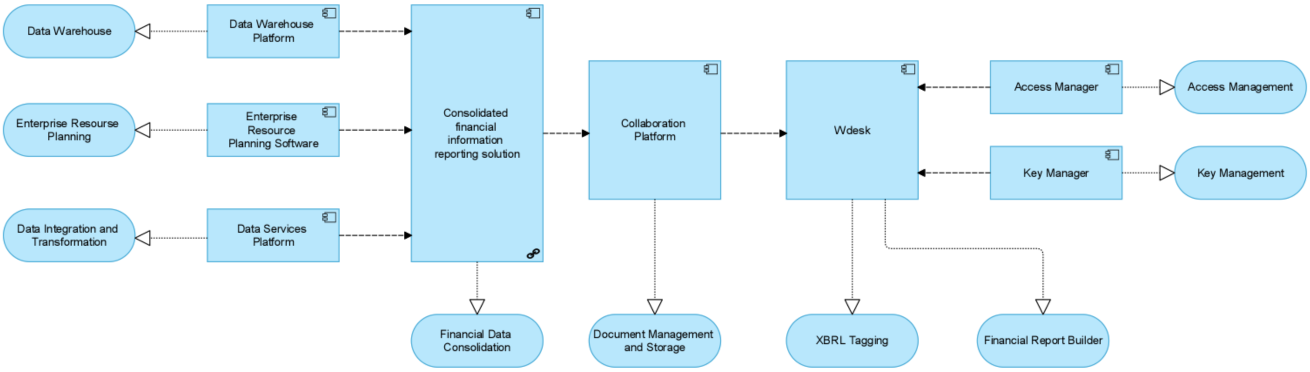


Figure 4.14: Baseline Financial Reporting Application Behaviour Model

Figure 4.15 shows the application behaviour model for *Carbon Reporting*. Similarly, the main application here is *Carbon Report Builder*, which consists of *Carbon Footprint Calculation Component* that is responsible for calculating GHG emissions and *Carbon Reporting Component* that is responsible for building a carbon report. The *Carbon Report Builder* gets data from *Sensor Data Storage Platform* that collects the data from sensors places along all organisation assets. The asset data is also managed in the *Asset Information Management Application*. Additionally, the authentication and authorisation of the users are needed through the *Authentication and Authorisation Application*, and the master data needs to be managed with the *Master Data Management Software*. The produced datasets are stored in the *Data Warehouse*.

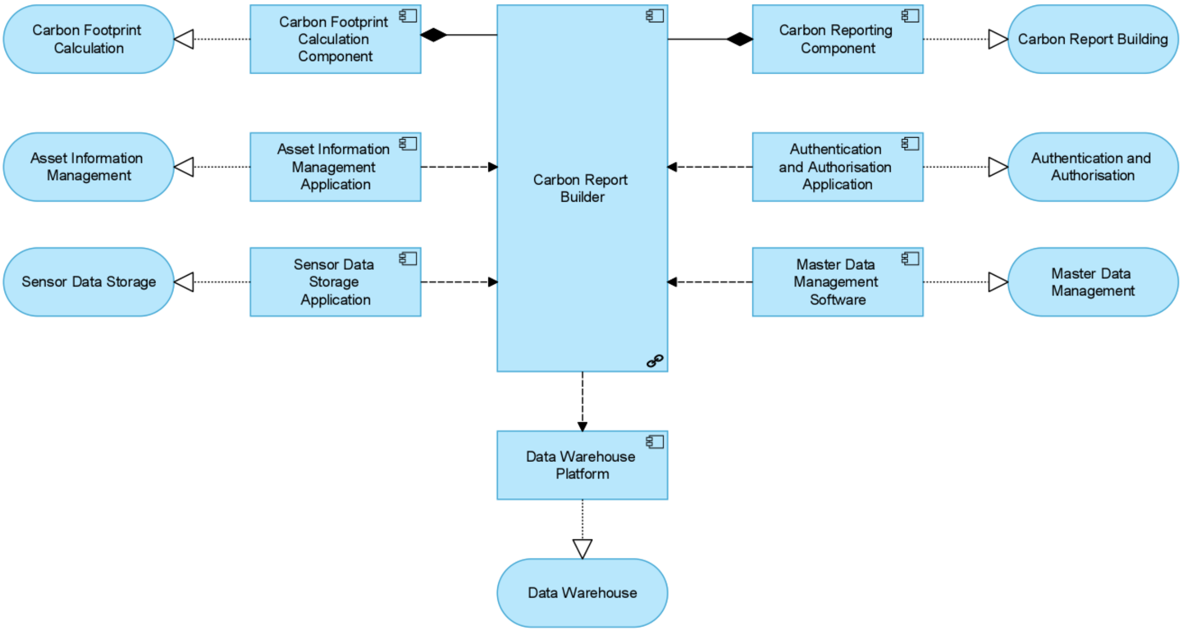


Figure 4.15: Baseline Carbon Reporting Application Behaviour Model

To reflect the overall idea of integrating the two application interaction flows, first, the high-level model was constructed, presented in Figure 4.16. It shows two possible options, first, with gathering both financial data from the *Consolidated financial information reporting solution* and carbon data from *Carbon report builder* in the *Collaboration platform*, from where it goes to *Wdesk*. This option is easier to implement since no extra development work is required, the financial data is already going to the platform, and the carbon data can easily be imported there too.

The second option implies creating an *Application Programming Interface (API) service* which would first serve as an endpoint to collect carbon and financial reporting software data. Then, the data would be sent to *Wdata* with another API endpoint. *Wdata* is another software by Workiva used for connecting and consolidating the data from multiple sources, including API endpoints. The produced dataset would then go to *Wdesk* for the further creation of the report. This option is harder to implement since it requires the development work of creating and defining needed endpoints and setting up the connections between carbon and financial reporting software and *Wdata* and *Wdesk*.

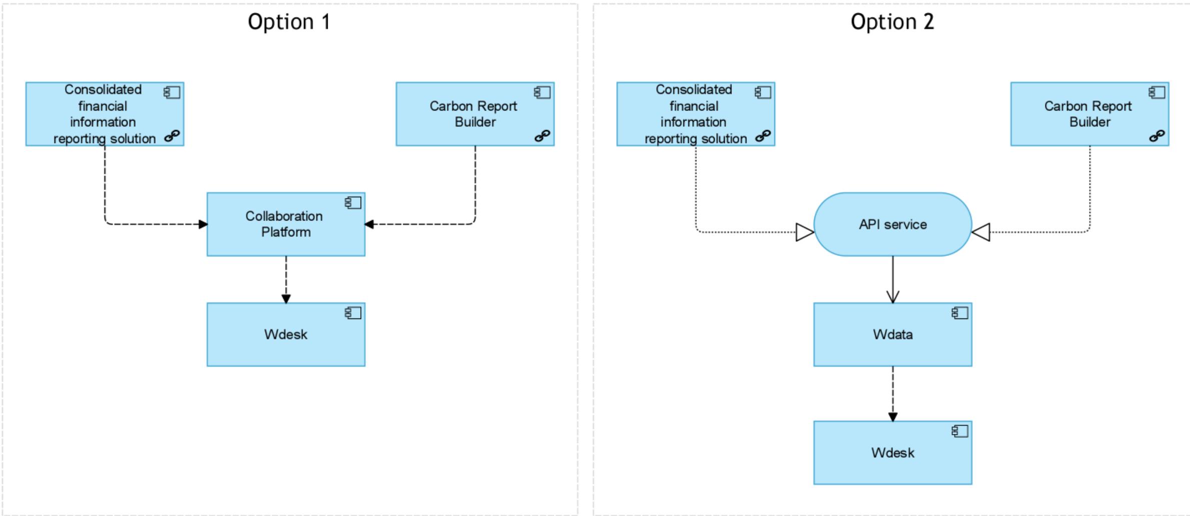


Figure 4.16: Two Options of Target High-Level Application Behaviour Model

Each option was then expanded with all supporting applications for both carbon and financial reporting, shown in Figure 4.17 and 4.18.

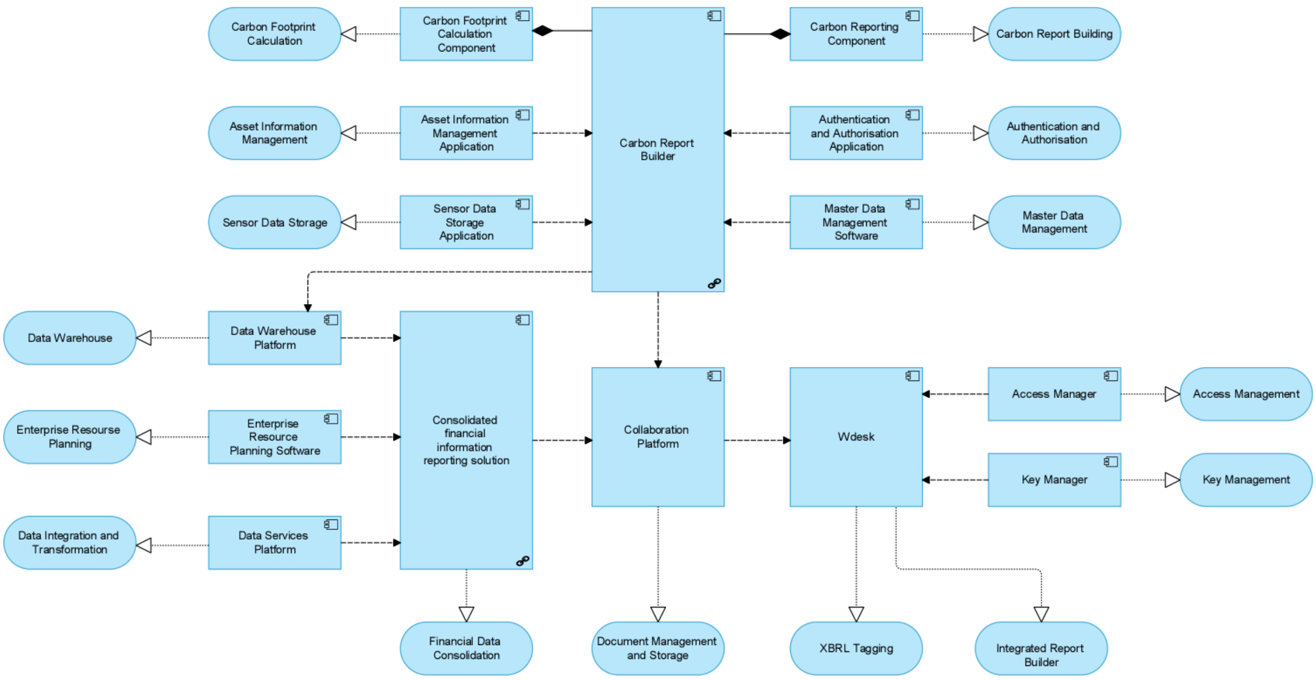


Figure 4.17: Target Application Behaviour Model (Option 1)

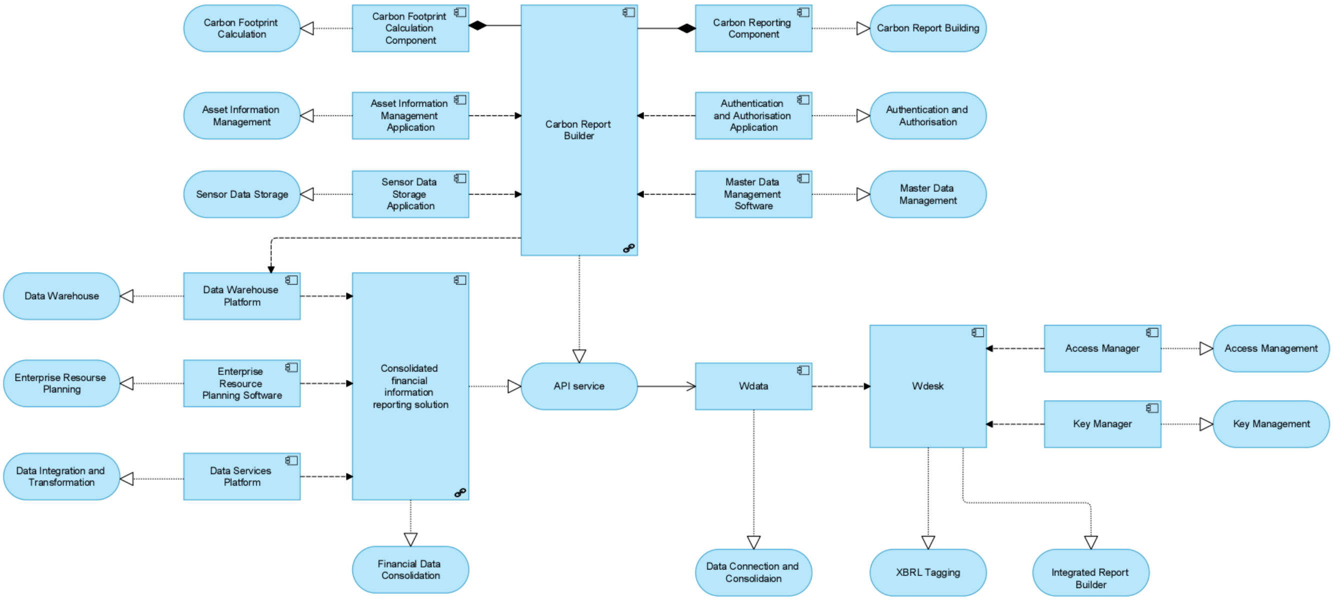


Figure 4.18: Target Application Behaviour Model (Option 2)

Next, the gap analysis was conducted for both high-level and expanded models. The high-level analysis (Figure 4.19) shows the need for transferring the data from the *Carbon Report Builder* to the *Collaboration Platform* for the first option and the need for the development of the API connection between the software and the implementation of *Wdata* for the second option.

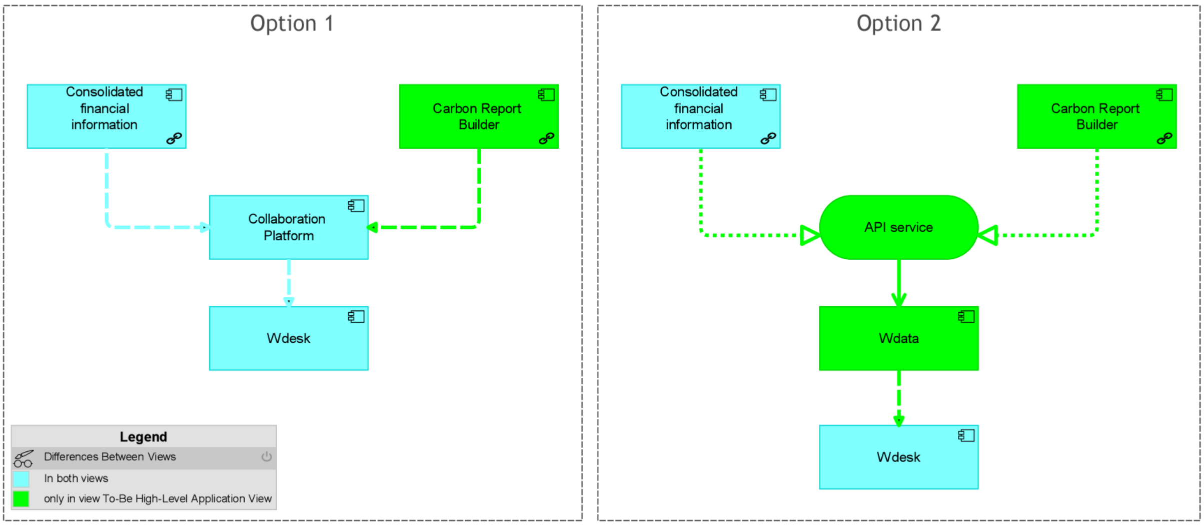


Figure 4.19: High-Level Gap Analysis for Application View

Furthermore, the overall gap analysis for the first option (Figure 4.20) reflects the added connection between the *Carbon Report Builder* and the *Collaboration Platform* as well as the new functionality of *Wdesk* that allows creating integrated reports.

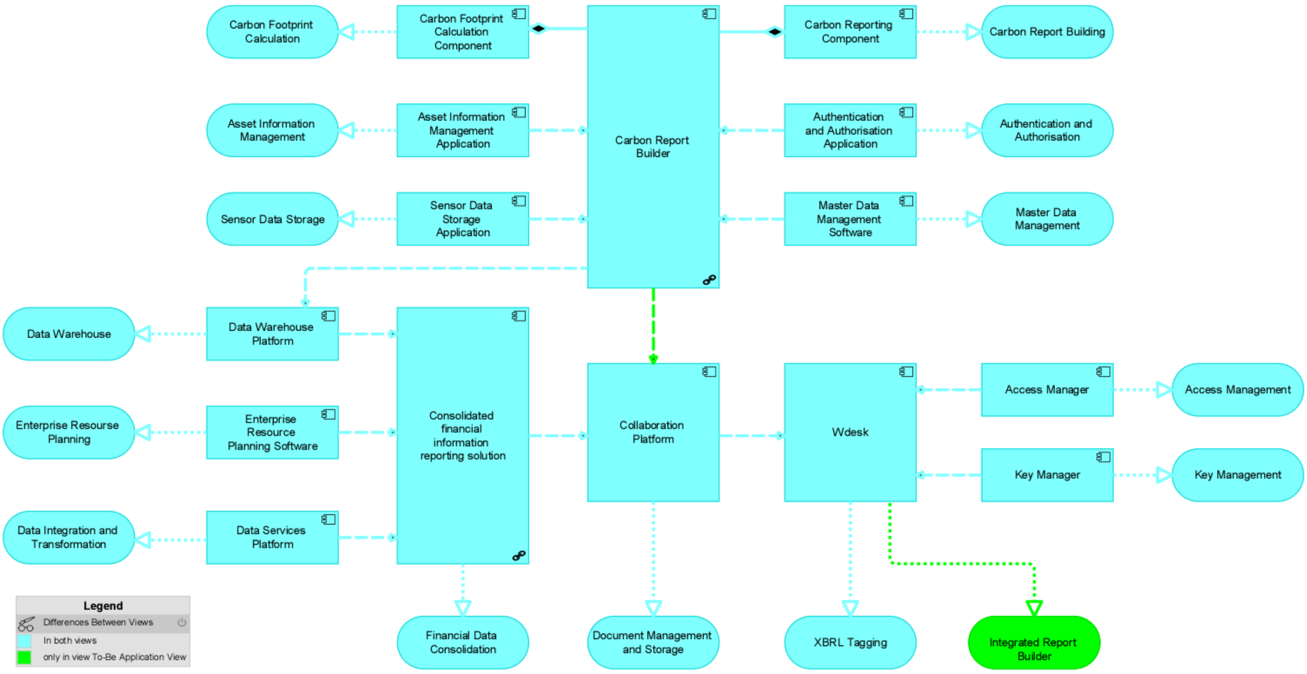


Figure 4.20: Gap Analysis for Application View (Option 1)

Similarly, the second option (Figure 4.21) adds the relation between the *Carbon Report Builder*, *Consolidated financial information reporting solution* and the *API service* which then sends data to the new component *Wdata* that collects and consolidates data before sending it to *Wdesk* with a role of the integrated report builder.

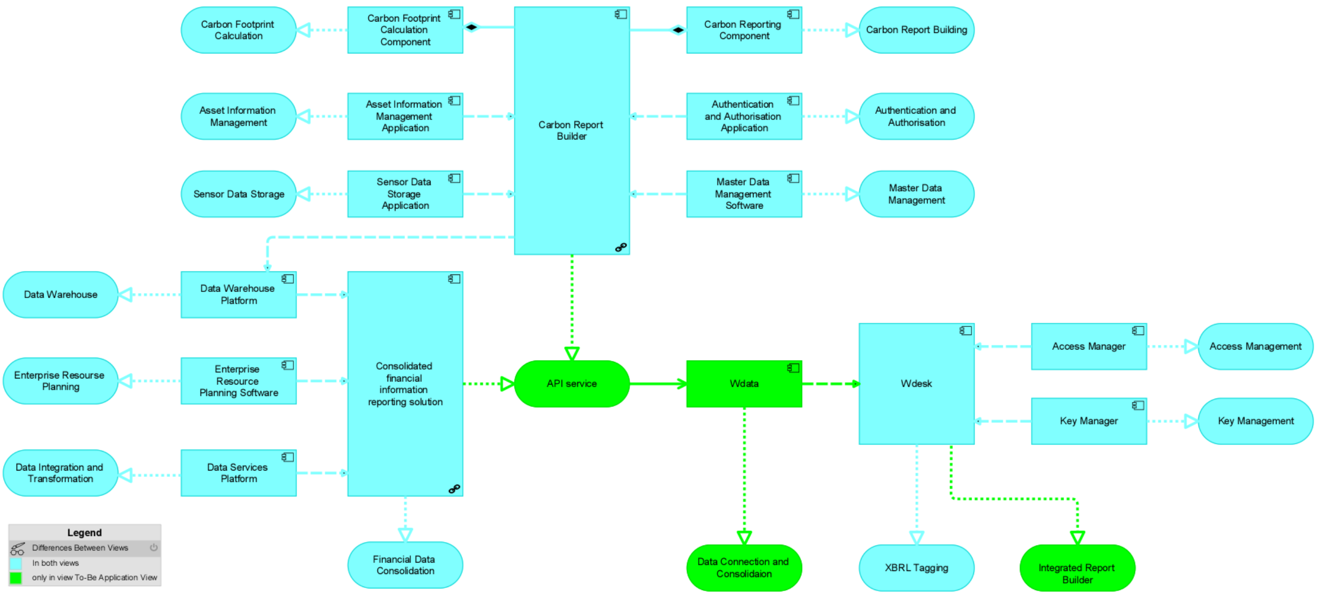


Figure 4.21: Gap Analysis for Application View (Option 2)

4.5 Data Architecture

Two specific viewpoints were selected for modeling the data architecture:

- The *information structure* viewpoint allows for identifying and organizing the key information entities. It helps to define the structure and composition of the data, ensuring that the necessary information is appropriately represented and organized.
- The *ERD* viewpoint focuses on the graphical representation of entities, their attributes, and the relationships between them. It offers a visual model that simplifies the understanding of complex data structures.

The data architecture can be comprehensively modeled by employing both the information structure and ERD viewpoints, ensuring the accurate representation of the information entities and their relationships. This facilitates effective data management, integration, and database design within the system.

4.5.1 Information Structure Model

The initial baseline models were developed to address financial and carbon reporting requirements, as shown in Figures 4.22 and 4.23. These models identified the essential entities necessary for generating reports in each domain.

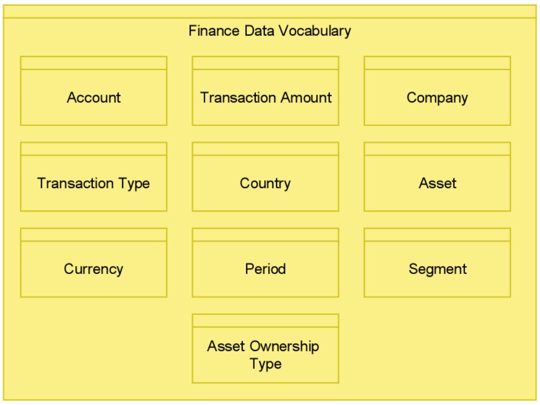


Figure 4.22: Baseline Information Structure Model for Financial Reporting

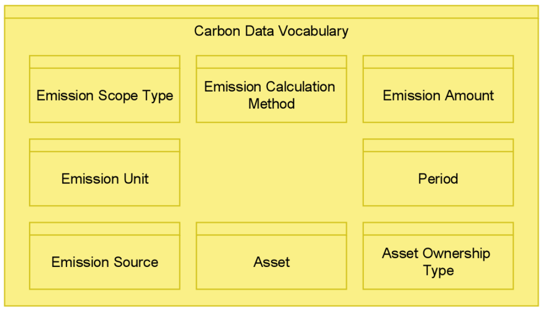


Figure 4.23: Baseline Information Structure Model for Carbon Reporting

For financial reporting, the following information is crucial: details about bank accounts, including transaction types, amounts, currencies, and the companies to which the accounts belong. These companies, in which large oil and gas corporations are typically divided, operate in different countries and various business segments. They possess diverse assets with varying ownership types, and the data needs to be stored for a specific duration.

Carbon reporting, on the other hand, requires data on emission amounts, including scope, calculation method, source, and units. These emissions originate from assets with different ownership types and are reported periodically.

The target integrated reporting model is depicted in Figure 4.24. This model aims to merge entities from both financial and carbon reporting into an integrated reporting domain. Figure 4.25 illustrates the difference between the target and baseline layers.

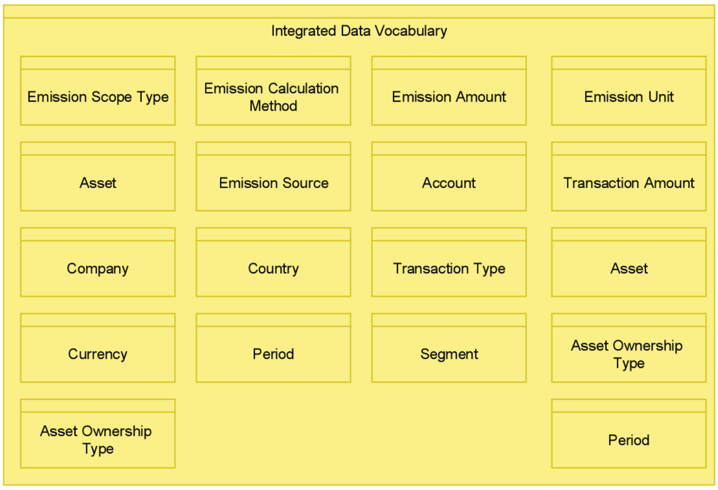


Figure 4.24: Target Information Structure Model for Integrated Reporting

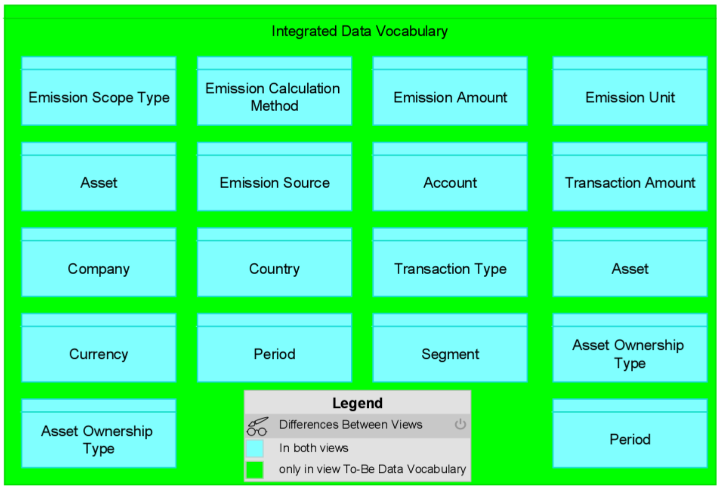


Figure 4.25: Gap Analysis for Information Structure View

4.5.2 Entity-Relationship Diagram

An ERD is a graphical representation of a database or information system's entities, relationships, and attributes. It helps to visually depict the structure and organization of data within a system [80].

In an ERD, *entities* represent the objects or concepts relevant to the modeled system. *Attributes*, on the other hand, describe the properties or characteristics of an entity. They provide detailed information about an entity and help to define its specific features [80].

Additionally, each entity has a specific attribute or combination of attributes that serves as a unique identifier for each record in a table called a *Primary Key (PK)*. It ensures data integrity and enables efficient retrieval and manipulation of data [80].

Finally, *relationships* define the associations or connections between entities in a system. They represent how entities interact or relate to each other. Different relationships can be depicted in an ERD, including one-to-one, one-to-many, and many-to-many relationships [80].

ERDs are modelled both for financial accounting [40] and emissions montoring [87] systems.

The ERD for the integrated reporting system is reflected in Figure 4.26. It includes 15 entities with attributes related to both carbon and financial reporting, connected with one-to-many relationships. The overview of the entities is presented in Table 4.2.

Therefore, the ERD depicts the emissions data reported for a certain period grouped by scope, units, source, asset, and calculation method. Additionally, the financial transactions data for the same period is stored grouped by currency, account, and transaction type.

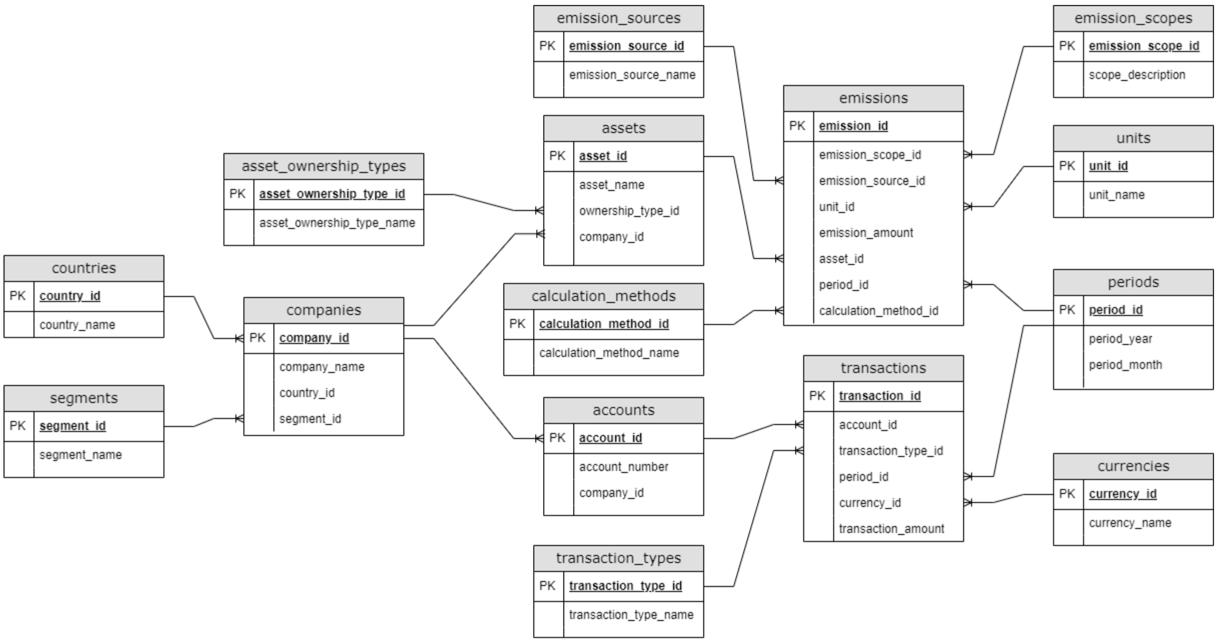


Figure 4.26: Entity-Relationship Diagram for Integrated Reporting System

Entity	**Description**
Emissions	Emissions generated by a particular source or activity.
Emission_sources	Specific sources or activities contributing to emissions.
Emission_scopes	Different scopes or boundaries used to classify emissions, such as Scope 1 and Scope 2 emissions.
Units	Measurement units used to quantify emissions.
Calculation_methods	Methods or algorithms employed to calculate or estimate emissions.
Assets	Tangible or intangible resources owned or controlled by an organization.
Asset_ownership_types	Different types of ownership associated with assets.
Companies	Individual companies or organizations involved in the emission reporting or management process.
Countries	Countries associated with the emissions or operations of the companies.
Segments	Specific divisions or segments within a company or organization.
Accounts	Financial accounts used to record transactions and financial data.
Transactions	Individual financial transactions going through the accounts.
Transaction_types	Different types of financial transactions (debit, credit).
Currencies	Currencies used to record financial transactions.
Periods	Specific time periods used for reporting emissions and financial data.

Table 4.2: Overview of Entities

4.6 Summary

The models reflecting the connection between the Strategy, Business, and Application layers of ArchiMate, both for baseline and target architecture, were created to ensure that the organization's business objectives are aligned with its IT systems and that IT solutions support the organization's strategic goals. These models represent the overall approach to the integration of carbon and financial reporting.

First, the high-level baseline architecture was modeled in Figure 4.27, which reflects separate *Financial Reporting* and *Carbon Reporting* architectures. The *Financial Reporting* business process realizes the *Financial Reporting and Disclosure Management*, *Financial Data Collection and Validation* and *Financial Data Tracking* capabilities and has the underlying connection from the *Consolidated financial information reporting solution* to *Wdesk* through the *Collaboration Platform*.

The *Carbon Reporting* business process serves the capabilities of *Carbon Reporting and Disclosure Management*, *Carbon Footprint Data Collection and Validation* and *Carbon Footprint Tracking* and mostly served by the *Carbon Report Builder* application.

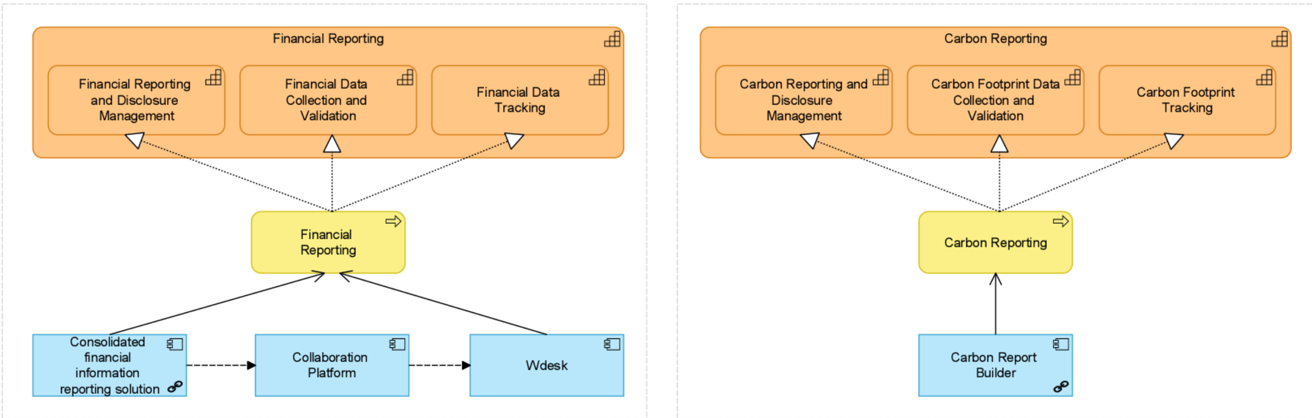


Figure 4.27: Overall High-Level Baseline Architecture

Next, the high-level overall target architecture was built in two versions based on the chosen option for the application layer (Figure 4.28 and Figure 4.29). These models include *Integrated Reporting* business process and realised capabilities (*Financial and carbon footprint data consolidation* and *Generation of integrated carbon and financial XBRL report*) and the changes in application interaction.

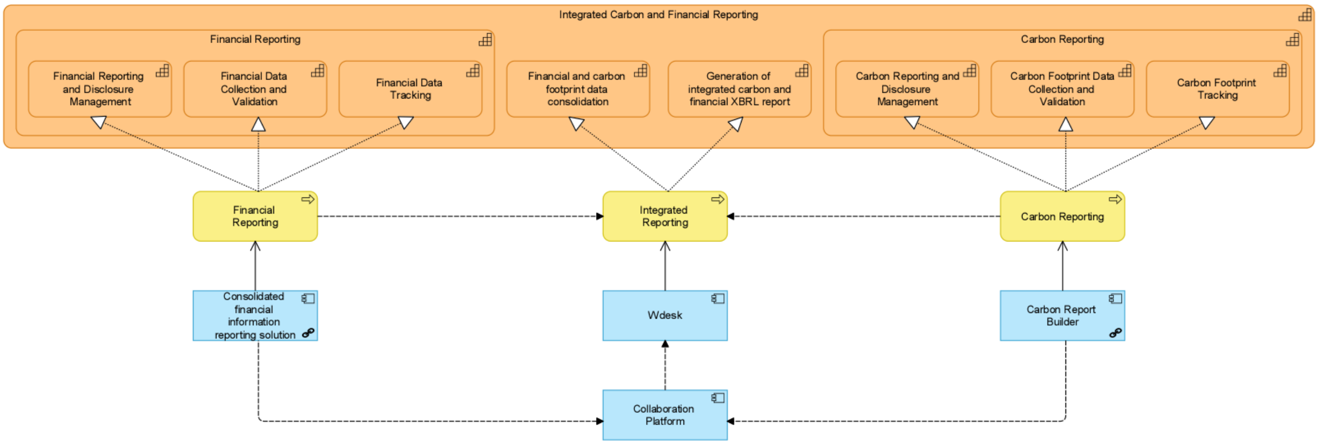


Figure 4.28: Overall High-Level Target Architecture (Option 1)

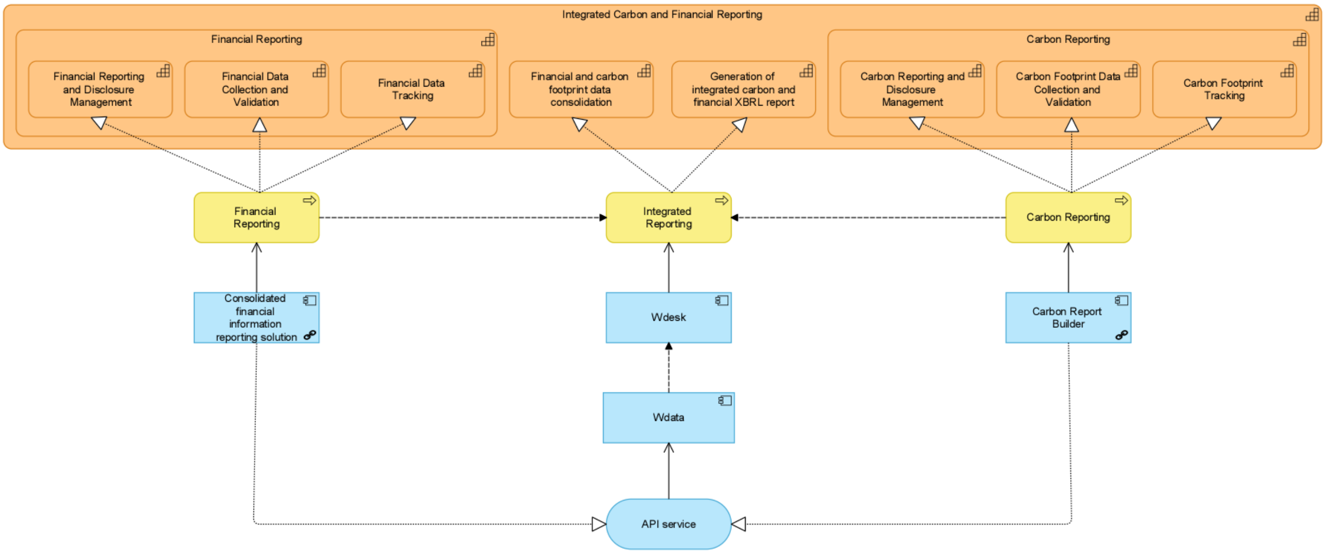


Figure 4.29: Overall High-Level Target Architecture (Option 2)

To reflect on the required changes, a gap analysis was conducted for both options. In Figure 4.30, the newly added *Integrated Reporting* process and the incoming flows from the existing processes can be seen. The new process realizes the added capabilities for the *Integrated Reporting* domain that combines already existing domains. Additionally, the connection between the *Carbon Report Builder* and the *Collaboration Platform* is reflected, proposed in the first option.

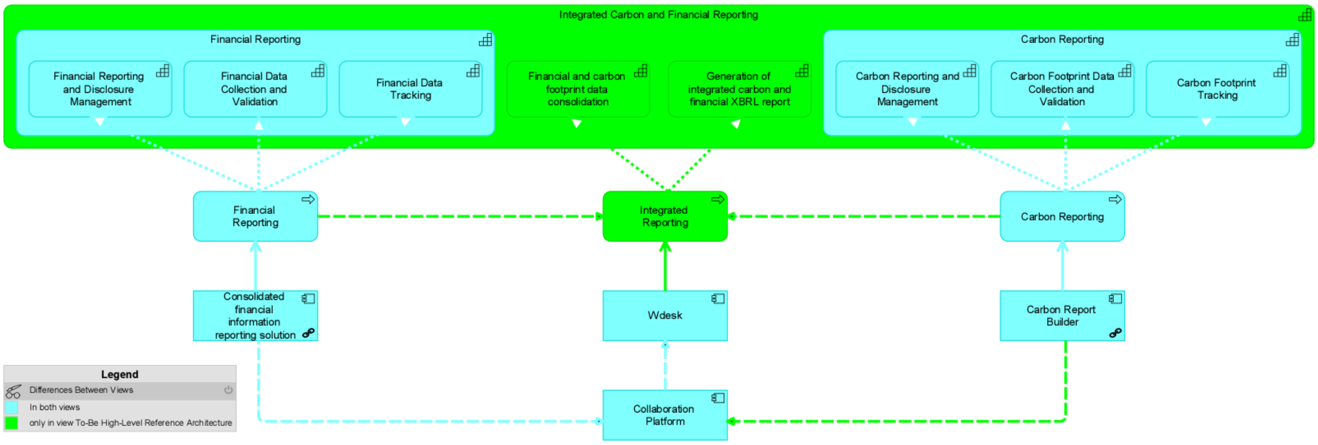


Figure 4.30: Gap Analysis Overall High-Level Architecture (Option 1)

In Figure 4.31, the same changes are made for the Strategy and Business layer. However, for the Application layer, the *Wdata* component is added as well as *API service* connecting the *Consolidated financial information reporting solution* and the *Carbon Report Builder* instead of the *Collaboration Platform*.

Figure 4.31: Gap Analysis Overall High-Level Architecture (Option 2)

Finally, the data architecture was built, incorporating two viewpoints: the information structure and the ERD. The information structure model identified key entities and their organization, while the ERD provided a visual representation of entities, attributes, and relationships.

The baseline models for financial and carbon reporting were developed, highlighting the necessary entities in each domain. Financial reporting included bank accounts, transactions, currencies, companies, segments, assets, and ownership types. Carbon reporting involved emissions, sources, scopes, units, and calculation methods.

The target integrated reporting model merges entities from both domains into an integrated reporting domain. The ERD depicted 15 entities related to financial and carbon reporting, interconnected through one-to-many relationships, based on the information structure model.

5 DEMONSTRATION

This chapter focuses on demonstrating the reference architecture by creating an example integrated XBRL report in Wdesk, using a case study with Shell.

The chapter aims to answer **RQ4**:

- *How can the reference architecture be demonstrated through an example XBRL report?*
  - What type of report would be suitable to showcase the reference architecture effectively?
  - Which regulations and standards should be considered when producing the example report?
  - Which specific XBRL taxonomy should be used to structure the data in the report?

Section 5.1 examines various report types published by Shell to determine which one would effectively showcase the reference architecture. Section 5.2 investigates the regulations and standards that Shell complies with, particularly in relation to carbon and financial reporting to determine the requirements for the example report.

Section 5.3 explains the process of choosing a specific XBRL taxonomy to structure the data in the report, while Section 5.4 describes the created example report and outlines the steps taken to produce it.

Finally, Section 5.5 provides a summary of each section and presents a conclusive answer to the research question.

5.1 Report Types

Shell publishes various reports annually to provide transparency and insights into its operations. These reports are available for public access and cover various company performance aspects. Some of the key reports published by Shell include [30]:

- *Annual Report and Accounts* provides an overview of Shell's financial performance, strategic initiatives, business activities, and governance structure [31];
- *Sustainability Report* focuses on the company's environmental and social performance, highlighting Shell's efforts in climate change, energy transition, biodiversity, community engagement, and sustainable development [36];
- *Energy Transition Progress Report* provides insights into Shell's progress in transitioning its business towards lower-carbon energy solutions [33];
- *Tax Contribution Report* provides information on tax payments and contributions to the countries and communities where Shell operates [38].

In addition to these annual reports, Shell also has internal reporting processes in place. The Executive Committee receives regular financial and carbon reports quarterly. These reports provide key financial performance indicators and carbon-related metrics to enable informed decision-making and monitoring of progress toward environmental targets.

Regarding the XBRL reporting, only the *Annual Report* is tagged using this standard, and internal reports do not undergo XBRL tagging. However, mapping carbon and financial data within these internal reports can be easier and more efficient for several reasons.

The audience for internal reports, specifically the Executive Committee, consists of individuals who deeply understand the company's operations, metrics, and reporting requirements. This targeted audience allows for a more detailed analysis and interpretation of the data, facilitating the mapping of carbon and financial metrics within the organization's specific goals and objectives.

Additionally, internal reports typically contain a narrower focus and smaller data volume than the comprehensive annual report. This streamlined dataset makes the mapping process more manageable and less time-consuming, enabling a more focused analysis of carbon-related and financial data within the internal reports.

Despite that, the data from internal reports is quite often confidential. Therefore, the data will be taken from publicly available sources like sustainability and annual report with keeping the internal focus. However, it can also be publicly shared due to the usage of only public data.

5.2 Regulations

Shell follows several regulations and reporting standards for reporting GHG emissions. These regulations and standards ensure transparency and consistency in the reporting process. Here are the key regulations and standards that Shell adheres to [39]:

- GRI in Annual and Sustainability Reports [34];
- SASB in Annual, Sustainability, and Energy Transition Progress Reports [35];
- TCFD in Annual Report [37].

Additionally, Shell considers the GHG protocol for calculating Scope 1 and 2 emissions [31]. By utilizing this protocol, Shell ensures consistency and comparability in its emission calculations, enabling effective monitoring and management of its environmental impact.

Furthermore, Shell complies with IFRS when preparing its financial statements. IFRS provides a globally accepted framework for financial reporting, ensuring transparency, consistency, and comparability of financial information [32].

5.3 XBRL Taxonomy

The report is produced in Wdesk, which has a limitation regarding taxonomy management. Users can only utilize the pre-loaded taxonomies provided within the software and cannot add or modify new taxonomies.

Considering this restriction, for a European company like Shell, the most appropriate pre-loaded taxonomy available in Wdesk would be the ESEF taxonomy [75]. This taxonomy is created by European financial markets regulator and supervisor European Securities and Market Authority

(ESMA) and designed to comply with European reporting standards, making it a suitable choice for companies operating within EU.

The ESEF taxonomy is the extension of IFRS taxonomy and is only used for financial reporting. However, based on the CSRD agreement, starting in 2024, companies will be obligated to adhere to the ESEF for their management reports. This entails preparing reports utilizing XBRL technology to mark sustainability information. A sustainability reporting taxonomy specifically designed for the ESRS will be developed to facilitate this process. This taxonomy will enable companies to appropriately tag the reported information in accordance with the established sustainability standards [75].

5.4 Example Report

The example report is divided into two sections:

- *General information* provides an overview of Shell's overall financial metrics and carbon emissions values. It maps the overall values of financial indicators with the corresponding carbon emissions across the entire company. This gives a broad perspective on the relationship between financial performance and environmental impact.
- *Information by segment* delves into a more detailed analysis by comparing financial and carbon metrics based on different business segments in which Shell's value chain is divided. This allows for a deeper understanding of financial and environmental performance variations across different parts of the organization.

Both sections follow a similar structure, incorporating the following elements:

- *Table with XBRL-tagged data* that enables standardized and structured data representation, facilitating further analysis;
- *Charts* illustrating the mapping between carbon and financial metrics that enable easier interpretation and identification of trends;
- *Textual conclusions* that highlight the financial implications and potential impacts for investors based on the observed patterns and relationships.

The complete report can be found in Appendix C. It is important to note that the XBRL functionality is not visible in the provided report, and a specific XBRL viewer would be necessary to access and fully utilize the tagged data. The following sections will explain the report's creation process and demonstrate certain parts of it.

5.4.1 Data Import & Preprocessing

Due to the lack of access to Shell reporting systems and the confidentiality of the data stored within them, the data for the report was imported manually to Wdesk. This manual import was necessary to ensure data security and compliance with confidentiality requirements.

The financial metrics used in the report were sourced from the 2022 Annual Report [77]. These metrics provided insights into the company's financial performance and were taken from the annual report for consistency and reliability.

On the other hand, the carbon metrics used in the report were obtained from the 2022 Sustainability Report [78]. These metrics reflect the company's environmental performance and provide information on carbon emissions.

Both financial and carbon metrics were gathered from 2018 to 2022. This multi-year timeframe allows for identifying trends and patterns in the data, providing a comprehensive analysis of the company's performance over time.

One of the report's sections focused on specific reporting segments defined by the company. The reporting segments used in the analysis are based on Shell's current reporting structure, as depicted in Figure 5.1 [79]. The current reporting segments in Shell are:

- *Integrated Gas* segment involves activities related to liquefied natural gas, gas-to-liquids fuel production, and other products. It encompasses the exploration and extraction of natural gas and liquids and the operation of upstream and midstream infrastructure. Additionally, it includes the marketing, trading, and optimization of liquefied natural gas, including its use as a fuel for heavy-duty vehicles.

- *Upstream* segment focuses on exploring and extracting crude oil, natural gas, and natural gas liquids. It also involves marketing, transportation, and the operation of the infrastructure necessary to deliver these resources to the market.

- *Marketing* segment consists of three distinct businesses: Mobility, Lubricants, and Sectors & Decarbonisation. The Mobility business manages Shell's retail network, including electric vehicle charging services. The Lubricants business produces, markets, and sells lubricants for various industries. The Sectors & Decarbonisation business supplies fuels, specialty products, low-carbon energy solutions, and services to commercial customers in sectors such as aviation, marine, commercial road transport, and agriculture.

- *Chemicals and Products* segment encompasses the manufacturing of chemicals, operation of refineries, and marketing of oil products globally. It includes a pipeline business, crude oil, oil products, petrochemicals trading, and activities related to oil sands extraction and conversion.

- *Renewables and Energy Solutions* segment focuses on Shell's efforts in renewable energy and sustainable solutions. It includes activities related to electricity generation, power, and pipeline gas marketing and trading, decarbonized hydrogen production and supply, carbon capture and storage development, carbon credit trading, and investments in nature-based projects.

- *Corporate* segment encompasses non-operating activities that support Shell's overall operations. This includes holdings and treasury functions, self-insurance activities, and headquarters and central functions. Finance expenses, income, and related taxes are reported under this segment.

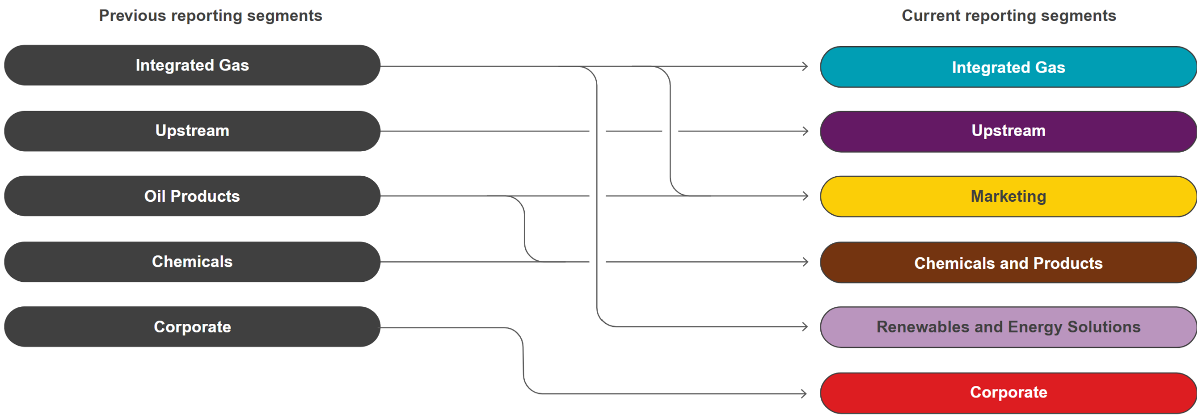


Figure 5.1: Reporting Segments in Shell [79]

However, it is important to note that the carbon and financial data reporting segments are not perfectly aligned. As a result, it was necessary to recalculate the financial data to match the narrower carbon reporting segments. This mapping of carbon and financial reporting segments is presented in Table 5.1, allowing for a consistent comparison between the two datasets.

Carbon Reporting Segment	Financial Reporting Segment
Integrated Gas	Integrated Gas Renewables and Energy Solutions
Upstream	Upstream
Downstream	Marketing Chemicals and Products
Other	Corporate

Table 5.1: Carbon and Financial Reporting Segments Mapping

The created Wdesk dataset is in Excel sheet format and serves as the foundation for creating the example report. The full dataset can be found in Appendix C.1. It contains the extracted and recalculated carbon and financial metrics described in the following section.

5.4.2 Used Metrics

In the example report, the carbon reporting section focused on Scope 1 (direct) and Scope 2 (indirect) emissions. However, different methods can be used to calculate these emissions. The report utilized the *operational control method* for both Scope 1 and Scope 2 emissions. This method considers emissions from sources owned or directly controlled by the company. The *equity method*, which calculates emissions based on the company's proportional share in other entities, was not used in the example report due to the unavailability of data for 2022 [70].

Regarding Scope 2 emissions, the report considered two methods: the *location-based method* and the *market-based* method. The *location-based method* calculates Scope 2 emissions based on the average emissions factor of the electricity grid in the company's operating region. It assumes that emissions associated with electricity consumption are proportional to the average emissions of the grid supplying the electricity [70].

On the other hand, the *market-based method* considers specific contracts and purchasing decisions made by the company for electricity procurement. It considers the emissions associated with the specific sources of electricity that the company purchases, including any renewable energy certificates or offsets [70].

For the financial reporting side, several metrics were considered:

- *Operational Expenses* - the costs incurred by the company in its day-to-day operations, including expenses related to production, administration, and sales;
- *Capital Expenditure* (only for general analysis) - the funds invested in acquiring or upgrading long-term assets, such as property, plant, and equipment;
- *Cash Capital Expenditure* - the cash outflows related to capital expenditures, providing insights into the company's cash flow management;
- *Adjusted Earnings* (only for analysis by segment) - the company's earnings after excluding certain one-time or non-recurring items to provide a clearer picture of the underlying financial performance of each segment.

These metrics were selected based on their relevance and potential for mapping with the carbon metrics, resulting in meaningful financial implications for investors. Each carbon metric was then mapped with the corresponding financial metric to identify correlations and insights. The specific mapping between the carbon and financial metrics is presented in Table 5.2.

Carbon Metric	**Financial Metric**
Scope 1 Emissions (Operational Control)	Operational Expenses Capital Expenditure (only for general analysis) Cash Capital Expenditure Adjusted Earnings (only for segment analysis)
Scope 2 Emissions (Operational Control) - location-based method	Operational Expenses Capital Expenditure (only for general analysis) Cash Capital Expenditure Adjusted Earnings (only for segment analysis)
Scope 2 Emissions (Operational Control) - market-based method	Operational Expenses Capital Expenditure (only for general analysis) Cash Capital Expenditure Adjusted Earnings (only for segment analysis)

Table 5.2: Carbon and Financial Metrics Mapping

5.4.3 XBRL tagging

The XBRL tagging process involved the following steps:

Step 1 *Setting up a fiscal calendar*: This step involves defining the reporting period, typically spanning multiple years on a quarterly or yearly basis, to ensure consistent reporting and comparison of financial data over time. In our case, this was yearly reporting from 2018 to 2022.

Step 2 *Defining default units and their accuracies*: Units are established to provide context for the reported data. Here, custom carbon reporting units were created, such as ”million tonnes CO_2e”, a standard unit used in environmental metrics to report carbon dioxide equivalent.

Step 3 *Creating an XBRL profile*: In this step, an XBRL profile is created based on the chosen taxonomy, in our case, ESEF. Setting up the Legal Identity Identifier (LEI) to identify reporting entities uniquely is essential, ensuring consistency and accuracy in financial reporting. For the case of an example report, a sample LEI was used.

Step 4 *Creating extension concepts*: Extension concepts can be added to the taxonomy to capture additional information specific to the reporting entity. Carbon reporting extension concepts were created for our case, such as Scope 1 and Scope 2 emissions.

Step 5 *Incorporating dimensions in the form of axis*: Dimensions add additional context to the reported data. In XBRL, dimensions represent different aspects or perspectives of the reported information. For our case, the emission calculation method and specific Scope 2 calculation method were added as dimensions.

Step 6 *Defining members for axis*: Dimensions can be specified within the taxonomy to derive specific metrics. Members were created to represent the different calculation methods (such as operational control and equity methods for emissions and market- and location-based methods for Scope 2 emissions), providing flexibility in reporting.

Step 7 *Tagging*: In this final step, metrics values are copied from the created dataset to the report document with external linking and mapped with an appropriate concept from the taxonomy. Additional parameters such as fiscal date, accuracy, units, dimensions, and their members must also be added during the tagging process.

The example of a tag in Wdesk is presented in Figure 5.2:

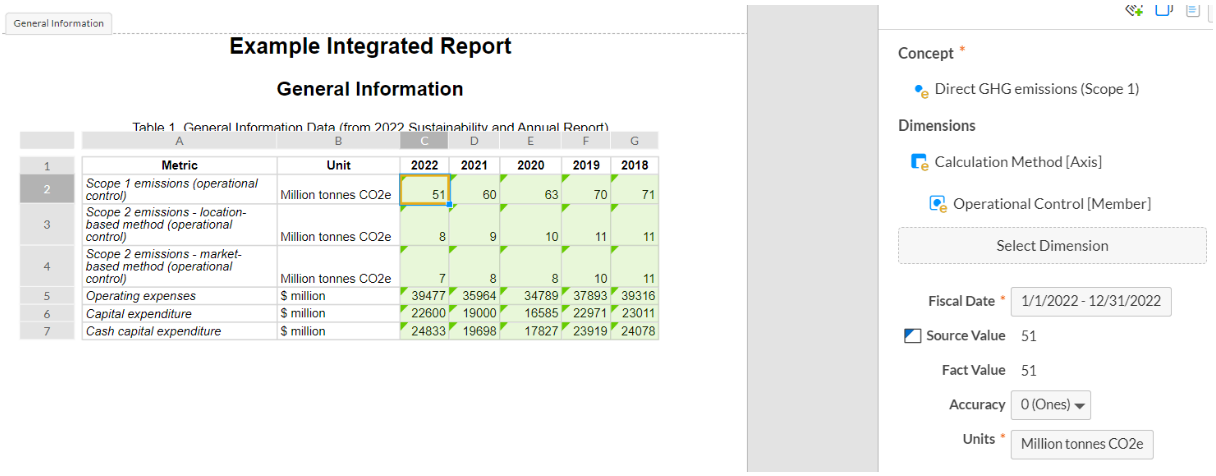
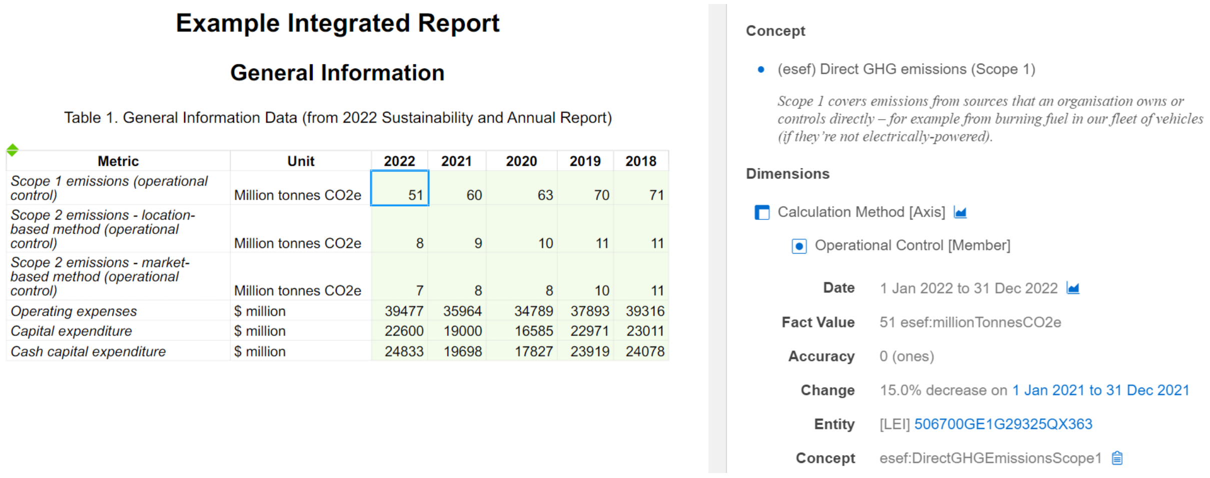


Figure 5.2: Tagged Value in Wdesk

The example of a ready tag in an XBRL viewer is presented in Figure 5.3:


Example Integrated Report

General Information

Table 1. General Information Data (from 2022 Sustainability and Annual Report)

Metric	Unit	2022	2021	2020	2019	2018
Scope 1 emissions (operational control)	Million tonnes CO2e	51	60	63	70	71
Scope 2 emissions - location-based method (operational control)	Million tonnes CO2e	8	9	10	11	11
Scope 2 emissions - market-based method (operational control)	Million tonnes CO2e	7	8	8	10	11
Operating expenses	$ million	39477	35964	34789	37893	39316
Capital expenditure	$ million	22600	19000	16585	22971	23011
Cash capital expenditure	$ million	24833	19698	17827	23919	24078

Figure 5.3: Tagged Value in XBRL Viewer

5.5 Summary

In this chapter, we discussed the suitable types of reports for effectively showcasing the reference architecture, the regulations and standards to consider when producing the example report, and the specific XBRL taxonomy for structuring the data.

Shell's various published reports, including the Annual Report and Accounts, Sustainability Report, Energy Transition Progress Report, and Tax Contribution Report, were considered as suitable options for demonstrating the reference architecture. However, for the purpose of this demonstration, the example report focused on internal reporting, utilizing publicly available data from Shell's sustainability and annual reports.

The regulations followed by Shell for reporting GHG emissions were outlined, including GRI, SASB, TCFD, and the GHG protocol for Scope 1 and 2 emissions. Additionally, Shell complies with IFRS for financial reporting, ensuring transparency, consistency, and comparability.

Considering the limitations of the Wdesk software in managing taxonomies, the ESEF taxonomy was identified as the most appropriate pre-loaded taxonomy for a European company like Shell. However, it should be noted that a specific taxonomy for the ESRS will be developed in accordance with the CSRD agreement starting in 2024.

The report was divided into two sections: general information and by segment. Both sections incorporated XBRL-tagged tables, charts showing the mapping between carbon and financial metrics, and conclusions highlighting financial implications and potential impacts for investors.

The data import and preprocessing process involved manually importing financial and carbon metrics from publicly available sources, such as the 2022 Annual Report and Sustainability Report. The final dataset included multi-year data from 2018 to 2022 to enable trend analysis.

The example report utilized the operational control method values for Scope 1 and 2 emissions and considered location-based and market-based methods values for Scope 2 emissions. Financial metrics (operational expenses, capital expenditure, cash capital expenditure, adjusted earnings) were selected for mapping with the carbon metrics to identify correlations and insights.

The complete example report, including the created dataset, can be found in Appendix C. However, it should be noted that the XBRL functionality is not visible in the provided report, and a specific XBRL viewer would be necessary to access and fully utilize the tagged data.

6 EVALUATION

This chapter focuses on evaluating the designed artifact and its demonstration. The evaluation process provides valuable insights into the designed artifact's effectiveness and helps identify areas for improvement. These insights are essential for ensuring that the artifact is useful and practical for its intended users and can ultimately contribute to advancing the field.

The chapter aims to answer **RQ5**:

- *To what extent do the reference architecture and the example XBRL report contribute to the implementation and adoption of integrated reporting?*
  - Are the reference architecture models usable and useful in the perceptions of practitioners in the field?
  - In what ways did the practitioners in the field find the example XBRL report helpful or limiting in their understanding and application of integrated reporting?

First, Section 6.1 describes the development of the interview guide, including prerequisites and conceptual basis overview, preliminary guide development, and its testing procedure, finishing with the final list of interview questions. Section 6.2 details the evaluation process, including the criteria used to select the interviewees and a description of the process.

Section 6.3 presents an overview and analysis of the interview results. Both qualitative and quantitative analyses are conducted to gain insights into the practitioners' perceptions. Section 6.4 discusses the results obtained from the evaluation.

Section 6.5 reflects on potential validity threats that may have influenced the evaluation results. Section 6.6 summarises each section's outcomes, culminating in an answer to the stated research question.

6.1 Interview Guide Development

This section follows the steps described in the framework by Kallio et al., overviewed in Section 3.6.1 [51].

6.1.1 Interview Prerequisites

The first phase of the framework aims to identify the prerequisites for using the SSI method to assess whether it is appropriate for the research. According to the framework, the SSI method is suitable for exploring individuals' attitudes and views regarding complex or emotionally sensitive topics and when the participants lack familiarity with the subject matter. It is also useful in addressing issues that participants may not have been accustomed to discussing, such as values, intentions, and ideals [51].

For the case of integrated carbon and financial reporting, the SSI method is suitable because the topic is new and relatively complex, and the interviewees lack familiarity with the subject. The system involves environmental, financial, and technical aspects, and the respondents typically have expertise in only one of these areas.

6.1.2 Retrieving Previous Knowledge

The second phase of the framework involves retrieving and critically appraising previous knowledge to gain a comprehensive understanding of the subject. A literature review is conducted to create a conceptual basis for the interview, and empirical knowledge is used to complement and deepen the theoretical background [51].

The conceptual basis for the interview was created by conducting a systematic literature review in Chapter 2, which allowed to get a preliminary understanding of the subject. Additionally, the methodology for conducting a SSI was investigated in the literature [1, 51, 59] supported by the research design theory [89].

Furthermore, several preliminary discussions were held with experts from an oil and gas company to gain empirical knowledge about the topic. The methodology for conducting a SSI was also discussed with researchers from academia.

6.1.3 Preliminary Interview Guide

The third phase of the framework includes defining a preliminary list of questions that guides the conversation toward the research subject during the interview. The questions should be participant-oriented, clearly worded, single-faceted, open-ended, and non-leading to encourage descriptive answers that reflect the personal experience of the respondents for the new concepts to emerge [51].

The SSI guide had two levels of questions: main themes and follow-up questions. Participants should be encouraged to speak freely about their perceptions and experiences within the main themes, which come in a progressive and logical order to create a relaxed environment. Follow-up questions are used in SSI to help participants understand the main themes and maintain conversation flow. They can be pre-designed or spontaneous, where pre-designed follow-up questions are used to keep consistency among different interviewees and spontaneous ones can ask for more information or examples. The follow-up questions can also be verbal, where the interviewer repeats the participant's point or expresses interest, or non-verbal, where the interviewer should remain silent and allow the participant to think aloud [51].

The structure for the questions was based on the UTAUT questionnaire, provided in Appendix D.1 [89]. The questionnaire included questions on the four main constructs that needed to be tailored to match the integrated carbon and financial reporting system case.

In addition to the main themes, control questions were also included in the interview guide with respect UTAUT moderators. These questions aimed to gain initial knowledge about the interviewees and their expertise. The *Experience* moderator was considered, as the research topic was deemed independent of age, gender, and voluntariness of use.

Furthermore, questions about the reference architecture and the demo report were included to evaluate the effectiveness of the designed artifact. These questions were designed to elicit the participants' opinions and feedback on the designed artifact and its demonstration.

6.1.4 Pilot Testing

The fourth phase of the framework implies conducting pilot testing to confirm the coverage and relevance of the preliminary interview guide and identify any needed changes. The testing can be conducted using *internal testing*, where the research team evaluates the guide to remove ambiguities and highlight any possible interviewer bias; *expert assessment*, where the guide is exposed to critique by specialists outside the team to assess its appropriateness and comprehensiveness; or *field-testing*, that simulates the real interview situation and provides crucial information about the implementation of the interviews, making the questions more relevant [51].

In the case of the integrated carbon and financial reporting approach, *internal testing* with researchers from academia was used for pilot testing of the SSI guide to ensure that the interview questions cover all relevant aspects of the topic. As this topic is relatively new and complex, there may be ambiguities or inappropriate leading questions that needed to be removed or the relevance and wording of questions might need to be refined.

6.1.5 Final Overview Guide

The final phase of the framework is creating a comprehensive and well-designed SSI guide that can effectively gather relevant and useful data for analysis. It involves refining and integrating all the information from previous phases to produce the complete interview guide. The aim is to ensure the guide is clear, concise, and addresses all the important aspects of the interview objectives [51]. The final questions list is presented in Appendix D.2.

6.2 Interview Process

This section describes the interview process, including interviewees selection criteria and the procedure itself.

6.2.1 Interviewees Selection

The selection of participants in the interview process is based on expertise and experience in carbon reporting, financial reporting, and EA modeling. The selection criteria included the following:

- *Relevant professional background*: Interviewees should have professional experience or expertise in carbon and/or financial reporting or architecture modeling within the oil and gas industry in EU. This ensures that their insights and perspectives are informed by practical knowledge and industry-specific insights.
- *Job position and role*: Preference was given to individuals holding positions such as sustainability managers, financial managers, reporting specialists, or data architects. These roles are likely to directly involve or be responsible for carbon and financial reporting activities.
- *Willingness to participate*: Interviewees should be willing and available to participate in the research study. Their active engagement and commitment to the interview process are crucial for obtaining meaningful insights and valuable contributions to the research.

6.2.2 Interview Procedure

The interview procedure included the following steps. First, it started with control questions to ensure a baseline understanding of the participants' knowledge and background. After that, the participants were shown the reference architecture for integrated carbon and financial reporting, followed by questions to assess their understanding and perception of the architecture.

Next, the participants were presented with an example XBRL report demonstrating the integration of carbon and financial reporting. They were also asked questions to evaluate their understanding and impressions of the report.

Additionally, in the end of the interview participants were asked to fill in the evaluation form with 16 questions based on the UTAUT framework. These questions were presented in the form of *one-stage Likert scale* in Table 6.1, allowing participants to rate their agreement or disagreement with each statement [3]. This scale was used to quantitatively analyze the interviewees' perception of the overall approach.

Strongly disagree	**Somewhat disagree**	**Neither agree nor disagree**	**Somewhat agree**	**Strongly agree**
1	2	3	4	5

Table 6.1: The Likert Scale Used in This Evaluation Study

By combining the quantitative ratings from the Likert scale with the qualitative insights gathered through open-ended questions, a comprehensive evaluation of the reference architecture and example report was obtained. This mixed-method analysis provided a more holistic understanding of participants' perceptions, allowing for a deeper understanding of their experiences and opinions.

6.2.3 Interview Participants

A total of five interviews were conducted with six individuals from diverse departments, encompassing financial reporting (with a specific emphasis on XBRL), carbon reporting, carbon management, and data architecture (covering both financial and carbon aspects). The first interview involved two participants who shared similar roles and expertise, while the subsequent four interviews were conducted individually with participants representing various departments and areas of specialization. The descriptive characteristics of the interviewees are provided in Table 6.2.

Interviewee ID	Role	Years of experience	EA Experience	Reporting Experience	XBRL Experience
1A	Senior Group Reporting and Data Analyst	15	-	+ (finance)	+ (validation)
1B	Accounting Policy Analyst	23	-	+ (finance)	+ (validation)
2A	Lead Data Architect Carbon & Environment	14	+ (carbon)	-	-
3A	IT Manager Environment & Carbon	24	-	+ (carbon)	-
4A	Senior Solution Data Architect Finance	19	+ (finance)	-	-
5A	Group Carbon Reporting Lead	25	-	+ (both)	-

Table 6.2: Overview of Interviewees

6.3 Interviews Results

This section describes the results of the interviews through conducting the qualitative (for SSI results) and quantitative (for evaluation form results) analysis with the content analysis technique described in Section 3.6.2. In the following sections, the process of analyzing the interview results will be described, including the methods used and the outcomes of the analysis.

6.3.1 Data Preparation & Transformation

The interviews were recorded in audio format and transcribed. The transcriptions were then rewritten in a comprehensible question-answer format for easier analysis. The transformed answers can be found in Appendix E of this document.

To further analyze the responses, the answers of each participant were compared with each other for each question. This comparison allowed for an overall conclusion to be drawn about the architecture and the example report.

Similarly, the evaluation form results were extracted and compiled into an Excel spreadsheet that can be referred to in Appendix F. There, two tables were created with a consistent structure. The columns of these tables represent the interviewee ID (as referenced in Table 6.2), and the rows represent the question ID (as referenced in Section D.2 specifically related to the UTAUT questions).

Table F.2 contains the actual responses provided by the interviewees in text format. On the other hand, Table F.1 contains the corresponding numeric values calculated based on the scale provided in Table 6.1. The average value and standard deviation for each question were also calculated to assess the overall impression of the participants. By plotting these values and analyzing the charts, conclusions were drawn regarding the architecture and the example report.

6.3.2 Interviews Content Analysis

This subsection presents an analysis of the SSI answers, providing key findings and valuable insights into the practical implications and potential impact of integrated reporting within the organizational context. Through this analysis, we aim to uncover valuable insights that can contribute to the advancement and successful implementation of the artifact.

Reference Architecture

The analysis of the conducted interviews provides insights into the content related to the reference architecture. The following conclusions can be drawn:

- *Clarity and understandability*: Overall, the feedback on the clarity and understandability of the reference architecture is mixed. While some interviewees found it clear and easy to understand, interviewees without prior knowledge of carbon and modeling architecture mentioned that it requires careful reading and understanding. There were also suggestions to improve the labeling of data flows between applications for better clarity.
- *Reflection of organization processes*: The consensus among the interviewees is that the reference architecture generally reflects the processes in the organization. However, some participants noted that the architecture might not completely reflect Shell's specific process, but it could still be applicable to different organizations. A few interviewees mentioned the need for additional details or validation steps throughout the process.
- *Compatibility with existing systems*: The overall confidence in the compatibility of the reference architecture with existing systems is high. Most interviewees expressed confidence that the architecture is compatible to a large extent. However, it was acknowledged that full automation might not be feasible due to the complexity of the processes involved and the need for stakeholder involvement. Emphasizing alignment with governance frameworks and enterprise architecture was also mentioned as important for ensuring compatibility.
- *Reporting requirements addressing*: The interviewees generally agreed that the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data. However, some participants mentioned that the architecture focuses more on bringing together carbon and financial data rather than delving into the specific details of reporting requirements. It was suggested that presenting the architecture to a broader group could help validate its adequacy.
- *Adoption challenges and limitations*: The interviewees highlighted several challenges and limitations. These include the complexity of data processes, manual steps, involvement of multiple stakeholders, resource constraints, accounting for carbon emissions, visibility across the supply chain, variations in regulations and calculations, the effort required for implementation and automation, and the need to align data hierarchies and address timing constraints. It was also noted that alignment with strategic direction, compliance with regulations, integration with the current landscape, and impact on automation capabilities could pose challenges.

In summary, while the reference architecture received mixed feedback, it generally aligns with the organization's processes and adequately addresses reporting requirements. However, various challenges and limitations must be addressed for successful adoption and use, including complexity, stakeholder involvement, resource constraints, and alignment with strategic direction and regulations.

Example XBRL report

The results of the interviews provided valuable feedback on the example XBRL report. Based on the analysis, we can make the following conclusions:

- *Overall impression*: The interviewees were impressed with the work done on the report, acknowledging the achievement of editing the taxonomy and tagging the data. They emphasized the value and usefulness of the report, suggesting its potential integration into carbon reporting standards. The need for a standardized carbon taxonomy across companies was noted as a limitation that could be addressed by encouraging its adoption.
- *Useful or informative sections*: The interviewees found various sections of the report useful, such as data comparison with graphs, implications for investors, and segment analysis. The inclusion of tables for data points related to the graphs was appreciated, as it ensured proper tagging and enhanced understanding.
- *Confusing or unclear sections*: Overall, no major confusion or lack of clarity was mentioned regarding the report's content. However, one interviewee mentioned the need for more time to thoroughly read the report before providing detailed feedback.
- *Data detailing and transparency*: The interviewees agreed that the report provided enough detail and transparency regarding the carbon and financial data. Tagging the data in tables and explaining the connections was considered valuable for transparency and facilitating data analysis.
- *Usability and user-friendliness*: The interviewees had positive views on the usability and user-friendliness of the report. Adding graphs was suggested to enhance user-friendliness, making the information more accessible and visually appealing. The report was described as understandable, easy to navigate, and visually appealing.

In conclusion, the interviewees provided valuable feedback on the demo XBRL report, highlighting its positive aspects, suggesting improvements, and emphasizing the need for standardized taxonomies and further integration into carbon reporting standards. The report was deemed useful, informative, and user-friendly, with an appropriate level of detail and transparency in presenting carbon and financial data.

6.3.3 Evaluation Form Content Analysis

The evaluation form results have provided valuable insights into the perceptions and attitudes of participants regarding the reference architecture and example XBRL report. This subsection presents a comprehensive overview of the general findings and the findings for each UTAUT domain [89], accompanied by corresponding charts, providing a deeper understanding of the implications and potential impact of the reference architecture and example XBRL report in the context of integrated reporting.

General Findings

Figure 6.1 provides an overview of the average scores and standard deviations for each question of the evaluation form based on the values from Table F.1. The average values overview the participants' collective perceptions and opinions regarding the evaluated artifact. They highlight the areas where there is strong agreement or disagreement and the overall level of satisfaction or effectiveness. The average scores range from 2.7 to 4.3, indicating variation in participants' evaluations. This suggests diversity in the perceived effectiveness or agreement with the evaluated aspects.

Questions with higher average scores, such as Q5 (4.3) and Q2, Q4, and Q7 (4), indicate a generally positive evaluation of those aspects. Participants tend to agree that these aspects are effective or valuable.

Questions with lower average scores, such as Q14 (2.7) and Q6 (3), suggest a less favorable evaluation of those aspects. Participants tend to have lower agreement or satisfaction in these areas.

The average score across all questions is 3.7, which can be considered a moderate overall evaluation. This indicates that, on average, participants find the evaluated artifact reasonably effective and valuable, but there is room for improvement.

The standard deviation values represent the dispersion or variability of the scores around the average for each question. A lower standard deviation indicates less variability, suggesting that participants' responses were relatively consistent for that particular question. Conversely, a higher standard deviation indicates greater variability, indicating a wider range of participant opinions or perceptions.

Most questions have standard deviations greater than 0, indicating variability in participants' responses. This suggests that participants have a range of opinions or perceptions regarding the evaluated aspects. Questions with lower standard deviations, such as Q2 (0), Q9 (0.52), and Q10 (0.55), indicate a higher agreement or consensus among participants. This implies that there is a relatively consistent viewpoint regarding these specific aspects.

Questions with higher standard deviations, such as Q13 (1.37) and Q6 and Q7 (1.26), suggest greater participant response variability. This implies a broader range of participant opinions or perceptions for these particular aspects. The average standard deviation across all questions is 0.87, indicating moderate variability in participants' responses overall.

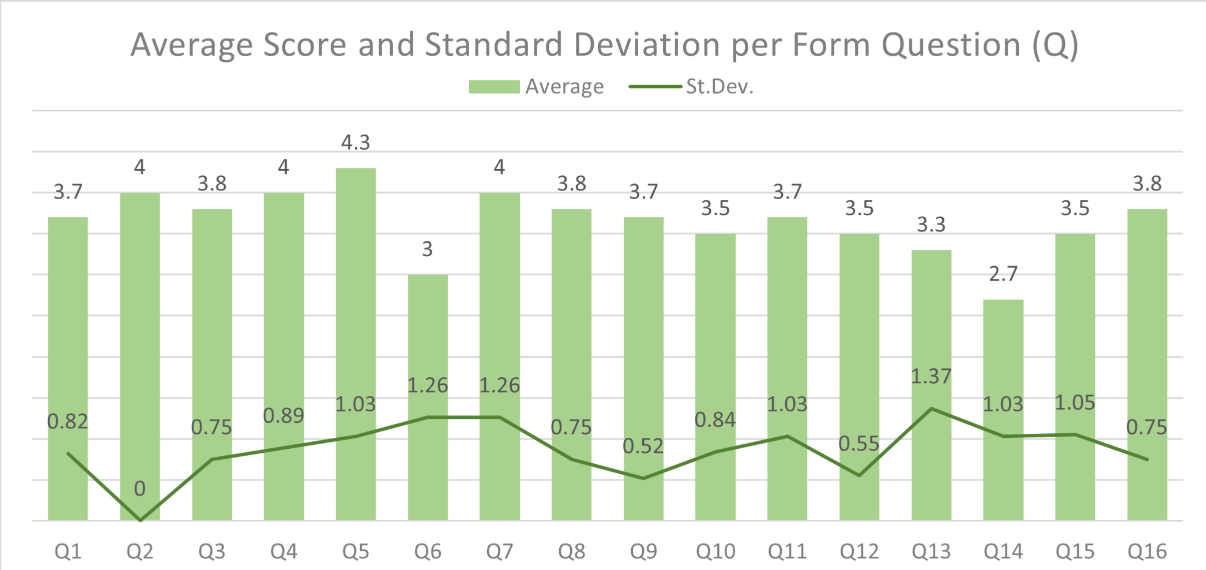


Figure 6.1: Average Score and Standard Deviation per Evaluation Form Question (Q)

Performance Expectancy

The detailed results for the *Performance Expectancy* domain are presented in Figure 6.2.

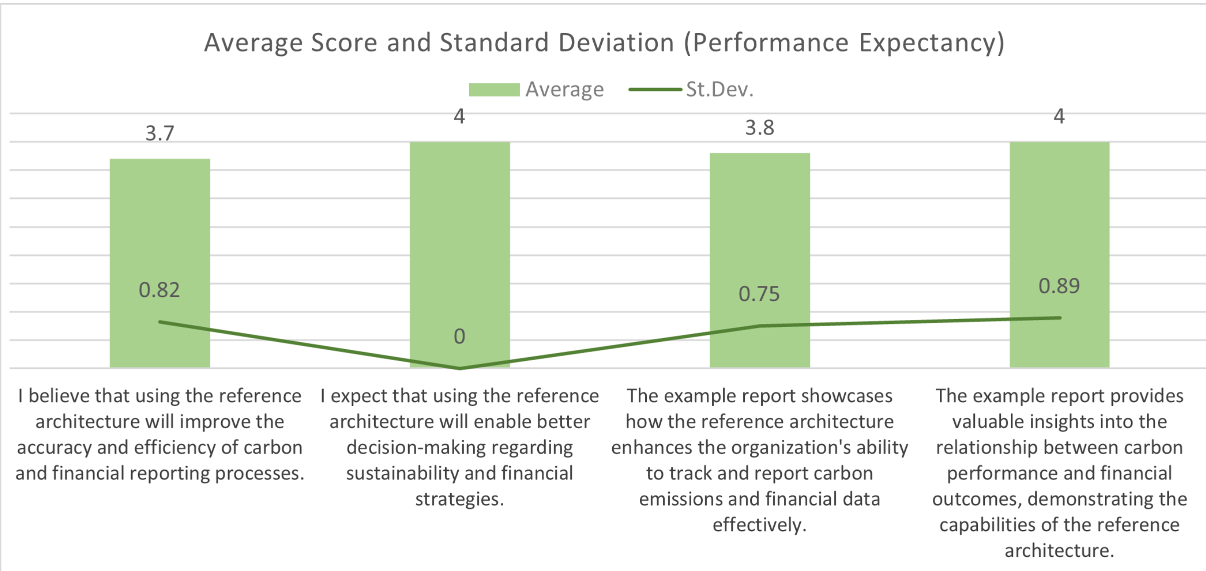


Figure 6.2: Average Score and Standard Deviation (Performance Expectancy)

From the chart, the following conclusions can be made:

- Participants generally believe that using the reference architecture will improve the accuracy and efficiency of carbon and financial reporting processes.
- Participants have high expectations that using the reference architecture will enable better decision-making regarding sustainability and financial strategies.

- Participants recognize that the example report showcases how the reference architecture enhances the organization's ability to track and report carbon emissions and financial data effectively.
- Participants find the example report valuable in providing insights into the relationship between carbon performance and financial outcomes, demonstrating the capabilities of the reference architecture.

Overall, participants have positive beliefs and expectations about the effectiveness of the reference architecture in improving reporting processes, decision-making, and providing valuable insights into carbon performance and financial outcomes.

Effort Expectancy

The results for the *Effort Expectancy* domain can be found in Figure 6.3.

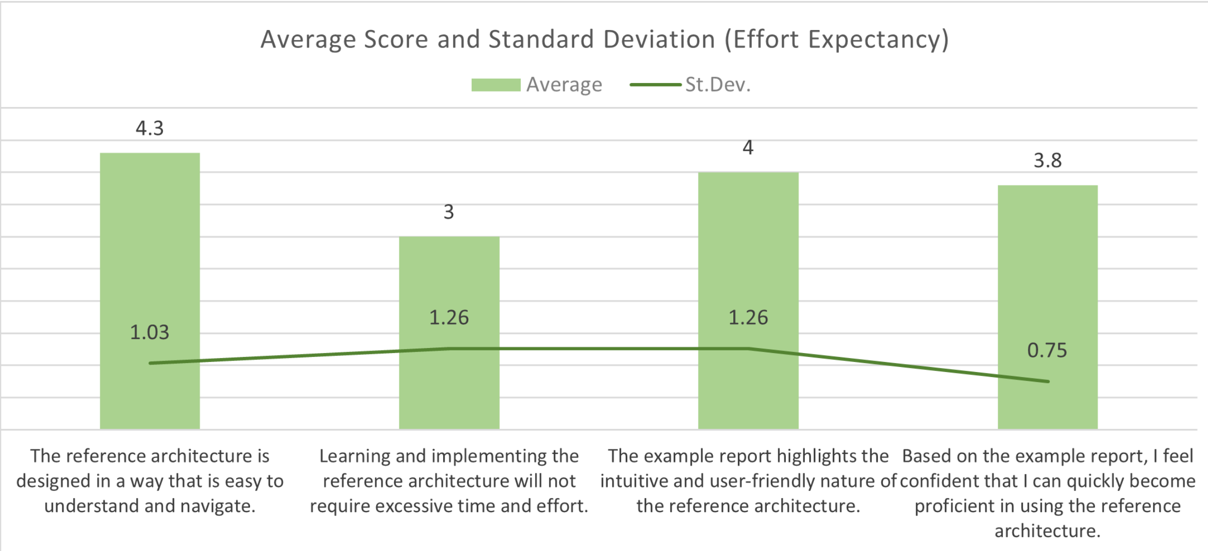


Figure 6.3: Average Score and Standard Deviation (Effort Expectancy)

From the chart, the following conclusions can be drawn:

- Participants generally perceive the reference architecture as designed in a way that is easy to understand and navigate.
- Participants have a moderate level of agreement that learning and implementing the reference architecture will not require excessive time and effort.
- Participants find the example report highlights the intuitive and user-friendly nature of the reference architecture.
- Participants feel relatively confident that they can quickly become proficient in using the reference architecture based on the example report.

Overall, participants generally perceive the reference architecture as easy to understand and navigate. However, there might be some uncertainty or disagreement regarding the effort and time required for learning and implementing it.

Social Influence

The overview of the results for the *Social Influence* domain is presented in Figure 6.4.

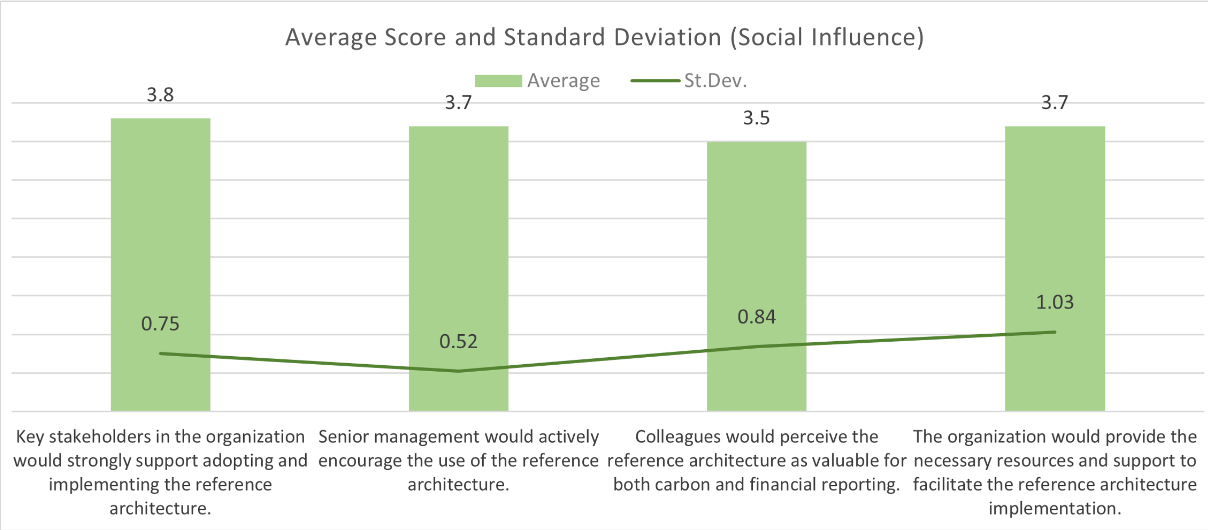


Figure 6.4: Average Score and Standard Deviation (Social Influence)

From the overview, the following conclusions can be drawn:

- Participants believe key stakeholders in the organization would strongly support adopting and implementing the reference architecture.
- Participants have a moderate level of agreement that senior management would actively encourage the use of the reference architecture.
- Participants believe their colleagues would perceive the reference architecture as valuable for both carbon and financial reporting.
- Participants have a moderate level of agreement that the organization would provide the necessary resources and support to facilitate the reference architecture implementation.

Overall, participants anticipate strong support from key stakeholders, active encouragement from senior management, and positive perceptions from colleagues regarding the value of the reference architecture for carbon and financial reporting.

Facilitating Conditions

The results for the *Facilitating Conditions* domain can be found in Figure 6.5.

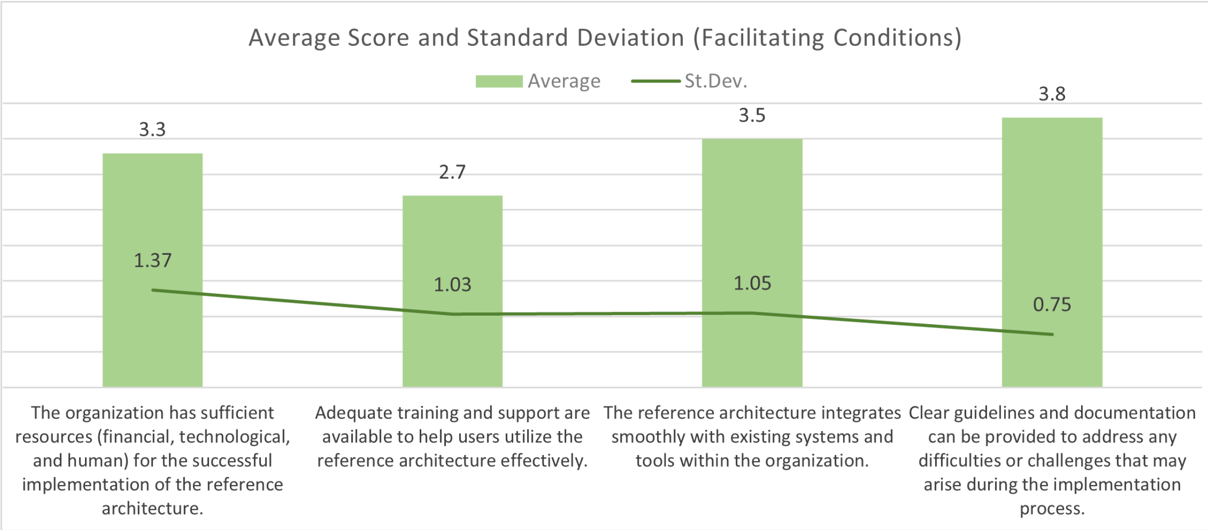


Figure 6.5: Average Score and Standard Deviation (Facilitating Conditions)

From the chart, the following conclusions can be made:

- Participants have a moderate level of agreement that the organization has sufficient resources for the successful implementation of the reference architecture.
- Participants perceive that adequate training and support are less available to help users utilize the reference architecture effectively.
- Participants generally believe the reference architecture integrates smoothly with existing systems and tools within the organization.
- Participants believe clear guidelines and documentation can be provided to address any difficulties or challenges that may arise during the implementation process.

Overall, participants believe that the organization has sufficient resources, adequate training and support, seamless integration with existing systems and tools, and the ability to provide clear guidelines and documentation to overcome challenges during implementation.

6.4 Discussion on the Evaluation Results

The overall feedback on the reference architecture and example XBRL report indicates that interviewees have a positive perception of these artifacts, highlighting their potential and promising nature. The fact that practitioners in the field find the model useful and usable demonstrates its value in facilitating the implementation and adoption of integrated reporting. This positive response suggests that the reference architecture and example XBRL report have the potential to enhance reporting accuracy, enable better decision-making, and improve the organization's ability to track and report carbon emissions and financial data effectively.

The practical implications of these findings are significant. The positive feedback indicates that the reference architecture and example XBRL report can be valuable tools for organizations seeking to adopt integrated reporting practices. The usability and user-friendliness of the model can contribute to a smoother implementation process and facilitate the understanding of complex carbon and modeling architecture concepts. Including informative visualizations and detailed explanations in the example XBRL report can enhance data analysis and promote transparency in reporting.

However, it is important to recognize the areas for improvement and lessons learned from this evaluation. The challenges identified, such as complexity, stakeholder involvement, resource constraints, and alignment with strategic direction and regulations, should be addressed to ensure the successful adoption and utilization of the reference architecture. Comprehensive support, guidance, and training may be necessary to overcome the learning curve associated with implementing the model. Additionally, the integration of standardized taxonomies and further alignment with carbon reporting standards can enhance the effectiveness and compatibility of the example XBRL report.

In summary, the positive reception and promising potential of the reference architecture and the example XBRL report suggest that they can contribute to the successful implementation and adoption of integrated reporting. However, addressing the identified challenges and incorporating the lessons learned will be essential for optimizing these artifacts and ensuring their practical usefulness in real-world scenarios.

6.5 Reflection on Validity Threats

While the conducted evaluation provides valuable insights into the reference architecture and the example XBRL report, some limitations should be acknowledged. First, the evaluation involved interviews with six practitioners from Shell. While these participants provided valuable feedback based on their expertise and experience, the sample size is relatively small. Therefore, it is important to recognize that the conclusions drawn from this evaluation may not fully capture the perspectives of all potential users or stakeholders. It is possible that additional participants may provide different insights or identify additional aspects of the architecture and report that were not addressed in this evaluation.

However, it is essential to note that given the focus on Shell's operations and the specific domain of carbon and financial data integration, the likelihood of obtaining significantly divergent perspectives from a larger sample size might be relatively low. The same knowledge and practices will likely be prevalent among practitioners in this specific context. Therefore, while expanding the sample size could provide a more comprehensive understanding, the overall feedback and conclusions are expected to remain consistent.

Second, further evaluation is necessary to improve the generalizability of the findings and validate the effectiveness of the reference architecture and example report. This evaluation can involve a larger and more diverse set of participants from different organizations within the energy sector or other relevant industries. By including a wider range of perspectives, it would be possible to identify additional strengths, weaknesses, and areas for improvement.

Additionally, conducting usability tests, pilot implementations, or gathering feedback from users who have actually used the reference architecture and example report in practice would provide more concrete evidence of their effectiveness and practicality. By conducting more extensive evaluations and gathering feedback from a larger and more diverse group of stakeholders, the generalizability of the findings can be enhanced, and any limitations or areas for improvement can be more effectively addressed.

6.6 Summary

This chapter presented a comprehensive evaluation of the designed artifact, comprising a reference architecture and an example XBRL report for integrated reporting. The evaluation aimed to assess the artifact's usability, usefulness, and effectiveness through SSI with industry professionals in the oil and gas sector.

During the evaluation process, we conducted interviews with a diverse group of participants, including accountants, financial analysts, and sustainability experts. These interviews provided valuable insights into the perceptions and experiences of professionals working in the field of integrated reporting.

The evaluation results indicated that the reference architecture was generally well-received by the participants. They found it usable, meaning it was easy to understand and navigate. The architecture was appreciated for its clarity and comprehensibility, allowing users to grasp the underlying concepts of integrated reporting. Most participants also expressed that the reference architecture was helpful in guiding organizations toward implementing integrated reporting practices.

However, there were some suggestions for improvement regarding the reference architecture. Participants noted that the architecture should be more compatible with existing information systems commonly used in the industry. They also recommended that it should better reflect the specific processes and requirements of different organizations. These insights highlight the importance of adaptability and customization when designing reference architectures for complex domains such as integrated reporting.

Regarding the example XBRL report, participants generally found it to be clear and understandable. The report successfully conveyed an integrated report's key elements and structure, enabling participants to grasp the fundamental principles of integrated reporting. Nonetheless, some participants suggested the inclusion of more user-friendly language and additional contextual information to enhance the usability of the example report.

Additionally, we conducted a quantitative analysis with the evaluation form based on the UTAUT to complement the qualitative findings. The average ratings for the reference architecture and the example XBRL report were positive, further validating their usability and usefulness.

In conclusion, the evaluation of the designed artifact demonstrated its value in addressing the research problem of integrated reporting. The feedback from industry professionals offered valuable insights for further refinement of the artifact. By incorporating the suggested improvements, such as increased compatibility with existing systems and better customization options, the artifact can be enhanced to serve better organizations seeking to implement integrated reporting practices effectively.

7 DISCUSSION

The chapter provides a comprehensive analysis of the limitations encountered throughout this research, identifies areas for future research, outlines potential future work, and presents recommendations for both practitioners in the field and Shell.

Additionally, this chapter answers **RQ6**:

- *What recommendations can be proposed to enhance the integration of carbon and financial reporting in the European oil and gas industry?*

7.1 Limitations

It is important to acknowledge several limitations that may impact the generalizability and completeness of the findings. These limitations can be grouped based on the respective chapter to which they are relevant.

In Chapter 2, where the systematic literature review was conducted, several limitations exist. First, some of the investigated standards regulating carbon reporting in the EU were not yet published, limiting the ability to fully assess and utilize them for integrated reporting. Additionally, the topic of integrated carbon and financial reporting is relatively new. Most literature found was high-level and centered around the potential integration of financial reporting sustainability or non-financial reporting, and not carbon reporting, which could have limited the depth of information obtained. Similarly, the available literature on XBRL reporting in the sustainability domain was limited, with a lack of published carbon reporting taxonomies serving as a baseline. Furthermore, the search was conducted in specific libraries using selected keywords, which may have overlooked relevant studies not captured by these criteria.

In Chapter 3, the research methods described, including the design, demonstration, and evaluation steps, have their own limitations. The reference architecture design and the example XBRL report may not fully capture all intricacies and complexities present in real-world scenarios, as the aim was to create industry-applicable models that are simplified and practical. Additionally, the sources used for evaluation may not cover all possible perspectives or viewpoints, potentially limiting the comprehensiveness of the evaluation process.

In Chapter 4, the design of the reference architecture is subject to certain limitations. The primary focus was placed on carbon emissions, specifically Scope 1 and 2 emissions data, while other greenhouse gases and Scope 3 emissions were not considered. This limitation restricted the comprehensive assessment of the organization's environmental impact. Additionally, other aspects related to sustainability reporting, such as waste management and health, were left out, potentially limiting the holistic view of integrated reporting. The architecture design did not encompass all levels of the ArchiMate framework and all phases of the TOGAF framework, which could have affected the completeness and depth of the design.

In Chapter 5, the demonstration of the integrated reporting approach using XBRL has its own limitations. The usage of primarily financial XBRL taxonomy (ESEF) required the creation of custom carbon concepts and units within it, as there are no widely adopted carbon reporting taxonomies available. The case study conducted on Shell may introduce company-specific information that may not be fully generalizable to other organizations. Furthermore, publicly available data from annual and sustainability reports may not capture the full range of data and complexities within organizations' internal systems. The manual import of data in the Wdesk and the exclusion of data convergence aspects limit the demonstration's ability to showcase fully automated and integrated reporting processes.

In Chapter 6, the evaluation of the integrated reporting approach is limited by the number of participants and the single organization focus. With only six participants from one organization, the sample size may not comprehensively represent diverse perspectives and experiences within the industry.

7.2 Future Research

The analysis of the limitations encountered in this research provides valuable insights for future research in integrated carbon and financial reporting in the European oil and gas industry. Several areas can be explored to address these limitations and further advance the understanding and implementation of integrated reporting.

Future research should investigate the upcoming carbon reporting standards and carbon XBRL taxonomies once published. Incorporating these standards and taxonomies into the integrated reporting framework would enhance the accuracy, comparability, and consistency of carbon reporting in the oil and gas industry.

Additionally, exploring alternative approaches to integrated reporting would be beneficial. This could involve considering other reporting frameworks, data exchange standards, or emerging technologies beyond XBRL that offer more efficient and effective ways of integrating carbon and financial reporting.

Furthermore, future research could explore the possibilities of combining carbon and financial reporting into a unified framework. This integrated approach would provide a more comprehensive view of an organization's sustainability performance, enabling better-informed decision-making.

Another critical area for future research is the potential integration of Scope 3 emissions and other aspects of sustainability reporting (health and waste management) within the architecture. By expanding the scope of reporting to include broader sustainability metrics, organizations can provide a more comprehensive view of their environmental impact and performance.

In addition to the aforementioned research areas, investigating the reporting of other greenhouse gases would also be valuable for advancing integrated carbon and financial reporting in the EU oil and gas industry. While carbon dioxide is the most commonly reported GHG, there are several other gases, such as methane and nitrous oxide, that contribute significantly to climate change. Future research could explore the challenges and opportunities of integrating the reporting of these greenhouse gases into the existing framework, considering their varying emission factors, measurement methodologies, and reporting requirements. By incorporating a broader range of greenhouse gases, organizations can provide a more accurate and comprehensive assessment of their environmental impact and align their reporting with evolving climate change mitigation strategies.

7.3 Future Work

Building upon the insights gained from the limitations identified in this research, there are several areas that could be addressed in future work to improve the implementation of integrated carbon and financial reporting in practice.

Future work should consider incorporating more layers of ArchiMate and include additional steps from the TOGAF framework to improve the architectural design. This would result in a more detailed and comprehensive representation of the integrated reporting process, ensuring that all relevant aspects are adequately addressed.

Next, future work should focus on implementing a proper report with a carbon-specific XBRL taxonomy and accurate data. This would involve designing and implementing standardized carbon concepts, units, and reporting structures within the XBRL framework. Additionally, ensuring the availability of reliable and comprehensive data for carbon emissions and financial information is crucial for generating informative and reliable integrated reports.

Automation and data convergence should also be key focus areas for future work. The current research relied on the manual data import and did not explore data convergence aspects. Automating the data collection, integration, and reporting processes would reduce manual efforts and improve efficiency. Exploring methods to converge data from various internal systems and sources would enable a more robust and comprehensive integrated reporting system.

Furthermore, future research should aim to test the proposed architecture and report on a larger sample of companies within the oil and gas sector in the EU. This would provide a broader perspective on the usability and effectiveness of the integrated reporting approach and allow for a more robust evaluation of its applicability in different organizational contexts, strengths, and areas for improvement.

Finally, future work should prioritize the development of comprehensive documentation that outlines the steps, guidelines, and definitions involved in the proposed integrated carbon and financial reporting approach. The documentation should address challenges, provide troubleshooting strategies, emphasize data quality assurance, and be regularly updated to reflect changes in standards and regulations. This would enhance transparency, efficiency, and knowledge sharing and facilitate the effective implementation of integrated reporting processes.

7.4 Recommendations for Practitioners

Several recommendations can be made to practitioners in the field of integrated carbon and financial reporting. To begin with, practitioners should continuously monitor and stay informed about the development and publication of carbon reporting standards. This will enable them to align their reporting practices with industry best practices and ensure compliance with regulatory requirements.

Next, while XBRL is a widely used reporting framework, practitioners should explore alternative methods for integrating carbon and financial reporting. This could involve considering other reporting technologies or frameworks that better suit their specific reporting needs and enable more comprehensive and accurate reporting.

Moreover, practitioners should consider incorporating additional aspects of sustainability reporting, such as waste management and health, in their integrated reporting processes. This will give stakeholders a more holistic view of the organization's sustainability performance and enable more informed decision-making.

Finally, to improve the effectiveness and usability of the integrated reporting architecture, practitioners should consider incorporating more layers of ArchiMate and including additional steps from the TOGAF framework. This will result in a more comprehensive and robust architecture that aligns with industry standards and best practices.

7.5 Recommendations for Shell

Specifically for Shell, the following recommendations can be made to enhance their integrated carbon and financial reporting efforts. First, Shell should closely follow the development and publication of carbon reporting standards and taxonomies and incorporate them into their reporting processes. By adopting these standards, Shell can ensure that their reports align with industry requirements, promote comparability, and enable more accurate and reliable reporting.

Shell should consider expanding the scope of their integrated reporting to include Scope 3 emissions and other greenhouse gases. Incorporating these additional aspects will give stakeholders a more comprehensive understanding of Shell's environmental impact and sustainability performance, enabling them to make more informed decisions.

Next, Shell could benefit from implementing a dedicated carbon XBRL taxonomy to enhance the reporting of carbon emissions and related financial data. By utilizing a specialized taxonomy, Shell can improve their integrated reports' accuracy, consistency, and comparability, making them more valuable for stakeholders and facilitating better data analysis and decision-making.

Shell should explore opportunities to automate the data import process and improve data convergence. By leveraging automation tools and techniques, Shell can streamline data collection from various systems and enhance data integrity, reducing manual errors and increasing reporting efficiency.

Finally, Shell should actively participate in industry forums, conferences, and collaborative initiatives to foster knowledge sharing and collaboration with other organizations in the oil and gas industry. By sharing experiences and learning from peers, Shell can drive innovation, improve reporting practices, and advance the adoption of integrated reporting in the industry.

8 CONCLUSION

This chapter concludes the research by answering the RQs set out at the beginning of the thesis and describing the contribution of the research to theory and practice.

8.1 Research Questions Answers

This section starts with answering the sub-research questions, followed by answering the main research question.

8.1.1 Carbon Reporting in Oil & Gas Industry in EU

In this section the RQ1 is answered:

- *What should be a suitable approach to carbon reporting in the oil and gas industry in the EU?*
  - What are the standards for regulating carbon reporting, and how are they (mis)aligned?
  - What kind of data does an oil and gas company need to report for carbon reporting?

The analysis of the primary standards regulating sustainability, specifically carbon reporting, and the quality of sustainability reporting in the oil and gas industry in the EU sheds light on the suitable approach to carbon reporting in this sector. The findings of the systematic literature review revealed that the existing standards are still developing, with most of them requiring reporting all three scopes of GHG emissions. Companies in the industry strive to comply with standards such as GRI guidelines, GHG Protocol, SASB standards, and TCFD. These standards target different stakeholder groups and cover general and climate-related matters.

However, the study identifies areas where the oil and gas industry can enhance its adherence to these standards. It highlights the importance of achieving greater consistency and comparability in reports, as companies often employ different terminology, reporting timeframes, and units of measurement.

Based on the research, a suitable approach to carbon reporting in the EU oil and gas industry involves utilizing the GHG Protocol as the primary data source, which includes reporting Scope 1-3 emissions and their intensities. Additionally, relevant topics from the GRI guidelines, particularly those related to emissions (EN15-E21), should be reported. As the ESRS and IFRS reach their final publication stage, their carbon-related disclosures should also be considered, given that ESRS reporting will be mandatory for EU companies starting in 2024. It is important to note that ESRS will be based on TCFD, and guidelines from TCFD should be considered, especially in terms of risks associated with emissions from all three scopes.

In summary, a suitable approach to carbon reporting in the EU oil and gas industry involves aligning with evolving standards, such as the GHG protocol, GRI guidelines, ESRS, and IFRS (merged with SASB). This approach should encompass reporting on all three scopes of emissions, ensuring consistency and comparability in reporting practices. Additionally, companies should consider incorporating TCFD guidelines to address climate-related risks associated with emissions. By adopting this approach, the oil and gas industry in the EU can enhance its carbon reporting practices and meet the evolving expectations of stakeholders.

8.1.2 Integrated Carbon & Financial Reporting Approaches

In this section the RQ2 is answered:

- *How to combine financial and carbon reporting in the oil & gas industry in the EU?*
  - What are the potential approaches to do that?
  - What are the implementation challenges of each approach?

Investigating trends in integrated reporting, the potential implementation of XBRL in sustainability and integrated reporting, and the analysis of existing and upcoming XBRL taxonomies provided insights into combining financial and carbon reporting in the oil and gas industry in the EU. The systematic literature review revealed a scarcity of practical approaches for integrated sustainability and financial reporting.

While the IR Framework provides a theoretical foundation for companies to deliver integrated reports, the practical implementation faces challenges due to the existing double-entry accounting system, which is difficult to change without corresponding legal amendments.

Among the practical implementation proposals, utilizing the XBRL standard shows promise. XBRL is already widely used for financial reporting, facilitating its integration with sustainability reporting and enhancing the usefulness and comparability of reports. However, there is a lack of validated cases in this specific area, highlighting the research gap.

Implementing an XBRL-based solution requires the development of a taxonomy supported by a legal standard, which is currently under development or only covers certain aspects of the sustainability domain. Furthermore, additional staff training, high implementation costs, and the need to educate stakeholders about the solution are among the challenges to be addressed.

In summary, the combination of financial and carbon reporting in the oil and gas industry in the EU can be achieved through practical approaches such as utilizing the XBRL standard. However, significant challenges related to taxonomy development, staff training, implementation costs, and stakeholder communication must be addressed. Future research should focus on developing and validating XBRL-based solutions for integrated reporting in the industry, considering the specific requirements and complexities of the oil and gas sector.

8.1.3 Reference Architecture for Integrated Carbon and Financial Reporting

In this section the RQ3 is answered:

- *How can a reference architecture be designed to facilitate the integration of carbon and financial reporting?*
  - What essential capabilities should an integrated carbon and financial reporting system possess?
  - Which business processes should be depicted in the reference architecture?

  - How can the interactions between the different applications within an integrated carbon and financial reporting system be designed?
  - What data should be included in the reference architecture to ensure comprehensive reporting and compliance with regulatory requirements and XBRL standards?

To answer these research questions, the study developed a baseline architecture and two versions of the target architecture, representing the integration of carbon and financial reporting (see Chapter 4). The architectures were based on the ArchiMate modeling language and consisted of three layers: Strategy, Business, and Application in combination with TOGAF ADM.

In the baseline architecture, separate financial and carbon reporting architectures were depicted. The financial reporting architecture included processes for financial reporting and disclosure management, financial data collection and validation, and financial data tracking. The carbon reporting architecture included processes for carbon reporting and disclosure management, carbon footprint data collection and validation, and carbon footprint tracking. The interactions between the applications involved in these processes were also illustrated.

In the target architectures, two options were presented. Option 1 included an integrated reporting process that combined the capabilities of financial reporting and carbon reporting. Option 2 introduced additional components, such as the Wdata component and an API service, to facilitate the integration of applications. Gap analyses were conducted to identify the changes required to move from the baseline to the target architectures for both options.

In addition to the architectural models, we also developed a data architecture consisting of an information structure model and an ERD. The information structure model identified key entities and their organization in the integrated reporting domain. The ERD depicted the entities related to financial and carbon reporting, their attributes, and their relationships.

To ensure comprehensive reporting and compliance with regulatory requirements and XBRL standards, the reference architecture included essential capabilities such as financial and carbon data consolidation, generation of integrated carbon and financial XBRL reports, and data tracking and validation. The depicted business processes included financial reporting and disclosure management, carbon reporting and disclosure management, and data collection and validation processes for both financial and carbon reporting. The interactions between the different applications within the integrated system were designed based on the chosen options, ensuring efficient data exchange and collaboration.

The data included in the reference architecture covered entities and attributes relevant to financial reporting (e.g., bank accounts, transactions, currencies) and carbon reporting (e.g., emissions, sources, scopes). By incorporating these data elements, the reference architecture enables comprehensive reporting and compliance with regulatory requirements and XBRL standards.

The designed reference architecture addresses the research questions by providing a comprehensive and integrated framework for carbon and financial reporting. It identifies essential capabilities, depicts relevant business processes, designs application interactions, and incorporates the necessary data elements to support comprehensive reporting and regulatory compliance.

8.1.4 Reference Architecture Demonstration

In this section the RQ4 is answered:

- *How can the reference architecture be demonstrated through an example XBRL report?*

- What type of report would be suitable to showcase the reference architecture effectively?
- Which regulations and standards should be considered when producing the example report?
- Which specific XBRL taxonomy should be used to structure the data in the report?

The suitable type of report chosen to showcase the reference architecture effectively in this research is an internal report utilizing publicly available data from Shell's sustainability and annual reports. This choice was made due to the confidentiality of reporting data and lack of access to the reporting systems.

In terms of regulations and standards, Shell follows several frameworks for reporting GHG emissions, including the GRI, SASB, TCFD, and the GHG protocol for Scope 1 and 2 emissions. For financial reporting, Shell complies with the IFRS, ensuring transparency, consistency, and comparability.

Regarding the specific XBRL taxonomy used to structure the data in the report, the ESEF taxonomy was identified as the most appropriate pre-loaded taxonomy for a European company like Shell. However, it is worth noting that a specific taxonomy for the carbon reporting standard ESRS will be developed in accordance with the CSRD agreement starting in 2024.

The built example report consists of two sections: general information and information by segment. Both sections incorporate XBRL-tagged data tables with corresponding charts illustrating the mapping between carbon and financial metrics and textual conclusions highlighting financial implications and potential impacts for investors.

The data import and preprocessing process for the example report involved manually importing financial and carbon metrics from publicly available sources, specifically the 2022 Annual Report and Sustainability Report. The dataset includes multi-year data from 2018 to 2022, enabling trend analysis.

For GHG emissions metrics, the example report utilizes the operational control method values for Scope 1 and Scope 2 emissions and considers both the location-based and market-based methods values for Scope 2 emissions. Financial metrics such as operational expenses, capital expenditure, cash capital expenditure, and adjusted earnings are selected for mapping with the carbon metrics to identify correlations and insights.

8.1.5 Reference Architecture and Example Report Evaluation

In this section the RQ5 is answered:

- *To what extent do the reference architecture and the example XBRL report contribute to the implementation and adoption of integrated reporting?*
  - Are the reference architecture models usable and useful in the perceptions of practitioners in the field?
  - In what ways did the practitioners in the field find the example XBRL report helpful or limiting in their understanding and application of integrated reporting?

To answer this question, the evaluation of the designed artifact provided valuable insights into the usability and usefulness of the reference architecture and the example XBRL report among practitioners in the field of integrated reporting. The findings indicate that both the reference architecture and the example XBRL report have a significant impact on the implementation and adoption of integrated reporting practices.

The reference architecture was well-received by industry professionals, who found it usable and helpful in guiding organizations toward implementing integrated reporting. The architecture's clarity and comprehensibility were appreciated, as they enabled users to grasp the underlying concepts and principles of integrated reporting. However, participants also highlighted the need for improvements, particularly in terms of compatibility with existing information systems and customization to meet the specific requirements of different organizations. These suggestions emphasize the importance of adaptability and customization in the design of reference architectures for integrated reporting.

Similarly, the example XBRL report was considered clear and understandable, effectively conveying the key elements and structure of an integrated report. Participants found it valuable in enhancing their understanding and application of integrated reporting. However, suggestions were made to make the report more user-friendly by incorporating additional contextual information.

The quantitative analysis using the UTAUT framework further supported the positive perception of the reference architecture and the example XBRL report, validating their usability and usefulness.

Overall, the evaluation of the designed artifact demonstrated its value in facilitating the implementation and adoption of integrated reporting. The reference architecture and the example XBRL report contribute significantly to guiding organizations and practitioners in understanding, implementing, and applying integrated reporting practices. However, further refinements are necessary to address the suggested improvements and ensure the artifact's effectiveness in supporting organizations' integrated reporting efforts.

8.1.6 Proposed Recommendations

In this section the RQ6 is answered:

- *What recommendations can be proposed to enhance the integration of carbon and financial reporting in the European oil and gas industry?*

Based on the research findings, several recommendations were proposed for practitioners in the field of integrated carbon and financial reporting. It is recommended that practitioners continuously monitor the development of carbon reporting standards and consider alternative methods for integration beyond XBRL. Additionally, incorporating additional aspects of sustainability reporting, such as waste management and health, can provide a more holistic view of an organization's sustainability performance.

For Shell specifically, it was recommended to closely follow the development of carbon reporting standards and taxonomies, expand the scope of integrated reporting to include Scope 3 emissions, and consider implementing a dedicated carbon XBRL taxonomy. Shell should also explore automation opportunities for data import and convergence and actively participate in industry forums and collaborative initiatives to drive innovation and knowledge sharing.

In conclusion, these recommendations aim to enhance the integration of carbon and financial reporting in the European oil and gas industry, promoting compliance, accuracy, comparability, and stakeholder engagement. By implementing these recommendations, organizations can improve their reporting practices and contribute to a more sustainable and transparent business environment.

8.1.7 Integration of Carbon and Financial Reporting in the European Oil & Gas Industry

In this section **the main RQ** is answered:

- *How can carbon and financial reporting be effectively integrated in the European oil and gas industry to accurately measure, monitor, and disclose the financial implications of greenhouse gas emissions?*

The main research question investigated in this study focuses on integrating financial and carbon reporting in the European oil and gas industry. The research findings provide valuable insights and recommendations in response to this question.

To begin with, the research explores suitable approaches to carbon reporting in the industry. Existing standards and guidelines such as GRI, GHG protocol, SASB, and TCFD are examined, considering their relevance to different stakeholders and coverage of reporting aspects. The research suggests incorporating all three scopes of GHG emissions and maintaining consistency and comparability. The GHG protocol, in combination with relevant topics from the GRI guidelines, is recommended as a suitable approach. Additionally, emerging standards like ESRS and IFRS, along with SASB, should be considered, focusing on addressing climate-related risks according to the TCFD guidelines.

Regarding integrating financial and carbon reporting, the research highlights practical approaches such as utilizing the XBRL standard. However, challenges such as developing a taxonomy supported by a legal standard, staff training, implementation costs, and effective stakeholder communication need to be addressed. Future research is suggested to focus on developing and validating XBRL-based solutions for integrated reporting in the oil and gas industry.

To establish a comprehensive reference architecture for carbon and financial reporting, the research emphasizes the importance of designing a structure encompassing essential capabilities, business processes, application interactions, and data elements. The ArchiMate modeling language is employed, and the architecture is divided into three layers: Strategy, Business, and Application in combination with TOGAF ADM. An information structure model and ERD are developed to illustrate entities and their relationships.

An example report based on publicly available data from Shell's sustainability and annual reports is presented to exemplify the integration of financial and carbon reporting in practice. Shell follows reporting frameworks such as GRI, SASB, TCFD, the GHG protocol for carbon reporting, and IFRS for financial reporting. The ESEF taxonomy is chosen for structuring the data in the report, although a specific taxonomy for the carbon reporting standard ESRS will be developed in the future.

The usability and value of the reference architecture and example report are assessed in the research. Practitioners find the reference architecture usable and valuable, providing guidance for organizations implementing integrated reporting. Suggestions for improvement include enhancing compatibility, customization, and integration with information systems. The example XBRL report is considered clear and understandable, aiding comprehension and application of integrated reporting.

Recommendations include continuously monitoring carbon reporting standards, exploring alternative integration methods beyond XBRL, incorporating additional aspects of sustainability reporting, expanding the scope to include Scope 3 emissions and other greenhouse gases, and actively participating in standard and taxonomy development, automation opportunities, and industry forums and initiatives.

In conclusion, this thesis addresses the main research question by providing insights into suitable approaches to carbon reporting, practical integration methods, reference architecture design, practical examples, and recommendations for improving integrated carbon and financial reporting in the European oil and gas industry. The research findings enhance reporting practices and facilitate the industry's transition toward a more sustainable future.

8.2 Contributions

This section outlines the contributions of the research to theory and practice.

8.2.1 Theoretical Contributions

This thesis contributed to the theory in several ways. To begin with, the relevant EU standards that regulate carbon reporting in the oil and gas industry were thoroughly analyzed. By examining these standards, the research enhanced our theoretical understanding of the regulatory landscape and its implications for integrated reporting practices.

Next, various theoretical approaches were explored to implement integrated carbon and financial reporting in the EU oil and gas industry. This thesis contributed to theoretical knowledge by providing insights into different methodologies and frameworks organizations can employ to effectively combine carbon and financial data in their reporting practices.

Finally, a novel contribution was made by designing a theoretical reference architecture. This architecture outlined the approach for integrating carbon and financial reporting in the European oil and gas industry. By providing a structured framework, the reference architecture can guide organizations in the theoretical implementation of integrated reporting practices.

8.2.2 Practical Contributions

This thesis also made significant contributions to practice in the field of carbon and financial reporting in the European oil and gas industry. First, the research went beyond theory by creating a practical example of an XBRL integrated carbon and financial report based on the designed reference architecture. This practical application demonstrated the feasibility of using XBRL for integrated reporting purposes, providing a tangible solution for organizations in the oil and gas industry.

Then, in this thesis, the effectiveness and usability of the proposed integrated reporting approach were evaluated through SSI and evaluation form from industry practitioners. This practical evaluation provided empirical evidence on the practical implications and challenges of implementing integrated reporting in the European oil and gas sector.

In conclusion, the research proposed practical recommendations for enhancing the integration of carbon and financial reporting in the European oil and gas industry. These recommendations offer practical guidance to organizations, policymakers, and industry stakeholders, aiding them in improving their reporting practices and aligning with sustainability objectives.

REFERENCES

[1] Omolola Adeoye􏰀Olatunde and Nicole Olenik. “Research and scholarly methods: Semi􏰀structured interviews”. In: *Journal of the American College of Clinical Pharmacy* 4 (May 2021). DOI: 10.1002/jac5.1441.

[2] Abdulsamad Alazzani and Wan Nordin Wan-Hussin. “Global Reporting Initiative’s environmental reporting: A study of oil and gas companies”. In: *Ecological Indicators* 32 (Sept. 2013), pp. 19–24. DOI: 10.1016/j.ecolind.2013.02.019.

[3] Gerald Albaum. “The Likert Scale Revisited”. In: *Market Research Society. Journal.* 39 (Mar. 1997), pp. 1–21. DOI: 10.1177/147078539703900202.

[4] Pouya Aleatrati Khosroshahi et al. “Business Capability Maps: Current Practices and Use Cases for Enterprise Architecture Management”. In: Jan. 2018. DOI: 10.24251/HICSS.2018.581.

[5] Samuil Angelov, Paul Grefen, and Danny Greefhorst. “A framework for analysis and design of software reference architectures”. In: *Information & Software Technology* 54 (Apr. 2012), pp. 417–431. DOI: 10.1016/j.infsof.2011.11.009.

[6] Claudia Arena, Saverio Bozzolan, and Giovanna Michelon. “Environmental Reporting: Transparency to Stakeholders or Stakeholder Manipulation? An Analysis of Disclosure Tone and the Role of the Board of Directors”. In: *Corporate Social Responsibility and Environmental Management* 22 (Apr. 2014). DOI: 10.1002/csr.1350.

[7] Hans-Knud Arndt, Henner Graubitz, and René Klesinski. “Using Topic Maps for Sustainability Reporting”. In: Jan. 2007, pp. 47–59. ISBN: 978-3-540-71334-0. DOI: 10.1007/978-3-540-71335-7_8.

[8] Viorel Avram et al. “The Institutionalization of the Consistency and Comparability Principle in the European Companies”. In: *Energies* 11 (Dec. 2018), p. 3456. DOI: 10.3390/en11123456.

[9] Francesca Bartolacci et al. “Twenty years of XBRL: what we know and where we are going”. In: *Meditari Accountancy Research* ahead-of-print (Sept. 2020). DOI: 10.1108/MEDAR-04-2020-0846.

[10] Sustainability Accounting Standards Board. *SASB Standards*. URL: https://www.sasb.org/standards/download/?lang=en-us (visited on 01/04/2023).

[11] Gloria Bondel, Anne Faber, and Florian Matthes. “Reporting from the Implementation of a Business Capability Map as Business-IT Alignment Tool”. In: Oct. 2018, pp. 125–134. DOI: 10.1109/EDOCW.2018.00027.

[12] Andrea Cardoni, Evgeniia Kiseleva, and Simone Terzani. “Evaluating the Intra-Industry Comparability of Sustainability Reports: The Case of the Oil and Gas Industry”. In: *Sustainability* 11 (Feb. 2019). DOI: 10.3390/su11041093.

[13] Task Force on Climate-related Financial Disclosures. *Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures*. URL: https://assets.bbhub.io/company/sites/60/2021/07/2021-TCFD-Implementing_Guidance.pdf (visited on 04/01/2022).

[14] Robert Cloutier et al. "The Concept of Reference Architectures". In: *Systems Engineering* 13 (Jan. 2009), pp. 14–27. DOI: 10.1002/sys.20129.

[15] CNN. *How to help Pacific Islanders cope with climate change and protect the environment*. URL: https://edition.cnn.com/2023/05/17/us/help-pacific-islanders-climate-change-protect-environment-iyw/index.html (visited on 05/21/2023).

[16] CNN. *Italy's 'once in a century' deadly floods are linked to climate crisis, researchers say*. URL: https://edition.cnn.com/2023/05/19/europe/italy-floods-climate-crisis-intl/index.html (visited on 05/21/2023).

[17] European Commission. *A European Green Deal*. URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (visited on 03/05/2023).

[18] Breeda Comyns. "Determinants of GHG Reporting: An Analysis of Global Oil and Gas Companies". In: *Journal of Business Ethics* (Oct. 2014), pp. 1–21. DOI: 10.1007/s10551-014-2517-9.

[19] Breeda Comyns and Frank Figge. "Greenhouse gas reporting quality in the oil and gas industry: A longitudinal study using the typology of "search", "experience" and "credence" information". In: *Accounting Auditing & Accountability Journal* 28 (Mar. 2015), pp. 403–443. DOI: 10.1108/AAAJ-10-2013-1498.

[20] Voicu Dragomir. "The disclosure of industrial greenhouse gas emissions: A critical assessment of corporate sustainability reports". In: *Journal of Cleaner Production* 29-30 (July 2012), pp. 222–237. DOI: 10.1016/j.jclepro.2012.01.024.

[21] Jorden Dye, Murdoch McKinnon, and Connie Van der Byl. "Green Gaps: Firm ESG Disclosure and Financial Institutions' Reporting Requirements". In: *Journal of Sustainability Research* 3 (Jan. 2021). DOI: 10.20900/jsr20210006.

[22] D.J. Easterbrook. "Greenhouse Gases". In: Sept. 2016, pp. 163–173. ISBN: 9780128045886. DOI: 10.1016/B978-0-12-804588-6.00009-4.

[23] Olga Efimova, Olga Rozhnova, and Olga Gorodetskaya. "XBRL as a Tool for Integrating Financial and Non-financial Reporting". In: *Digital Science 2019*. 2020, pp. 135–147. ISBN: 978-3-030-37737-3.

[24] EFRAG. *The preview of ESRS PoC XBRL Taxonomy Package*. URL: https://www.efrag.org/Lab4 (visited on 01/17/2023).

[25] Alessio Faccia, Francesco Manni, and Fabian Capitanio. "Mandatory ESG Reporting and XBRL Taxonomies Combination: ESG Ratings and Income Statement, a Sustainable Value-Added Disclosure". In: *Sustainability* 13 (Aug. 2021), p. 8876. DOI: 10.3390/su13168876.

[26] Samuel Fankhauser et al. "The meaning of net zero and how to get it right". In: *Nature Climate Change* 12 (Dec. 2021). DOI: 10.1038/s41558-021-01245-w.

[27] Francisco Flores Muñoz et al. "The Role of XBRL on EMAS Reporting: An Analysis of Organisational Values Compatibility". In: *Scientific Annals of Economics and Business* 65 (Dec. 2018), pp. 497–514. DOI: 10.2478/saeb-2018-0025.

[28] John Gerring. "What is a Case Study and What is it Good For?" In: *American Political Science Review* 98 (May 2004), pp. 341–354. DOI: 10.1017/S0003055404001182.

[29] Donna Gill, Sonia Dickinson, and Arno Scharl. “Communicating Sustainability: A Web Content Analysis of North American, European and Asian Firms”. In: *Journal of Communication Management* 12 (July 2008), pp. 243–262. DOI: 10.1108/13632540810899425.

[30] Shell Global. *Annual Publications*. URL: https://www.shell.com/about-us/annual-publications.html (visited on 05/23/2023).

[31] Shell Global. *Annual Report and Accounts*. 2022. URL: https://reports.shell.com/annual-report/2022/ (visited on 05/23/2023).

[32] Shell Global. *Basis of Preparation*. URL: https://reports.shell.com/annual-report/2022/consolidated-financial-statements/notes/basis-of-preparation.html (visited on 05/23/2023).

[33] Shell Global. *Energy Transition Progress*. 2022. URL: https://reports.shell.com/energy-transition-progress-report/2022/ (visited on 05/23/2023).

[34] Shell Global. *GRI Table*. URL: https://reports.shell.com/sustainability-report/2021/our-performance-data/gri-table.html (visited on 05/23/2023).

[35] Shell Global. *SASB: Oil and Gas Exploration and Production Standard*. URL: https://www.shell.com/sustainability/transparency-and-sustainability-reporting/voluntary-reporting-standards-and-esg-ratings/_jcr_content/root/main/section/list/list_item_copy_1179703050.multi.stream/1657005857495/f7d02724978035b71c4d6
sasb-mapping-2021.pdf (visited on 05/23/2023).

[36] Shell Global. *Sustainability Report*. 2022. URL: https://reports.shell.com/sustainability-report/2022/ (visited on 05/23/2023).

[37] Shell Global. *Task Force on Climate-related Financial Disclosures (TCFD)*. URL: https://www.shell.com/sustainability/transparency-and-sustainability-reporting/voluntary-reporting-standards-and-esg-ratings/_jcr_content/root/main/section/list/list_item_copy_382432832.multi.stream/1684740994911/d02c4bb8eeffa25b8d8795
shell-tcfd-mapping-table.pdf (visited on 05/23/2023).

[38] Shell Global. *Tax Contribution Report*. 2021. URL: https://reports.shell.com/tax-contribution-report/2021/ (visited on 05/23/2023).

[39] Shell Global. *Voluntary Reporting Standards and ESG Ratings*. URL: https://www.shell.com/sustainability/transparency-and-sustainability-reporting/voluntary-reporting-standards-and-esg-ratings.html#vanity-aHR0cHM6Ly93d3cuc2hlbGwuY29tL3N1c3RhaW
(visited on 05/23/2023).

[40] Javi Gorostiza et al. “Development of an Accounting Information System with Data Migration for Company ABC”. In: *International Journal of Computing Sciences Research* 1 (Dec. 2017), pp. 50–64. DOI: 10.25147/ijcsr.2017.001.1.15.

[41] European Financial Reporting Advisory Group. *First Set of draft ESRS*. URL: https://www.efrag.org/lab6 (visited on 01/04/2023).

[42] The Open Group. *ArchiMate® 3.1 Specification*. URL: https://pubs.opengroup.org/architecture/archimate3-doc/toc.html (visited on 03/26/2023).

[43] The Open Group. *The TOGAF® Standard, 10th Edition*. 2022. URL: https://publications.opengroup.org/c220 (visited on 04/30/2023).

[44] Matthew Haigh and Matthew Shapiro. “Carbon Reporting: Does It Matter”. In: *Accounting Auditing & Accountability Journal* 25 (Jan. 2012), pp. 105–125. DOI: 10.1108/09513571211191761.

[45] Christian Herzig and Stefan Schaltegger. “Corporate Sustainability Reporting. An Overview”. In: vol. III. Jan. 2006, pp. 301–324. ISBN: 978-1-4020-4079-5. DOI: 10.1007/978-1-4020-4974-3_13.

[46] Saeid Homayoun and Faisal Al-Thani. “A Sustainability Accounting: Case Study on Exploration, Production and Midstream Activities at Maersk Oil”. In: *International Journal of Energy Economics and Policy* 6 (Mar. 2016), pp. 20–27.

[47] Global Reporting Initiative. *GRI 11: Oil and Gas Sector*. 2021. URL: https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/ (visited on 01/04/2023).

[48] Global Reporting Initiative. *XBRL Taxonomy*. URL: https://www.globalreporting.org/reporting/reporting-support/xbrl (visited on 01/24/2023).

[49] Hiroki Iwata and Keisuke Okada. “Greenhouse gas emissions and the role of the Kyoto Protocol”. In: *Environmental Economics and Policy Studies* 16 (Oct. 2012). DOI: 10.1007/s10018-012-0047-1.

[50] Bertrand Janus and Helen Murphy. “Sustainability Reporting And The Oil And Gas Industry - Challenges And Emerging Trends”. In: (Apr. 2013). DOI: 10.2118/164965-MS.

[51] Hanna Kallio et al. “Systematic methodological review: developing a framework for a qualitative semi-structured interview guide”. In: *Journal of Advanced Nursing* 72 (May 2016). DOI: 10.1111/jan.13031.

[52] Barbara Kitchenham. *Kitchenham, B.: Guidelines for performing Systematic Literature Reviews in software engineering. EBSE Technical Report EBSE-2007-01*. Jan. 2007.

[53] Matteo La Torre et al. “Improving corporate disclosure through ifrsxbrl: An evidence-based taxonomy structure for Integrated Reporting”. In: *Journal of Intellectual Capital* 19 (Jan. 2018), pp. 00–00. DOI: 10.1108/JIC-03-2016-0030.

[54] Theo Le Guenedal et al. *Net Zero Carbon Metrics*. Feb. 2022.

[55] David Lubin and Daniel Esty. *Bridging the Sustainability Gap*. URL: https://sloanreview.mit.edu/article/bridging-the-sustainability-gap (visited on 01/19/2022).

[56] Lisa Madlberger et al. “Ontology-based Data Integration for Corporate Sustainability Information Systems”. In: Dec. 2013. DOI: 10.1145/2539150.2539208.

[57] Jolanta Maj. “Corporate Social Responsibility and Diversity Reporting in Polish Companies from the Basic Materials and Oil & Gas Sectors Listed on the Warsaw Stock Exchange”. In: Aug. 2016, pp. 123–130. ISBN: 978-619-7105-67-4.

[58] Athanasios Mandilas et al. “Sustainability Reporting in the Oil and Gas Sector: Implementation in Greece”. In: Oct. 2021, pp. 231–243. ISBN: 978-981-33-6635-0. DOI: 10.1007/978-981-33-6636-7_12.

[59] Michele McIntosh and Janice Morse. “Situating and Constructing Diversity in Semi-Structured Interviews”. In: *Global Qualitative Nursing Research* 2 (Aug. 2015). DOI: 10.1177/2333393615597674.

[60] Daria Miścikowska. “An Exploratory Study on Preparers’ Perception of ESEF Reporting: Evidence from the Warsaw Stock Exchange”. In: *Folia Oeconomica Stetinensia* 22 (June 2022), pp. 191–218. DOI: 10.2478/foli-2022-0010.

[61] Javier Mora and María Mora. “[XBRL in practice] XBRL and Integrated Reporting. The Spanish Accounting Association Taxonomy approach”. In: *The International Journal of Digital Accounting Research* 12 (Jan. 2012). DOI: 10.4192/1577-8517-v12_3.

[62] United Nations. *Paris Agreement*. 2015. URL: https://unfccc.int/process-and-meetings/the-paris-agreement (visited on 03/21/2023).

[63] United Nations. *United Nations Framework Convention on Climate Change*. 1992. URL: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf (visited on 03/23/2023).

[64] Robert Newcombe. “From client to project stakeholders: A stakeholder mapping approach”. In: *Construction Management & Economics* 21 (Dec. 2003), pp. 841–848. DOI: 10.1080/0144619032000072137.

[65] UN News. *New temperature records, food security threats likely as El Niño looms*. URL: https://news.un.org/en/story/2023/05/1136312 (visited on 05/21/2023).

[66] Ken Peffers et al. “A design science research methodology for information systems research”. In: *Journal of Management Information Systems* 24 (Jan. 2007), pp. 45–77.

[67] Joana Peixoto et al. “Project Risk Management Methodology: A Case Study of an Electric Energy Organization”. In: *Procedia Technology* 16 (Dec. 2014), pp. 1096–1105. DOI: 10.1016/j.protcy.2014.10.124.

[68] Maciej Piechocki, André Gräning, and Harald Kienegger. “XBRL as eXtensible reporting language for EU reporting”. In: Jan. 2007, pp. 147–174. ISBN: 978-3-8350-0835-9. DOI: 10.1007/978-3-8350-9633-2_7.

[69] Cesar Poveda. “Potential Benefits of Developing and Implementing Environmental and Sustainability Rating Systems: Making the Case for the Need of Diversification”. In: *International Journal of Sustainable Built Environment* 4 (June 2015). DOI: 10.1016/j.ijsbe.2014.12.003.

[70] Greenhouse Gas Protocol. *Corporate Standard*. URL: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf (visited on 01/04/2023).

[71] Greenhouse Gas Protocol. *Corporate Value Chain (Scope 3) Standard*. URL: https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf (visited on 01/04/2023).

[72] Muhammad Rashid and Emad Benhelal. “Reduction of Greenhouse Gas Emissions from Gas, Oil and Coal Power Plants in Pakistan by Carbon Capture and Storage (CCS): A Review”. In: *Chemical Engineering & Technology* (Aug. 2020). DOI: 10.1002/ceat.201900297.

[73] Integrated Reporting. *International <IR> Framework*. URL: http://www.integratedreporting.org/wp-content/uploads/2022/08/IntegratedReportingFramework_081922.pdf (visited on 01/19/2022).

[74] Fumiko Satoh. “XBRL Taxonomy for Estimating the Effects of Greenhouse Gas Emissions on Corporate Financial Positions”. In: vol. 7. Apr. 2011, pp. 34–55. DOI: 10.4018/jebr.2011040104.

[75] European Securities and Market Authorities. *Electronic Reporting*. URL: https://www.esma.europa.eu/issuer-disclosure/electronic-reporting (visited on 05/21/2023).

[76] Peter Seele. “Digitally Unified Reporting How XBRL-based real-time transparency helps in combining integrated sustainability reporting and performance control”. In: *Journal of Cleaner Production* 136 (Feb. 2016). DOI: 10.1016/j.jclepro.2016.01.102.

[77] Shell. *Data Supplements*. URL: https://www.shell.com/investors/results-and-reporting/data-supplements.html (visited on 05/25/2023).

[78] Shell. *Greenhouse gas and energy data*. 2022. URL: https://reports.shell.com/sustainability-report/2022/our-performance-data/greenhouse-gas-and-energy-data.html (visited on 05/25/2023).

[79] Shell. *Note 8 - Segment information*. 2022. URL: https://reports.shell.com/annual-report/2022/consolidated-financial-statements/notes/segment-information.html (visited on 05/25/2023).

[80] Il-Yeol Song, Mary Evans, and Eui Kyun Park. “A Comparative Analysis of Entity-Relationship Diagrams”. In: *Journal of Computer and Software Engineering* 3 (Jan. 1995).

[81] International Financial Reporting Standard. *IFRS Sustainability Disclosure Standards*. URL: https://www.ifrs.org/projects/work-plan/general-sustainability-related-disclosures/ (visited on 01/04/2023).

[82] SASB Standards. *Structured Reporting Using XBRL*. URL: https://www.sasb.org/structured-reporting-xbrl/ (visited on 01/17/2023).

[83] Piotr Staszkiewicz and Aleksander Werner. "Reporting and Disclosure of Investments in Sustainable Development". In: *Sustainability* 13 (Jan. 2021), p. 908. DOI: 10.3390/su13020908.

[84] Arpad Toth, Cecília Szigeti, and Alex Suta. "Carbon Accounting Measurement with Digital Non-Financial Corporate Reporting and a Comparison to European Automotive Companies Statements". In: *Energies* 14 (Sept. 2021). DOI: 10.3390/en14185607.

[85] University of Twente. *University of Twente Student Theses*. URL: https://essay.utwente.nl/ (visited on 05/18/2023).

[86] UNFCCC. *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. 1997. URL: https://unfccc.int/documents/2409 (visited on 03/21/2023).

[87] Hakki Ozgur Unver. "A Manufacturing Energy and GHG Emissions Monitoring System – Supporting Eco-efficiency with Business Intelligence". In: *INTERNATIONAL JOURNAL OF INFORMATICS TECHNOLOGIES* 10 (2017), p. 53.

[88] Rob Vanwynsberghe and Samia Samia Khan. "Redefining Case Study". In: *International Journal of Qualitative Methods* 6 (June 2007). DOI: 10.1177/160940690700600208.

[89] Viswanath Venkatesh et al. "User Acceptance of Information Technology: Toward a Unified View". In: *MIS Quarterly* 27 (Sept. 2003), pp. 425–478. DOI: 10.2307/30036540.

[90] David Walker. "Sustainability: Environmental management, transparency and competitive advantage". In: *Journal of Retail and Leisure Property* 7 (Mar. 2008). DOI: 10.1057/rlp.2008.4.

[91] Wan Nurul Wan Ahmad, Marisa de Brito, and L.A. Tavasszy. "Sustainable supply chain management in the oil and gas industry: A review of corporate sustainability reporting practices". In: *Benchmarking: An International Journal* 23 (Aug. 2016), pp. 1423–1444. DOI: 10.1108/BIJ-08-2013-0088.

[92] Zhoujie Wang et al. "Oil and gas pathway to net-zero: Review and outlook". In: *Energy Strategy Reviews* 45 (Jan. 2023), p. 101048. DOI: 10.1016/j.esr.2022.101048.

[93] Liv Watson and Brad Monterio. "The Next Stage in the Evolution of Business Reporting – The Journey Towards an Interlinked, Integrated Report". In: (Jan. 2011).

[94] Matthew Wegener, Réal Labelle, and Lambert Jerman. "Unpacking carbon accounting numbers: A study of the commensurability and comparability of corporate greenhouse gas emission disclosures". In: *Journal of Cleaner Production* 211 (Nov. 2018). DOI: 10.1016/j.jclepro.2018.11.156.

[95] Christina Wong et al. "Strategies for Building Environmental Transparency and Accountability". In: *Sustainability* 13 (Aug. 2021), p. 9116. DOI: 10.3390/su13169116.

[96] Workiva. *Overview of the Wdesk Platform*. URL: https://www.workiva.com/en-nl/resources/overview-wdesk-platform (visited on 05/07/2023).

[97] XBRL. *An Introduction to XBRL*. URL: https://www.xbrl.org/the-standard/what/an-introduction-to-xbrl/ (visited on 01/17/2023).

A SYSTEMATIC LITERATURE REVIEW

A.1 Inclusion & Exclusion Criteria

Research Question	Inclusion Criteria	Exclusion Criteria
1, 1b	• Any study that discussed sustainability/carbon/non-financial reporting in the oil & gas industry in English.	• Studies without a case study or with a non-EU case study. • Studies focus on narrow aspects of sustainability reporting rather than reporting practices in general.
1a	• Studies discussing EU and international regulations in carbon/sustainability reporting in the oil & gas industry mentioned by experts in the field in English.	• Studies discussing international standards such as GRI with a non-EU case study. • Studies not directly focusing on standards but using them as a supporting instrument.
2a	• Studies that discussed integrated reporting in the context of sustainability and financial reporting convergence in English. • Studies discussing XBRL in the context of sustainability or integrated reporting in English.	• Studies that focused on other aspects of non-financial reporting (for example, social) or did not propose any particular solution. • Studies that discussed XBRL not in the context of sustainability or integrated reporting and instead used it as a supporting instrument.

Table A.1: Inclusion & Exclusion Criteria

A.2 Included & Excluded Studies

A.2.1 Carbon Reporting in Oil & Gas Industry in EU

The following studies were included:

1. Homayoun, Saeid & Al-Thani, Faisal. (2016). A Sustainability Accounting: Case Study on Exploration, Production and Midstream Activities at Maersk Oil. [46]
2. Cardoni, Andrea & Kiseleva, Evgeniia & Terzani, Simone. (2019). Evaluating the Intra-Industry Comparability of Sustainability Reports: The Case of the Oil and Gas Industry. [12]
3. Avram, Viorel & Calu, Daniela Artemisa & Dumitru, Valentin & Dumitru, Madalina & Glăvan, Mariana & Jinga, Gabriel. (2018). The Institutionalization of the Consistency and Comparability Principle in the European Companies. [8]
4. Gill, Donna & Dickinson, Sonia & Scharl, Arno. (2008). Communicating Sustainability: A Web Content Analysis of North American, European and Asian Firms. [29]
5. Alazzani, Abdulsamad & Wan-Hussin, Wan Nordin. (2013). Global Reporting Initiative's environmental reporting: A study of oil and gas companies. [2]
6. Comyns, Breeda. (2014). Determinants of GHG Reporting: An Analysis of Global Oil and Gas Companies. [18]
7. Dragomir, Voicu. (2012). The disclosure of industrial greenhouse gas emissions: A critical assessment of corporate sustainability reports. [20]
8. Dye, Jorden & McKinnon, Murdoch & Van der Byl, Connie. (2021). Green Gaps: Firm ESG Disclosure and Financial Institutions' Reporting Requirements. [21]

The below-mentioned standards were analyzed:

1. Global Reporting Initiative (GRI). Oil & Gas Sector Standard (GRI 11) and Emissions Standard (GRI 305). [47]
2. Greenhouse Gas (GHG) protocol. Corporate Standard [70] and Corporate Value Chain (Scope 3) Standard. [71]
3. Sustainability Accounting Standards Board (SASB). Oil & Gas Standards [10].
4. International Financial Reporting Standard (IFRS). Sustainability Disclosure Standards. [81]
5. The Financial Stability Board. The Task Force on Climate-related Financial Disclosures (TCFD). [13]
6. European Financial Reporting Advisory Group. European Sustainability Reporting Standards (ESRS). [41]

The excluded studies were the following:

1. Janus, Bertrand & Murphy, Helen. (2013). Sustainability Reporting And The Oil And Gas Industry - Challenges And Emerging Trends. [50]

   Reason: the study is very generic and does not propose any model validated by the case study.

2. Wegener, Matthew & Labelle, Réal & Jerman, Lambert. (2018). Unpacking carbon accounting numbers: A study of the cnsurability and comparability of corporate greenhouse gas emission disclosures. [94]

   Reason: a case study is Canadian.

3. Maj, Jolanta. (2016). Corporate Social Responsibility and Diversity Reporting in Polish Companies from the Basic Materials and Oil & Gas Sectors Listed on the Warsaw Stock Exchange. [57]

   Reason: the study focuses on social aspects rather than sustainability.

4. Comyns, Breeda & Figge, Frank. (2015). Greenhouse gas reporting quality in the oil and gas industry: A longitudinal study using the typology of "search", "experience" and "credence" information. [19]

   Reason: the study discusses the quality principles of sustainability reporting rather than the practical implications.

5. Poveda, Cesar. (2015). Potential Benefits of Developing and Implementing Environmental and Sustainability Rating Systems: Making the Case for the Need of Diversification. [69]

   Reason: ESRS is meant as Environmental and Sustainability Rating Systems, not as European Sustainability Reporting Standards.

6. Mandilas, Athanasios & Kourtidis, Dimitrios & Pantelidou, Ioanna & Chatzoudes, Dimitrios. (2021). Sustainability Reporting in the Oil and Gas Sector: Implementation in Greece. [58]

   Reason: no clear explanation of how the case study was conducted, only textual description.

7. Wan Ahmad, Wan Nurul & de Brito, Marisa & Tavasszy, L.A.. (2016). Sustainable supply chain management in the oil and gas industry: A review of corporate sustainability reporting practices. [91]

   Reason: the study mostly focuses on supply chain management.

A.2.2 Integrated Carbon & Financial Reporting Approaches

The following studies were included:

1. Staszkiewicz, Piotr & Werner, Aleksander. (2021). Reporting and Disclosure of Investments in Sustainable Development. Sustainability. [83]
2. Efimova, O., Rozhnova, O., Gorodetskaya, O. (2020). XBRL as a Tool for Integrating Financial and Non-financial Reporting. [23]
3. Seele, Peter. (2016). Digitally Unified Reporting How XBRL-based real-time transparency helps in combining integrated sustainability reporting and performance control. [76]
4. Bartolacci, Francesca & Caputo, Andrea & Fradeani, Andrea & Soverchia, Michela. (2020). Twenty years of XBRL: what we know and where we are going. [9]
5. Madlberger, Lisa & Thöni, Andreas & Wetz, Peter & Schatten, Alexander & Tjoa, A Min. (2013). Ontology-based Data Integration for Corporate Sustaa inability Information Systems. [56]
6. Faccia, Alessio & Manni, Francesco & Capitanio, Fabian. (2021). Mandatory ESG Reporting and XBRL Taxonomies Combination: ESG Ratings and Income Statement, a Sustainable Value-Added Disclosure. [25]
7. Arndt, Hans-Knud & Graubitz, Henner & Klesinski, René. (2007). Using Topic Maps for Sustainability Reporting. [7]
8. Miścikowska, Daria. (2022). An Exploratory Study on Preparers' Perception of ESEF Reporting: Evidence from the Warsaw Stock Exchange. [60]
9. Satoh, Fumiko. (2011). XBRL Taxonomy for Estimating the Effects of Greenhouse Gas Emissions on Corporate Financial Positions. [74]
10. La Torre, Matteo & Valentinetti, Diego & Dumay, John & Rea, Michele. (2018). Improving corporate disclosure through XBRL: An evidence-based taxonomy structure for Integrated Reporting. [53]
11. Mora, Javier & Mora, María. (2012). [XBRL in practice] XBRL and Integrated Reporting. The Spanish Accounting Association Taxonomy approach. [61]

Additionally, the following grey literature was analyzed:

1. Lubin, David and Esti, Daniel. (2014). Bridging the Sustainability Gap. [55]
2. International Integrated Reporting Council. The International <IR> Framework. [73]
3. eXtensible Business Reporting Language (XBRL). [97]
4. Sustainability Accounting Standards Board. XBRL Taxonomy. [82]
5. European Financial Reporting Advisory Group. The preview of ESRS PoC XBRL Taxonomy Package. [24]

The sources that were excluded are presented below:

1. Watson, Liv & Monterio, Brad. (2011). The Next Stage in the Evolution of Business Reporting – The Journey Towards an Interlinked, Integrated Report. [93]

   Reason: the study is not accessible.

2. Flores Muñoz, Francisco & Valentinetti, Diego & Rodríguez, María & Mena-Nieto, Angel. (2018). The Role of XBRL on EMAS Reporting: An Analysis of Organisational Values Compatibility. [27]

   Reason: the study focuses not on sustainability or integrated reporting but on corporate planning and control.

3. Piechocki, Maciej & Gräning, André & Kienegger, Harald. (2007). XBRL as eXtensible reporting language for EU reporting. [68]

   Reason: the study investigates the usage of XBRL for energy performance rather than for sustainability domain.

4. Toth, Arpad & Szigeti, Cecília & Suta, Alex. (2021). Carbon Accounting Measurement with Digital Non-Financial Corporate Reporting and a Comparison to European Automotive Companies Statements. [84]

   Reason: the paper does not directly investigate the potential implementation of XBRL and rather focuses on the carbon accounting quality in the automotive industry.

5. Global Reporting Initiative. (2013). XBRL taxonomy. [48]

   Reason: the taxonomy is no longer accessible.

B TREATMENT DESIGN MODELS

B.1 Business Capability Map

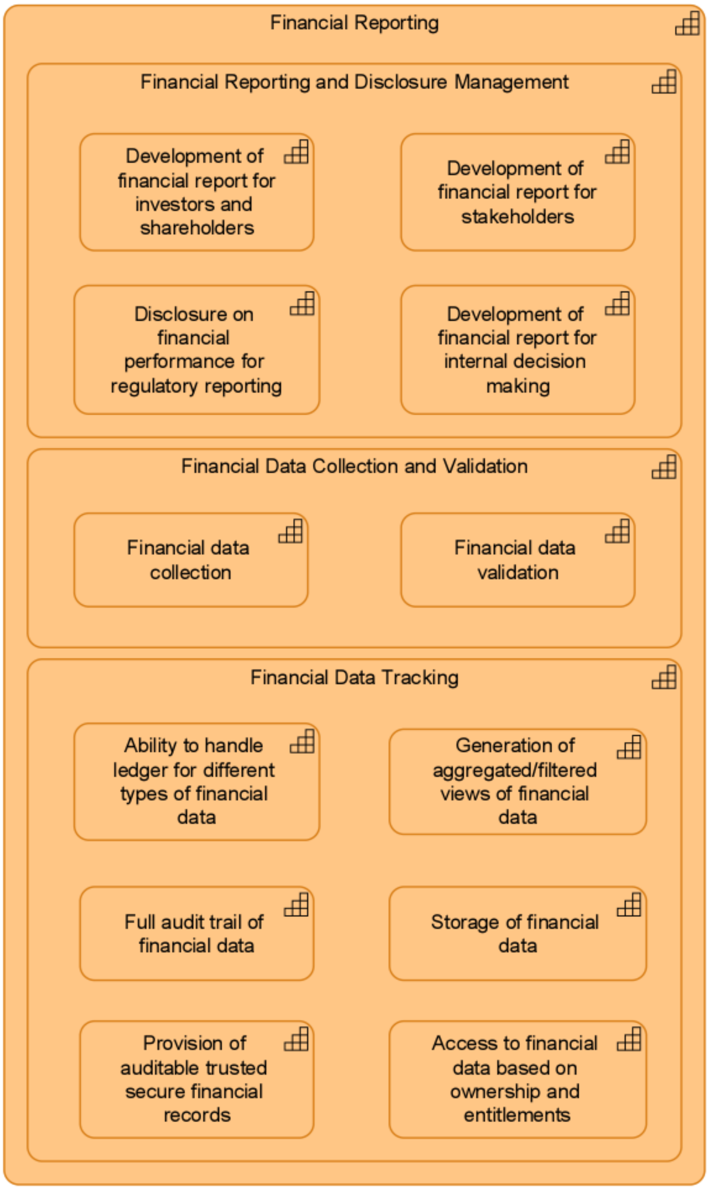


Figure B.1: Business Capability Map for Financial Reporting

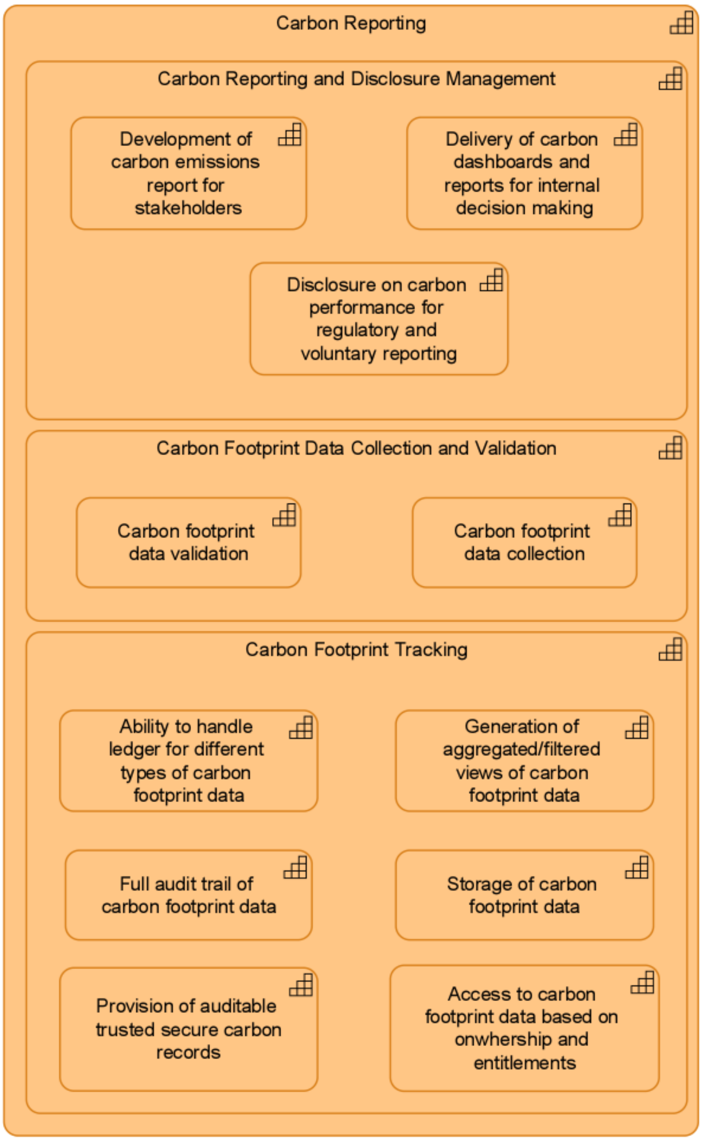


Figure B.2: Business Capability Map for Carbon Reporting

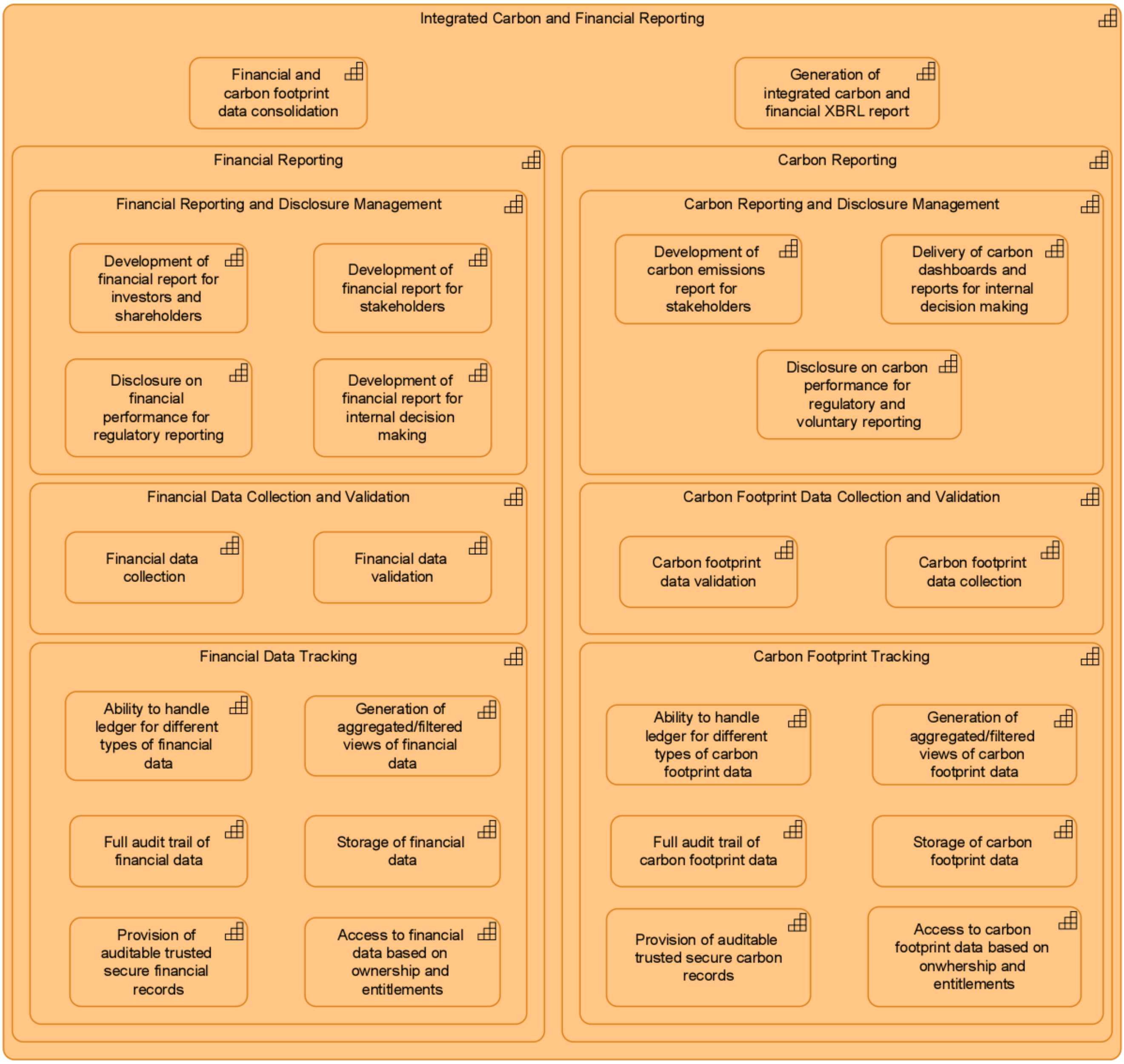


Figure B.3: Business Capability Map

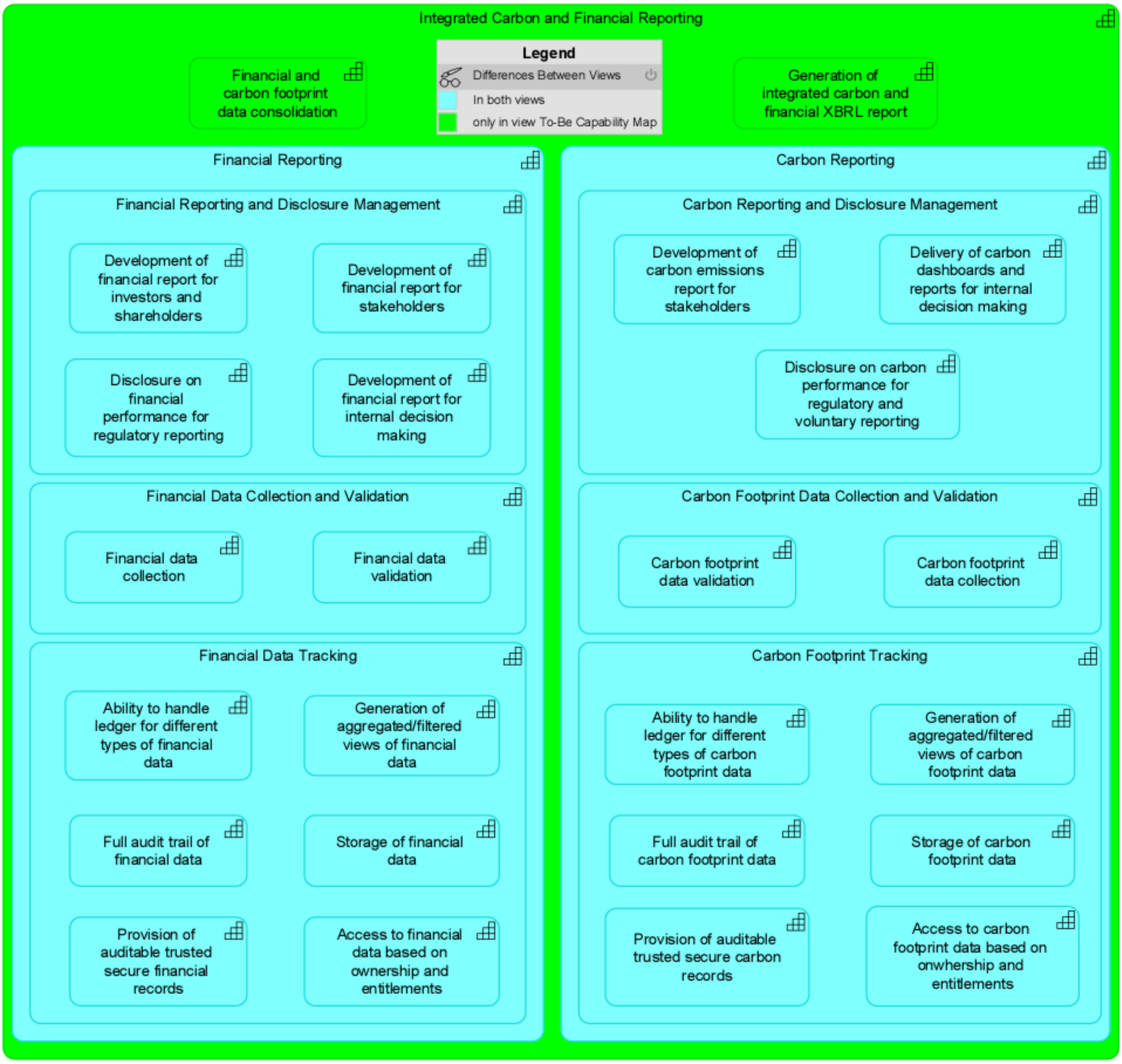


Figure B.4: Gap Analysis for Business Capability Map

B.2 Business Architecture

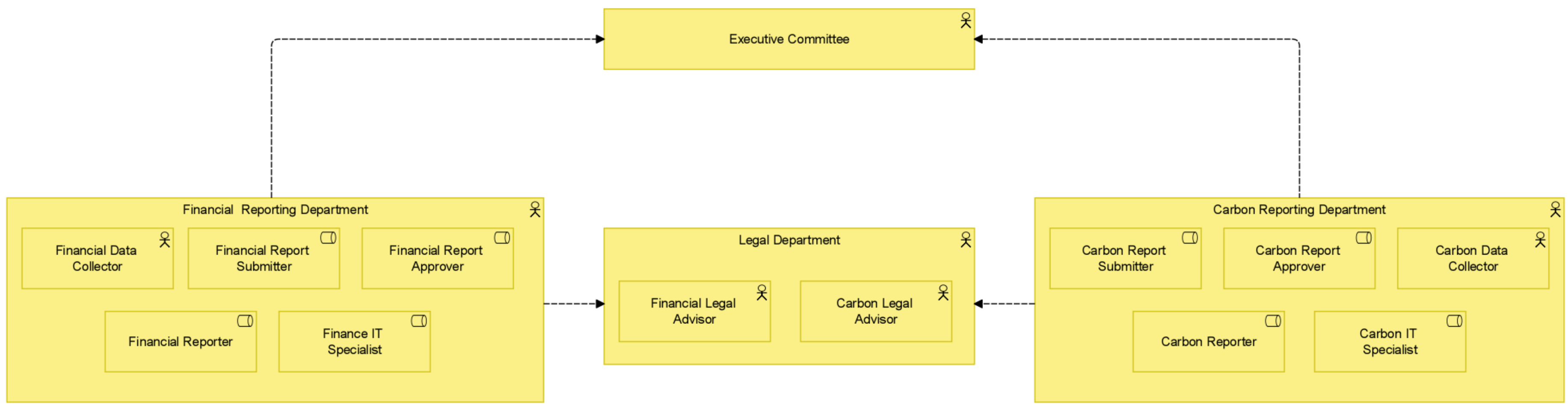


Figure B.5: Baseline Organization Structure

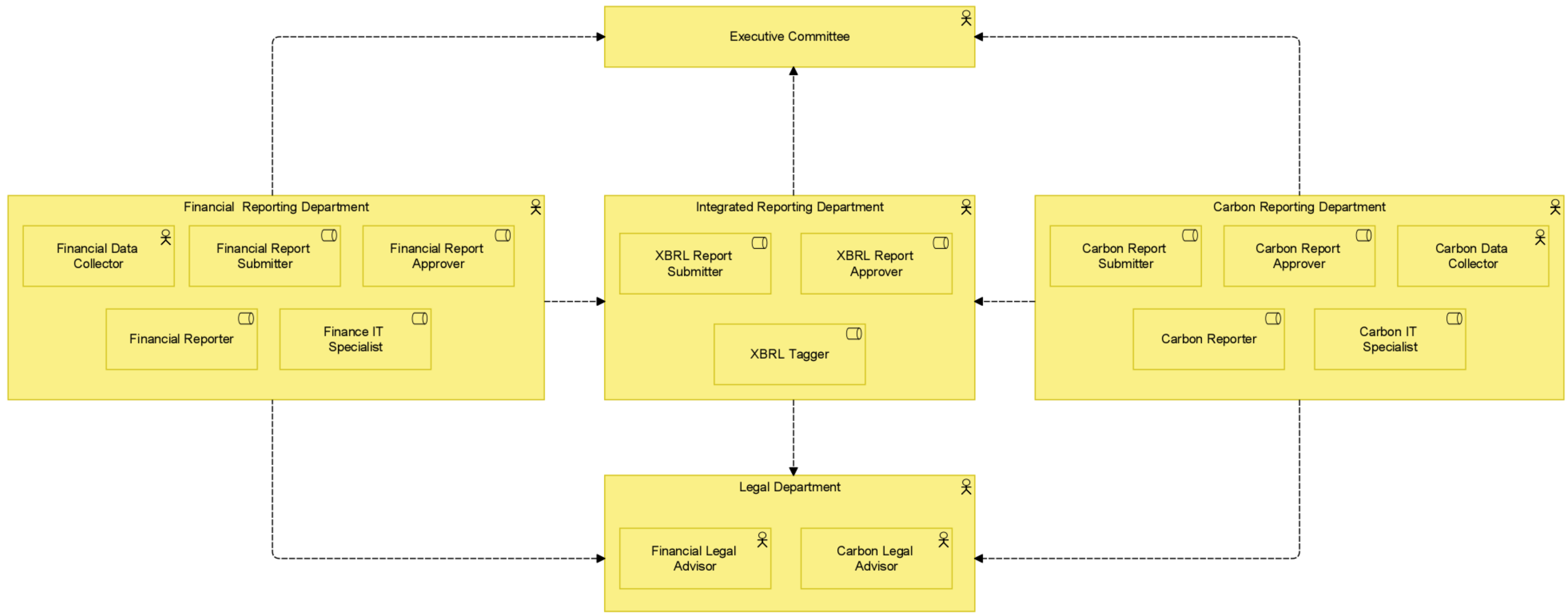


Figure B.6: Target Organization Structure

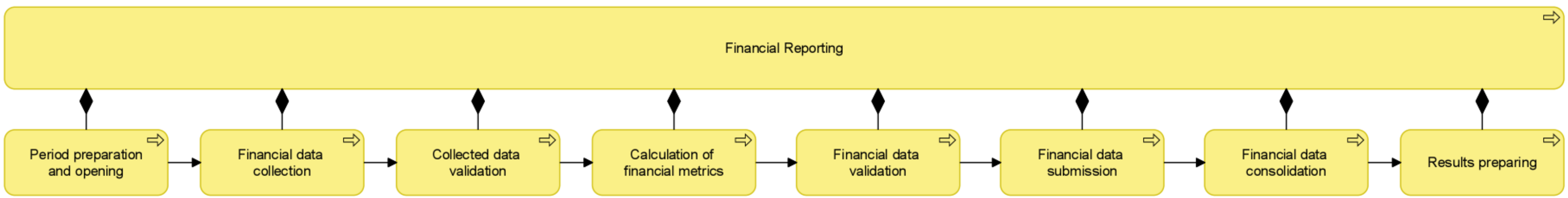


Figure B.7: Baseline Financial Reporting Business Process Model

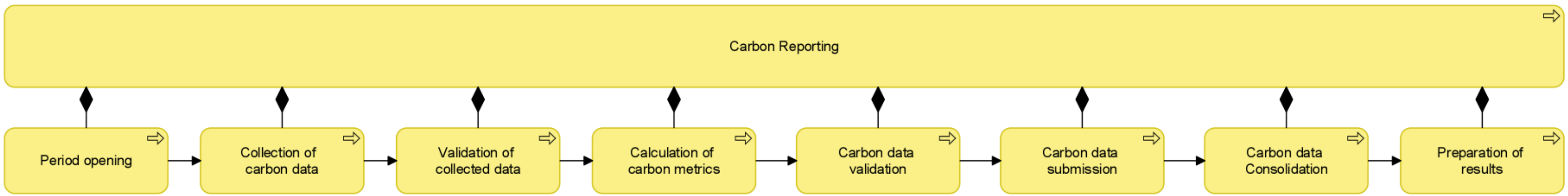


Figure B.8: Baseline Carbon Reporting Business Process Model

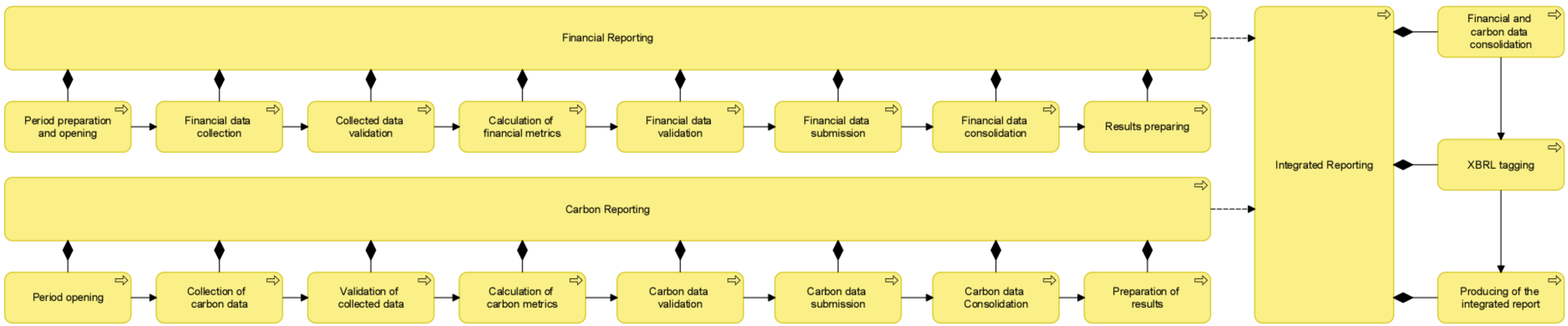


Figure B.9: Target Business Process Model

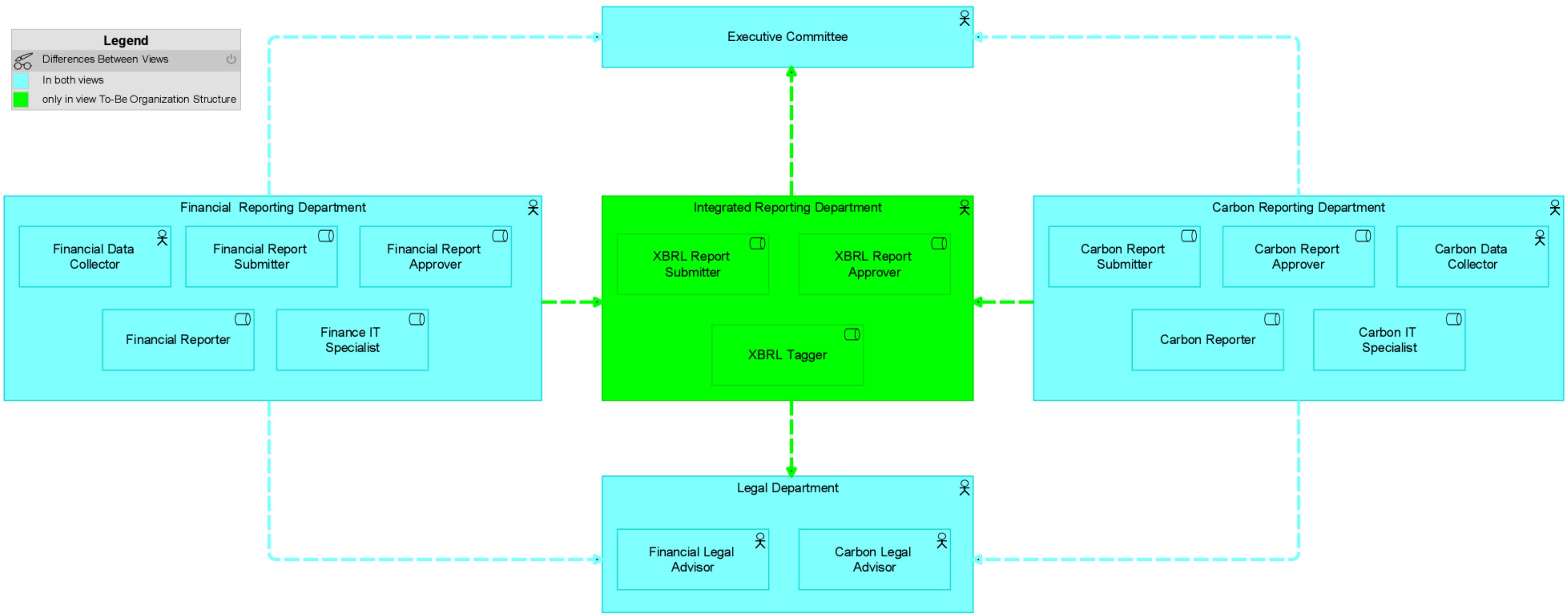


Figure B.10: Gap Analysis for Organization Structure

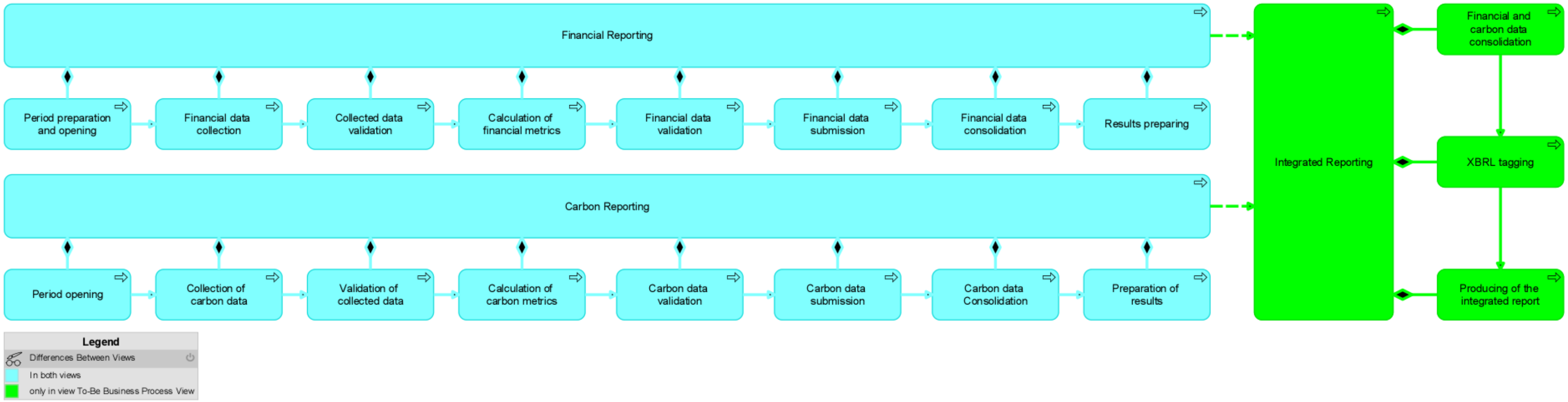


Figure B.11: Gap Analysis for Business Process Model

B.3 Application Architecture

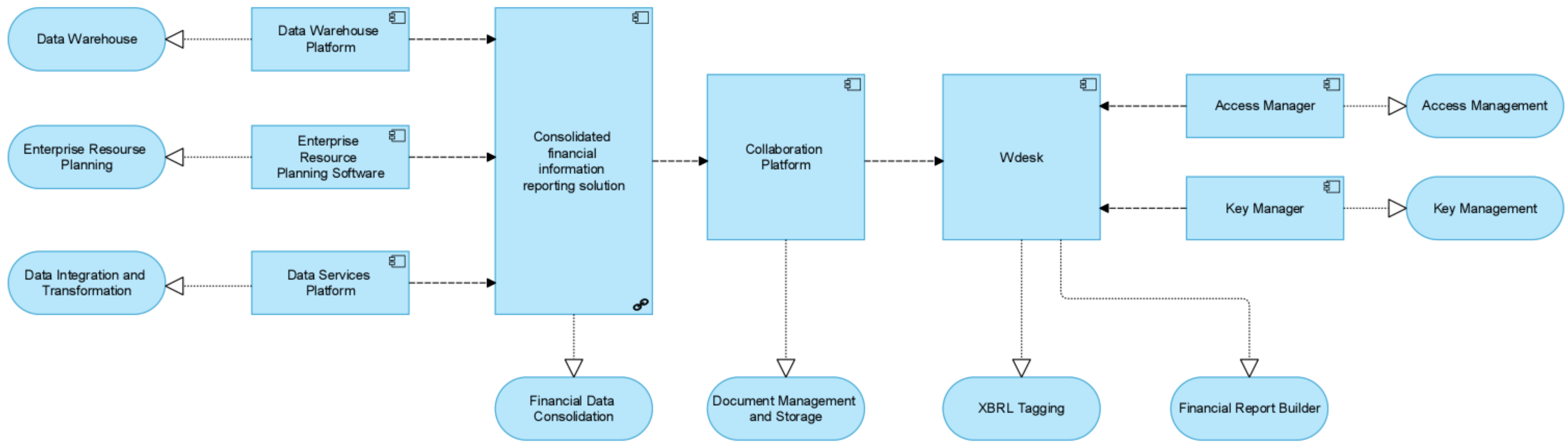


Figure B.12: Baseline Financial Reporting Business Process Model

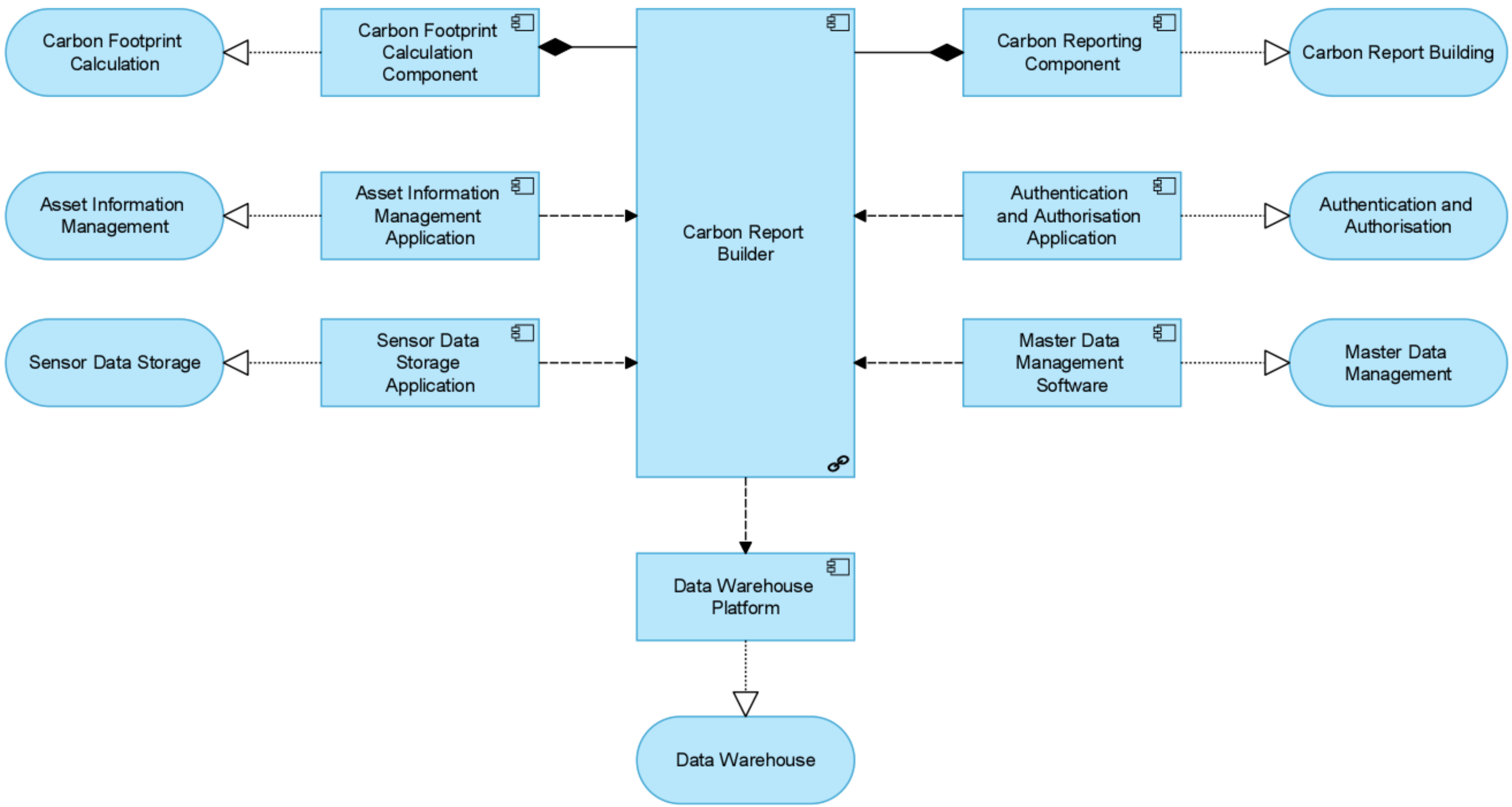


Figure B.13: Baseline Carbon Reporting Business Process Model

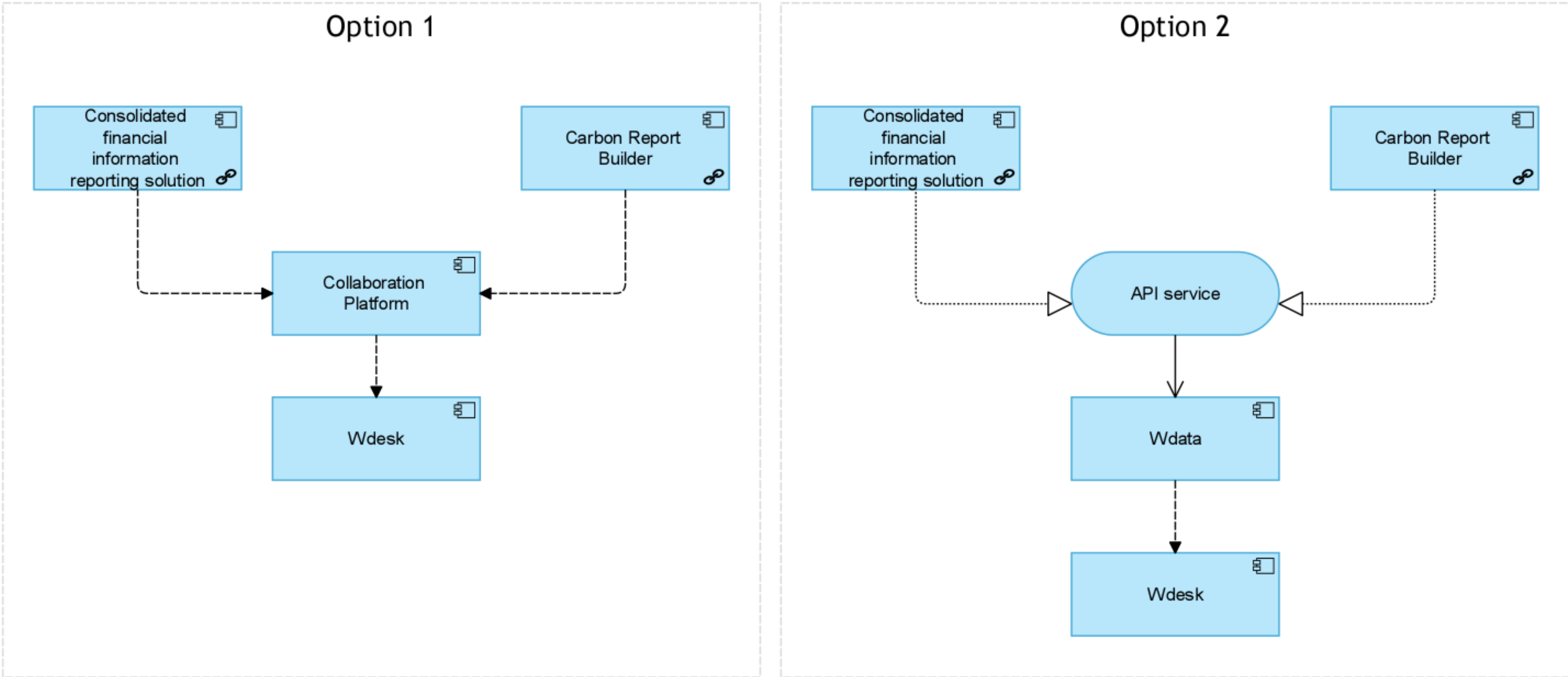


Figure B.14: Two Options of Target High-Level Application Behavior Model

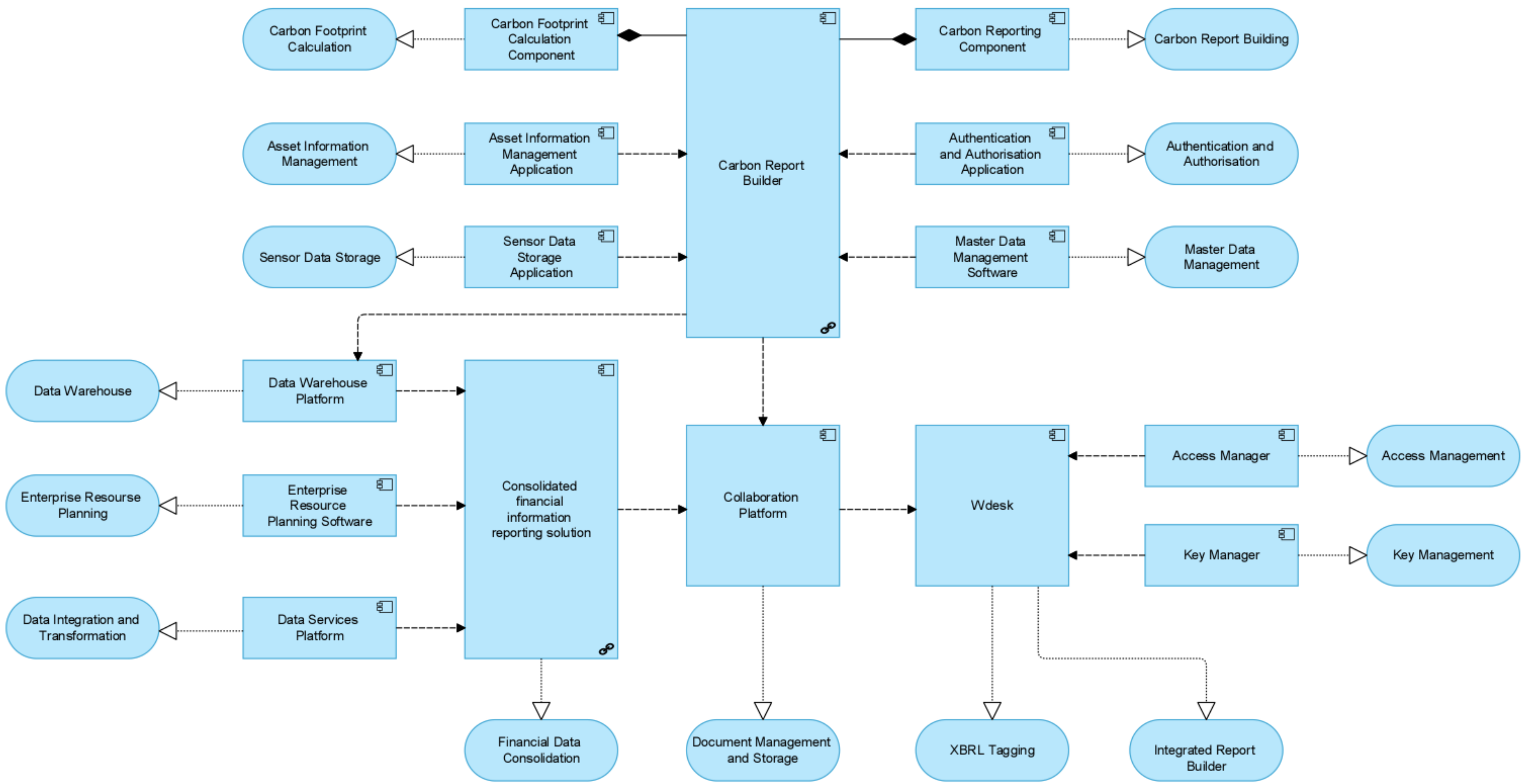


Figure B.15: Target Application Behavior Model (Option 1)

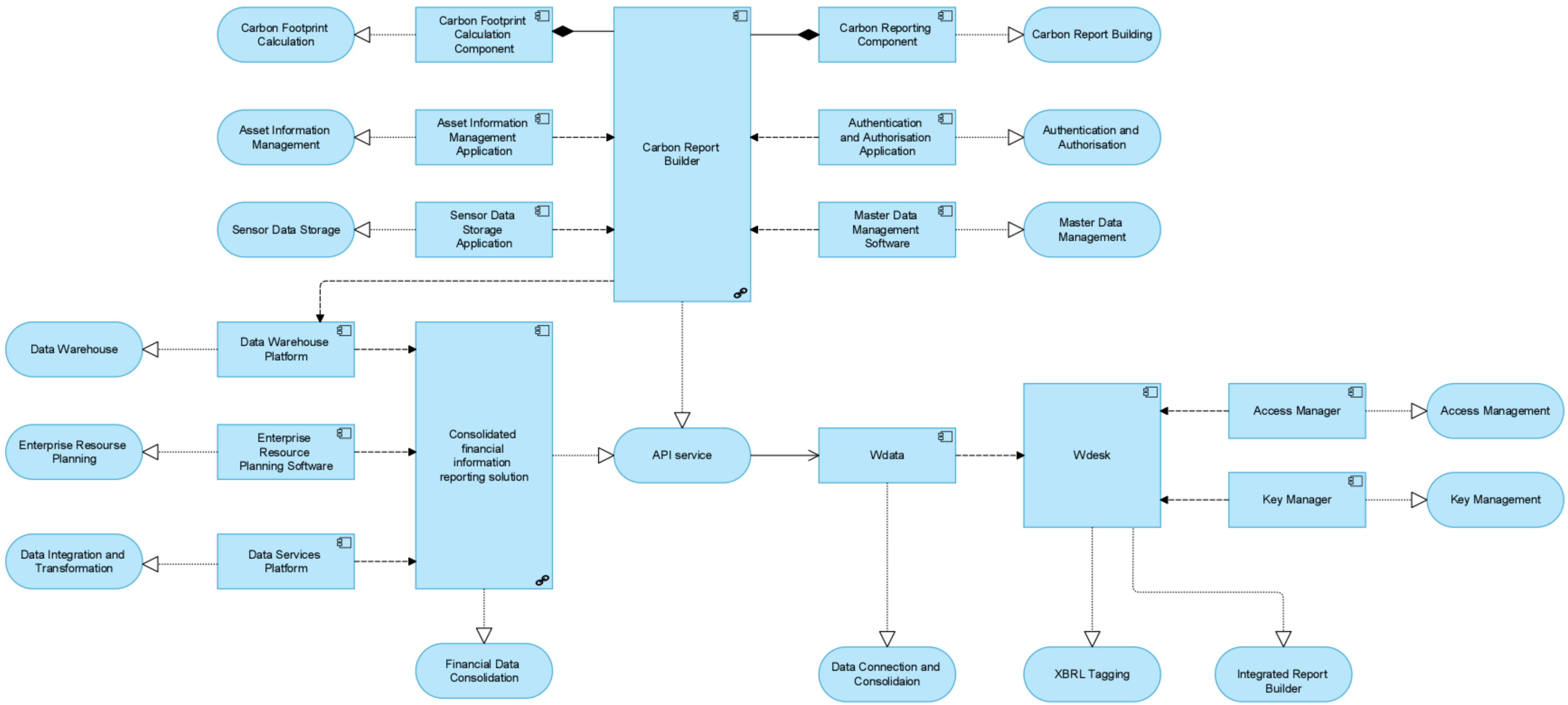


Figure B.16: Target Application Behavior Model (Option 2)

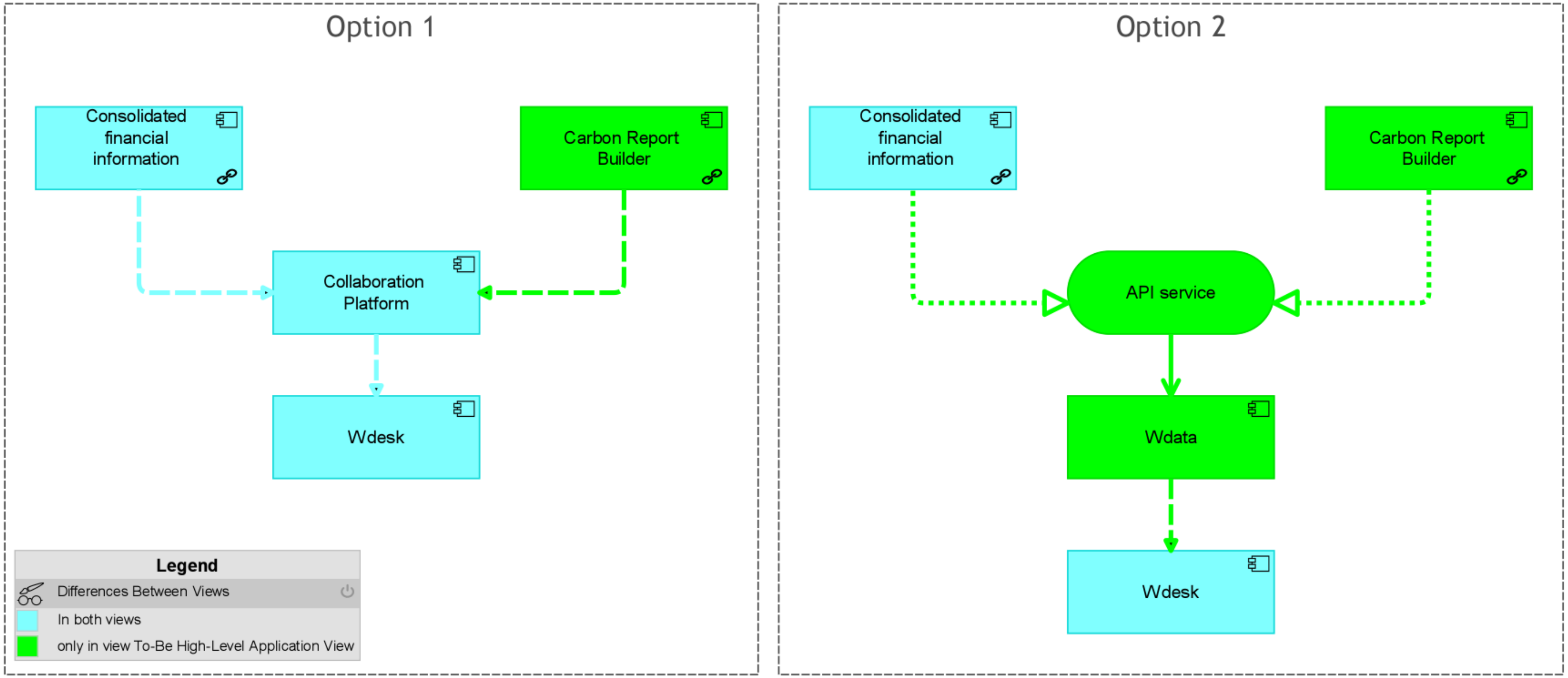


Figure B.17: High-Level Gap Analysis for Application View

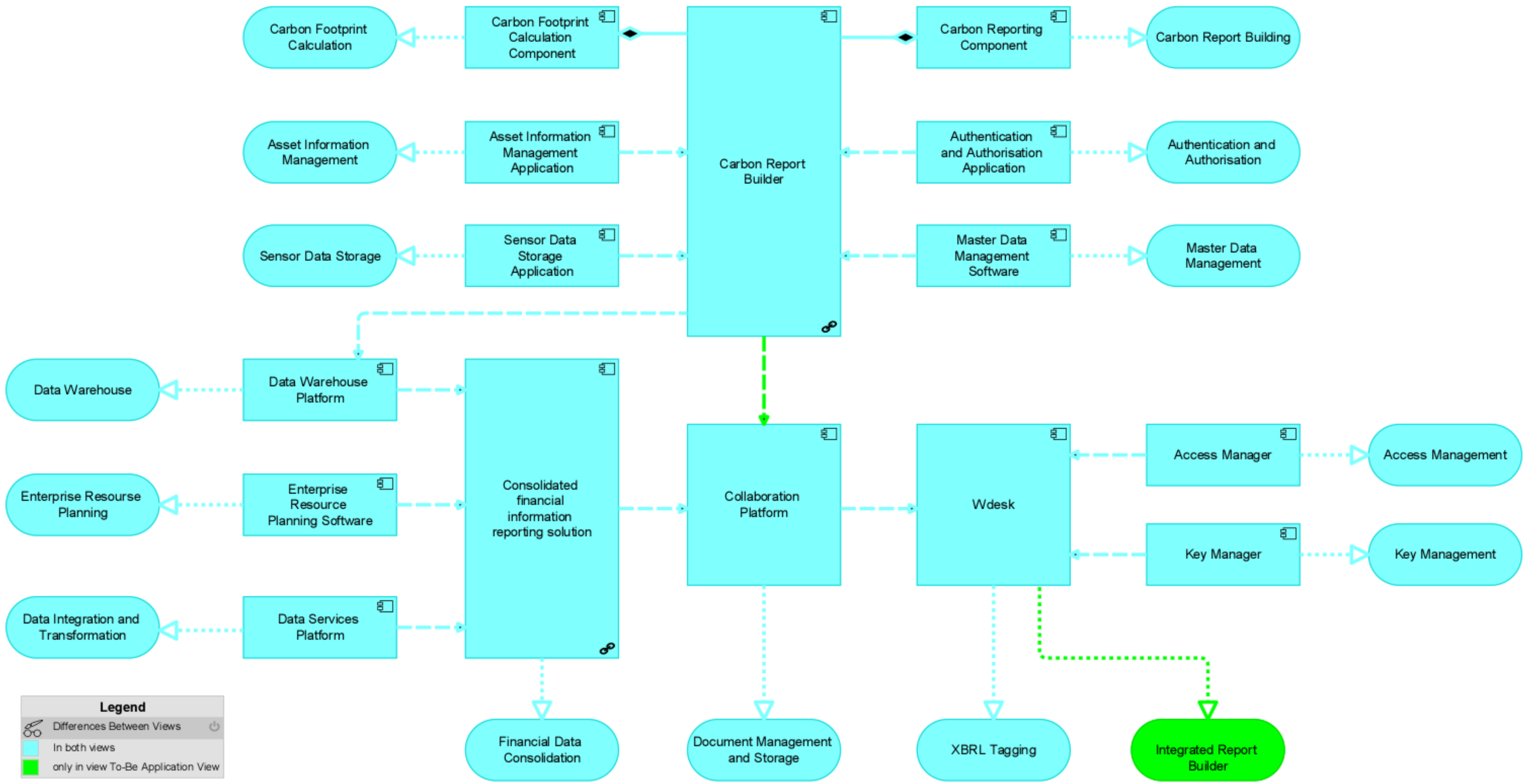


Figure B.18: Gap Analysis for Application View (Option 1)

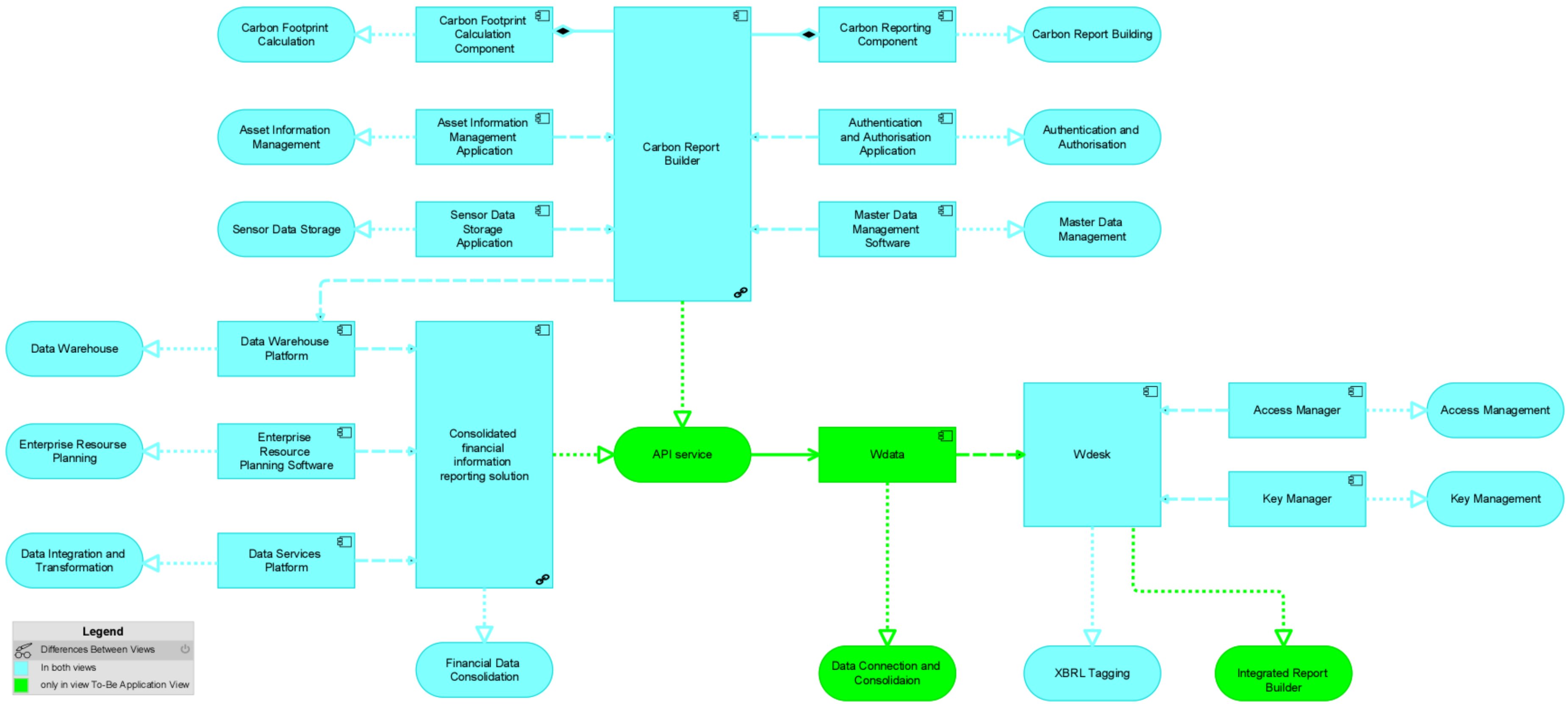


Figure B.19: Gap Analysis for Application View (Option 2)

B.4 Data Architecture

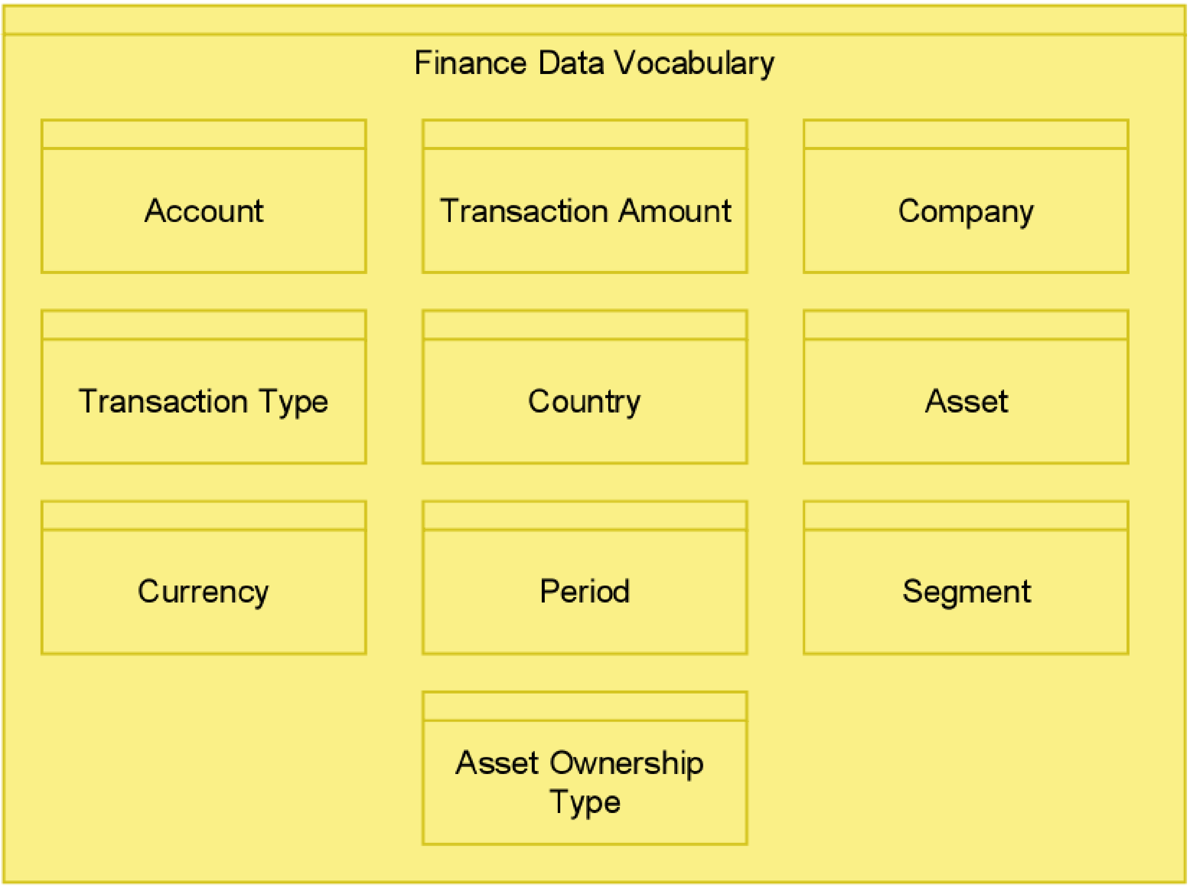


Figure B.20: Baseline Information Structure Model for Financial Reporting

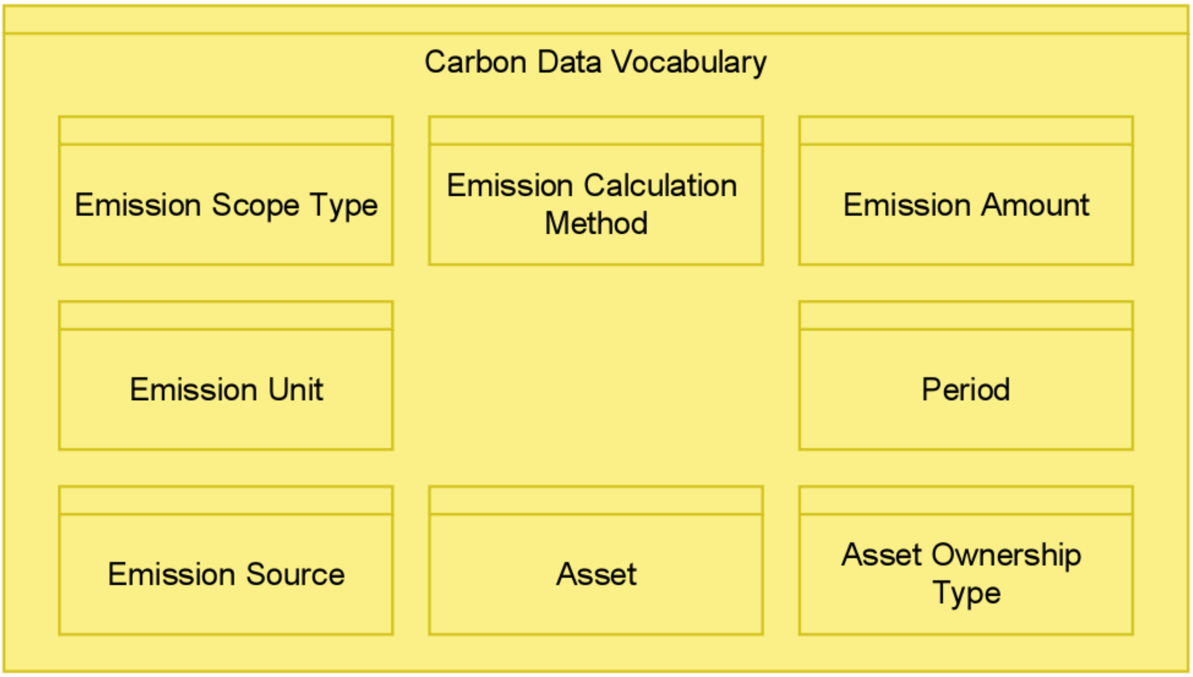


Figure B.21: Baseline Information Structure Model for Carbon Reporting

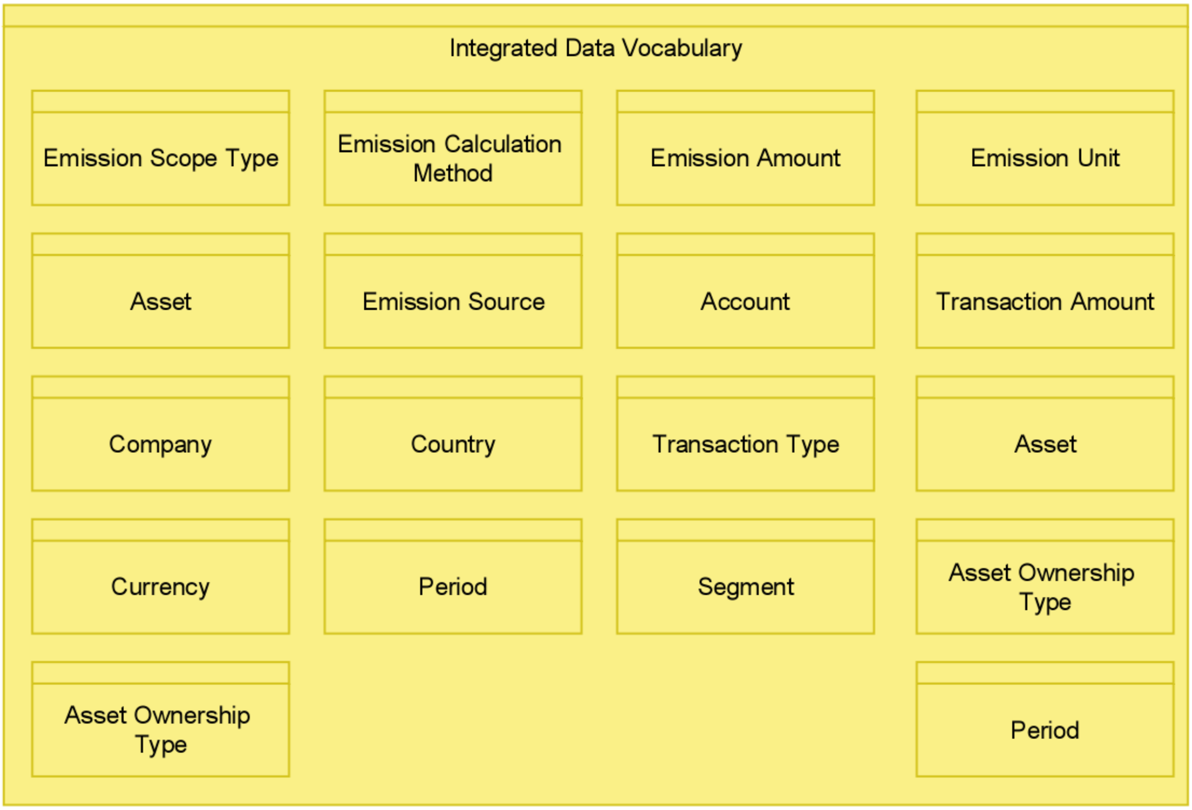


Figure B.22: Target Information Structure Model for Integrated Reporting

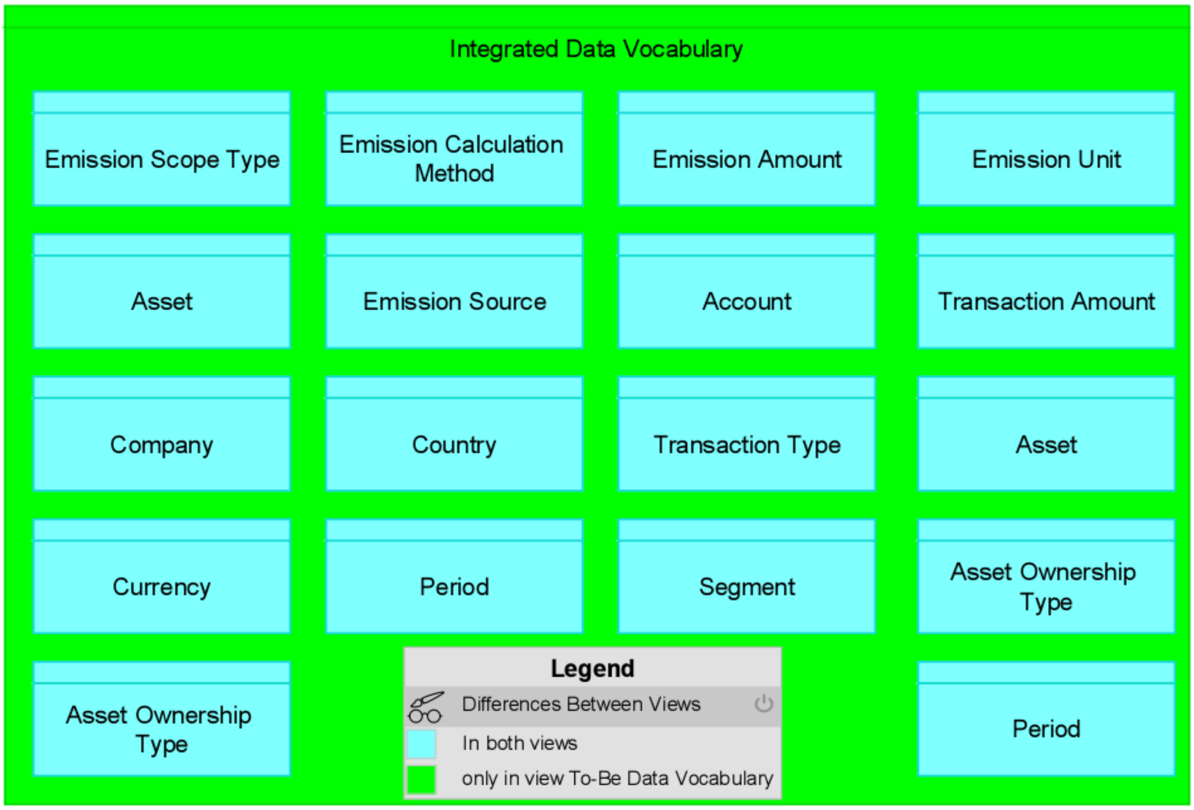


Figure B.23: Gap Analysis for Information Structure View

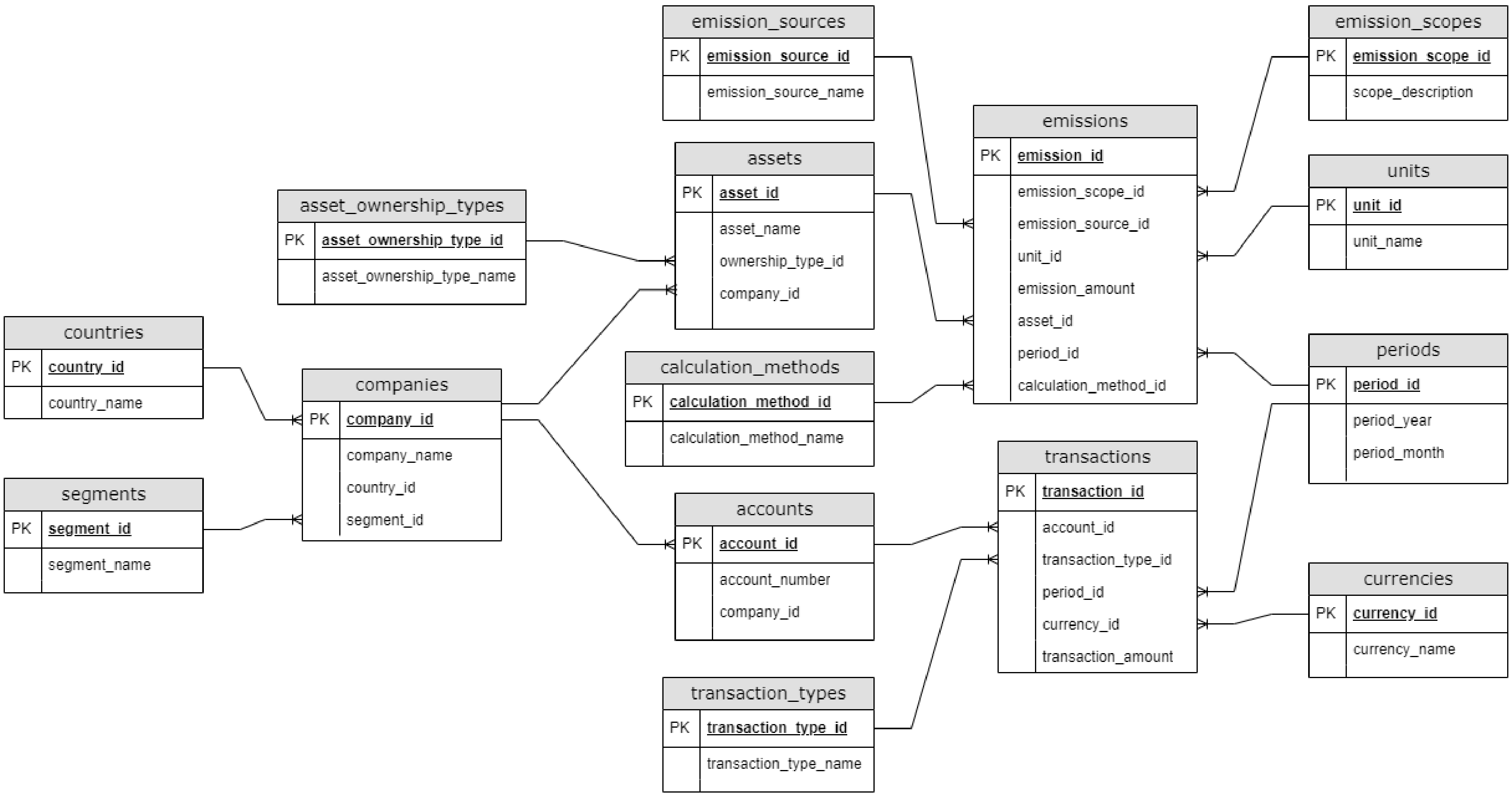


Figure B.24: Entity-Relationship Diagram

B.5 Overall Architecture

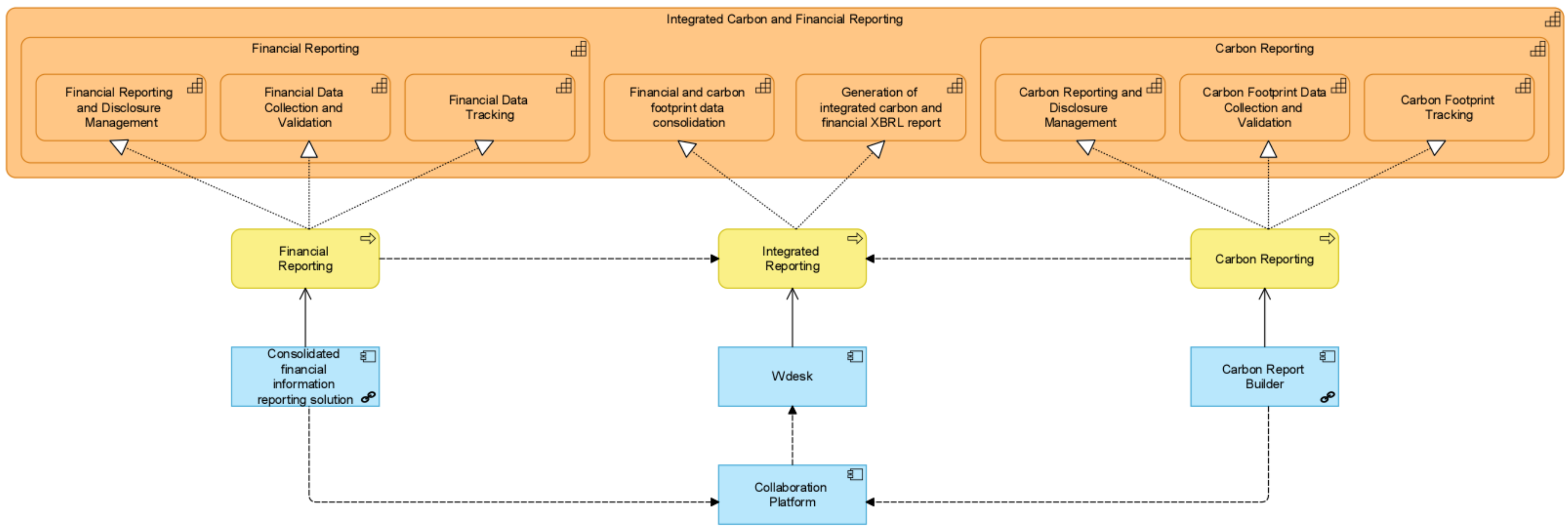


Figure B.25: Overall High-Level Target Architecture (Option 1)

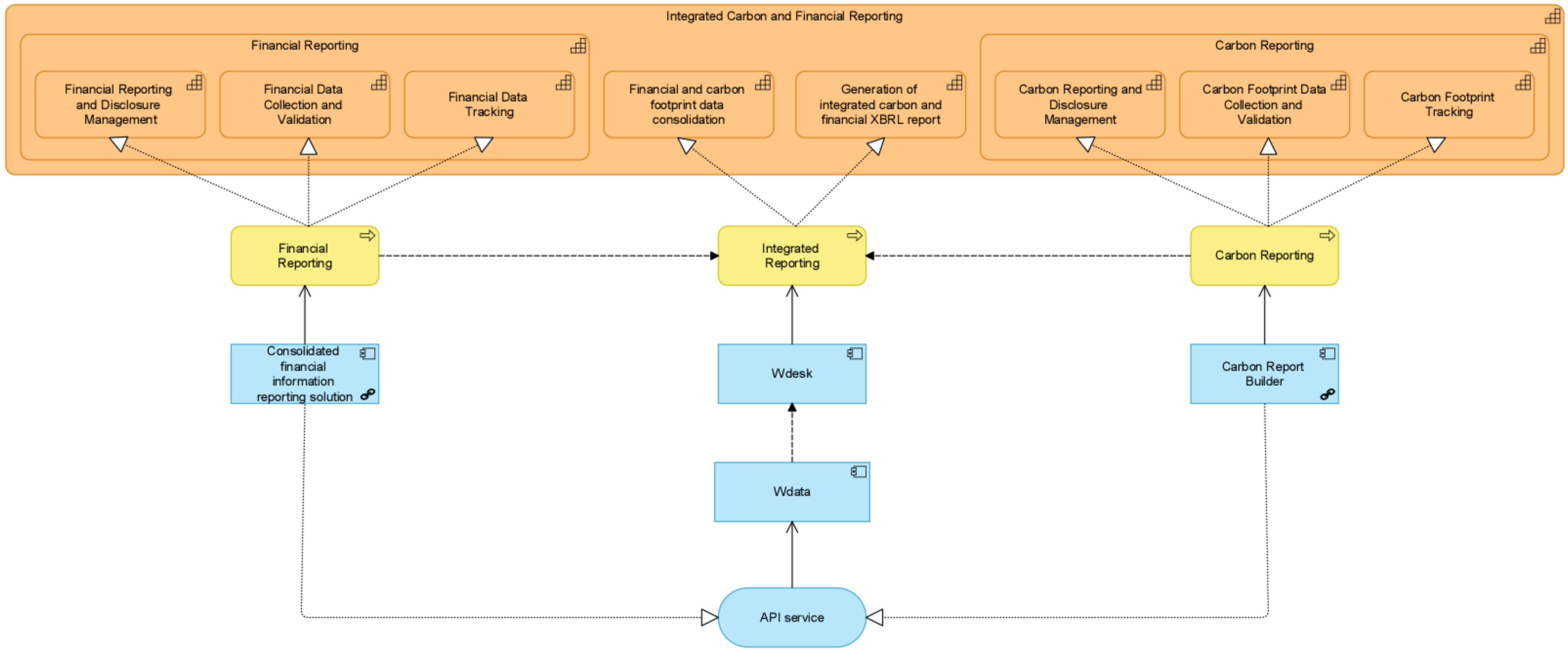


Figure B.26: Overall High-Level Target Architecture (Option 2)

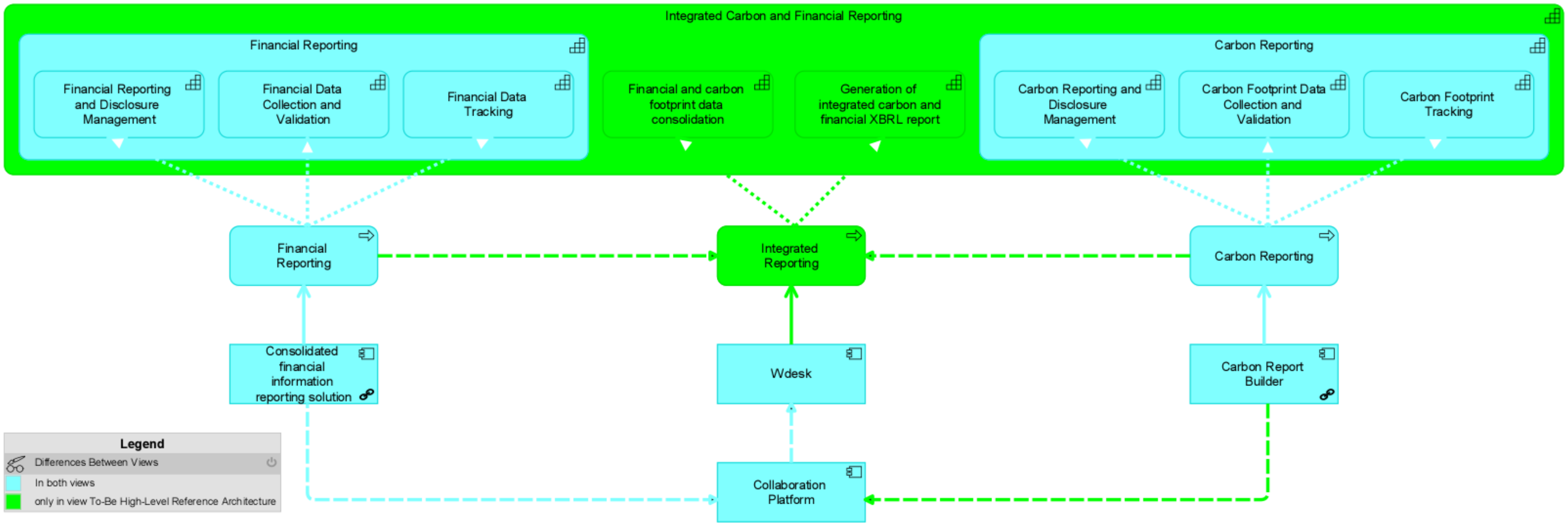


Figure B.27: Gap Analysis Overall High-Level Architecture (Option 1)

Figure B.28: Gap Analysis Overall High-Level Architecture (Option 2)

C EXAMPLE REPORT

C.1 Wdesk Dataset

	Unit	2022	2021	2020	2019	2018
Scope 1 GHG emissions (operational control)	Million tonnes CO2e	51	60	63	70	71
Scope 1 emissions by business						
Upstream	Million tonnes CO2e	8.3	11.7	12.8	12.9	14.8
Integrated Gas	Million tonnes CO2e	14.7	15.5	14.1	16.3	13
Downstream	Million tonnes CO2e	27.3	32.6	35.8	40.2	42.7
Other	Million tonnes CO2e	0.2	0.2	0.2	0.2	0.8
Scope 2 GHG emissions (operational control)						
Scope 2 emissions - market-based method	Million tonnes CO2e	7	8	8	10	11
Scope 2 emissions - location-based method	Million tonnes CO2e	8	9	10	11	11
Scope 2 emissions by business (market-based method)						
Upstream	Million tonnes CO2e	0.5	0.6	0.6	1.1	1.4
Integrated Gas	Million tonnes CO2e	1.4	1.4	1.5	1.6	2.4
Downstream	Million tonnes CO2e	5.2	5.6	6	6.9	6.8
Other	Million tonnes CO2e	0.1	0.1	0.1	0.2	0.2
Scope 2 emissions by business (location-based method)						
Upstream	Million tonnes CO2e	0.4	0.6	0.6	1.1	1.2
Integrated Gas	Million tonnes CO2e	2.4	2.6	2.7	2.7	2.4
Downstream	Million tonnes CO2e	5.2	5.5	6.1	7.1	6.8
Other	Million tonnes CO2e	0.2	0.1	0.2	0.2	0.2
Operating expenses	$ million	39477	35964	34789	37893	39316
Integrated Gas	$ million	8828	7271	6816	6968	6381
Upstream	$ million	10364	10324	10650	11209	11297
Downstream	$ million	19745	17848	16819	19230	21236
Other	$ million	540	524	505	486	403
Adjusted Earnings	$ million	39870	19289	4846	16462	21404
Of which:						
Integrated Gas	$ million	17882	8805	4011	8574	9407
Upstream	$ million	17319	8015	-2426	4898	6489
Downstream	$ million	7473	5583	6903	6908	7846
Other	$ million	-2805	-3115	-3642	-3918	-2337
Cash capital expenditure						
Capital expenditure	$ million	22600	19000	16585	22971	23011
Cash capital expenditure	$ million	24833	19698	17827	23919	24078
Of which:						
Integrated Gas	$ million	7734	5861	4494	4596	4324
Upstream	$ million	8143	6168	7099	9845	11629
Downstream	$ million	8669	7448	5972	9060	7855
Other	$ million	287	221	262	418	269

C.2 Wdesk Report

Example Integrated Report

General Information

Table 1. General Information Data (from 2022 Sustainability and Annual Report)

Metric	Unit	2022	2021	2020	2019	2018
Scope 1 emissions (operational control)	Million tonnes CO2e	51	60	63	70	71
Scope 2 emissions - location-based method (operational control)	Million tonnes CO2e	8	9	10	11	11
Scope 2 emissions - market-based method (operational control)	Million tonnes CO2e	7	8	8	10	11
Operating expenses	$ million	39477	35964	34789	37893	39316
Capital expenditure	$ million	22600	19000	16585	22971	23011
Cash capital expenditure	$ million	24833	19698	17827	23919	24078

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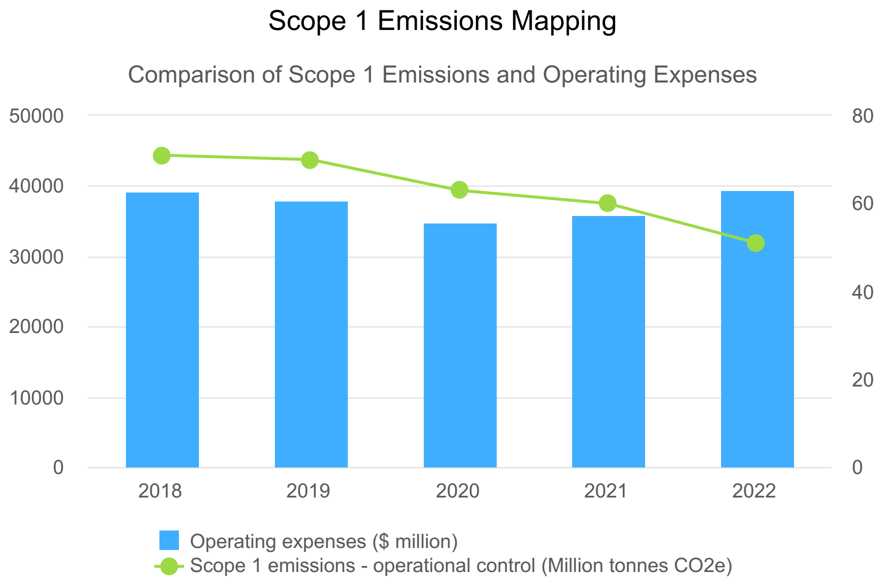


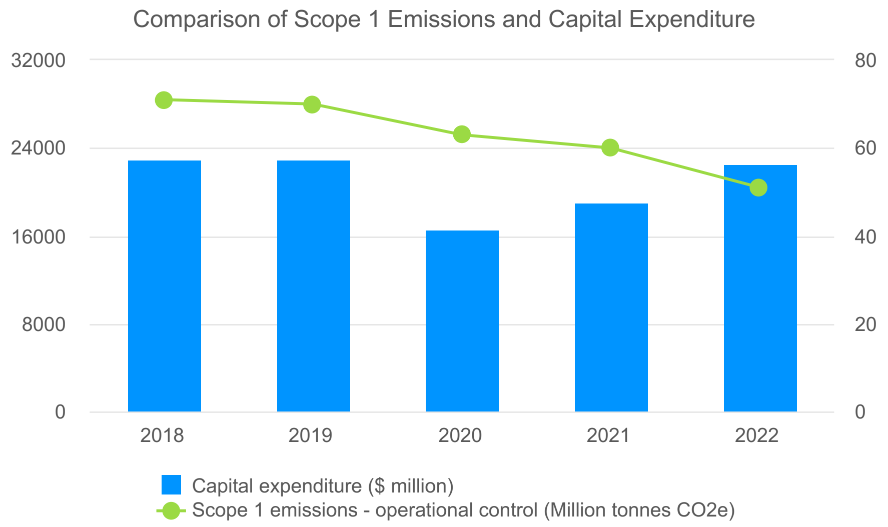
Cost of Emissions Management: In general, there is a decreasing trend in Scope 1 emissions from 2018 to 2022, while operating expenses have remained relatively stable. This suggests that Shell has been successful in managing its emissions without significant increases in operating expenses. It indicates that the company may have implemented cost-effective emission reduction strategies or invested in more energy-efficient technologies.

Operational Efficiency: The decrease in Scope 1 emissions from 2018 to 2022, combined with stable operating expenses, indicates improved operational efficiency in managing emissions. This suggests that Shell has been able to reduce its emissions while maintaining its operational costs. Investors can view this positively as it demonstrates the company's ability to optimize operations and reduce its environmental impact without incurring substantial additional expenses.

Regulatory Risks and Compliance Costs: While the data provided doesn't explicitly outline regulatory risks or compliance costs, a decreasing trend in Scope 1 emissions over the years suggests that Shell has been proactive in managing potential regulatory risks. By investing in emission reduction initiatives, the company may be mitigating future compliance costs associated with changing environmental regulations.

Sustainability Performance: The decrease in Scope 1 emissions from 2018 to 2022 indicates Shell's commitment to reducing its environmental impact. This commitment is further supported by the relatively stable operating expenses, suggesting that the company has allocated resources to emission reduction initiatives. Investors focused on sustainability would likely view this positively, as it demonstrates the company's dedication to environmental responsibility.

In summary, based on the provided data, Shell has shown a decreasing trend in Scope 1 emissions while maintaining stable operating expenses. This indicates successful emissions management, improved operational efficiency, potential mitigation of regulatory risks, and a commitment to sustainability. These factors can positively impact the financial implications for investors, showcasing the company's ability to balance environmental concerns with cost-effective operations.



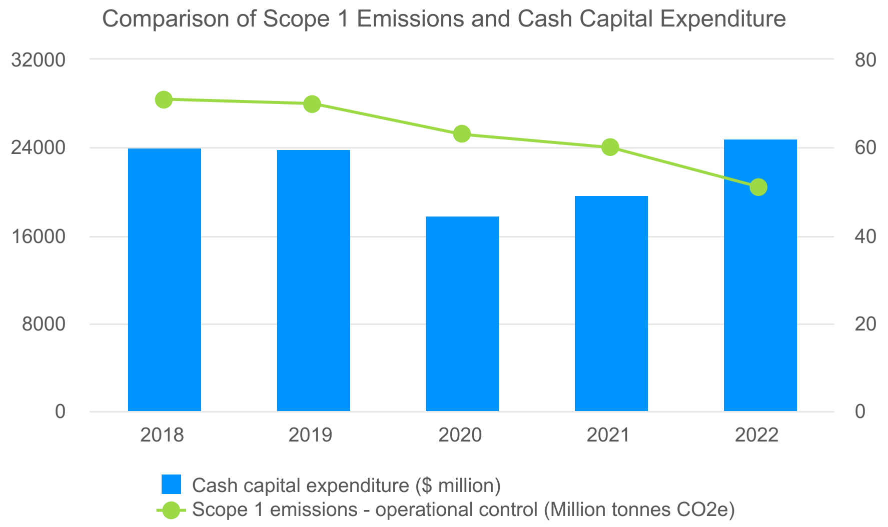
Investment in Emission Reduction: The data does not explicitly provide information on specific emission reduction projects or initiatives. However, the increase in capital expenditure from 2018 to 2022 suggests that Shell has been investing in its capital assets, which could potentially include projects aimed at reducing Scope 1 emissions. Investors can view this positively, as it indicates a financial commitment to addressing the company's direct emissions.

Long-term Cost Savings: While the data does not directly capture the long-term cost savings associated with emission reduction investments, it is possible that investing in cleaner technologies and emission reduction projects could lead to lower operational costs over time. By adopting more energy-efficient processes and technologies, Shell may be able to reduce its energy consumption and associated expenses. Investors should consider the potential cost-saving benefits of these investments and the timeline for realizing those savings.

Regulatory Compliance: Higher Scope 1 emissions can indicate potential regulatory risks and compliance costs. By investing in emission reduction projects and technologies, Shell may be mitigating these risks and ensuring compliance with environmental regulations. The capital expenditure allocated to emission reduction initiatives suggests a financial commitment to meet regulatory requirements. Investors should consider the potential penalties or fines associated with non-compliance and the company's efforts to address these risks.

Technological Advancements: The capital expenditure figures indicate the company's investment in technological advancements and innovation. While the data does not explicitly specify the focus of these investments, a higher capital expenditure in relation to emissions may suggest a commitment to research and development of new technologies aimed at reducing emissions. Investors interested in technological leadership and sustainability may see this as a positive indication of Shell's strategic positioning.

In summary, based on the provided data, Shell's increasing capital expenditure suggests a financial commitment to investment in capital assets, which could potentially include emission reduction projects. This commitment reflects a proactive approach to sustainability and environmental responsibility. While the data does not provide a detailed breakdown of emission reduction investments or specific cost savings, investors should consider the potential long-term cost savings, regulatory compliance, and technological advancements associated with these investments.



Financial Commitment to Emission Reduction: The increase in cash capital expenditure from 2018 to 2022 suggests that Shell has made a financial commitment to invest in capital assets, which could include emission reduction projects. This indicates a tangible allocation of cash resources towards addressing direct emissions. Investors can view this as a positive signal of the company's commitment to sustainability and environmental responsibility.

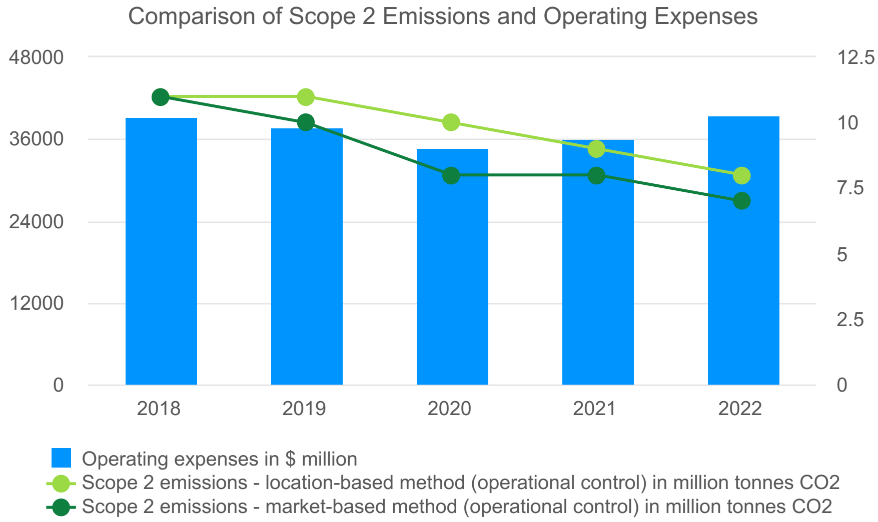
Operational Efficiency and Cost-effectiveness: When comparing the ratio of cash capital expenditure to Scope 1 emissions, we observe a decreasing trend from 2018 to 2022. This suggests that Shell has been able to achieve emission reductions without disproportionately high cash outflows. It indicates operational efficiency and effective resource allocation in managing emissions. Investors may view this positively as it demonstrates the company's ability to achieve emission reduction targets in a cost-effective manner.

Regulatory Compliance and Risk Mitigation: The higher cash capital expenditure in relation to Scope 1 emissions indicates a proactive approach to regulatory compliance and risk mitigation. By investing in emission reduction initiatives, Shell is likely addressing potential regulatory risks and working towards meeting environmental regulations. This can help mitigate potential financial risks associated with non-compliance. Investors should consider the company's efforts to align with evolving regulatory frameworks.

Long-term Financial Impact: Cash capital expenditure represents the actual cash spent on capital investments, which can have a direct impact on the company's short-term liquidity position. By mapping Scope 1 emissions with cash capital expenditure, investors can assess the immediate financial impact of emission reduction initiatives. It provides insights into the company's allocation of financial resources for emissions management and its commitment to balancing sustainability goals with financial stability.

In summary, based on the provided data, Shell's increasing cash capital expenditure demonstrates a financial commitment to invest in emission reduction projects and technologies. The decreasing ratio of cash capital expenditure to Scope 1 emissions suggests operational efficiency in managing emissions. The higher cash capital expenditure indicates a proactive approach to regulatory compliance and risk mitigation. Lastly, investors should consider the company's allocation of financial resources for emissions management and the potential impact on its short-term liquidity position.

Scope 2 Mapping



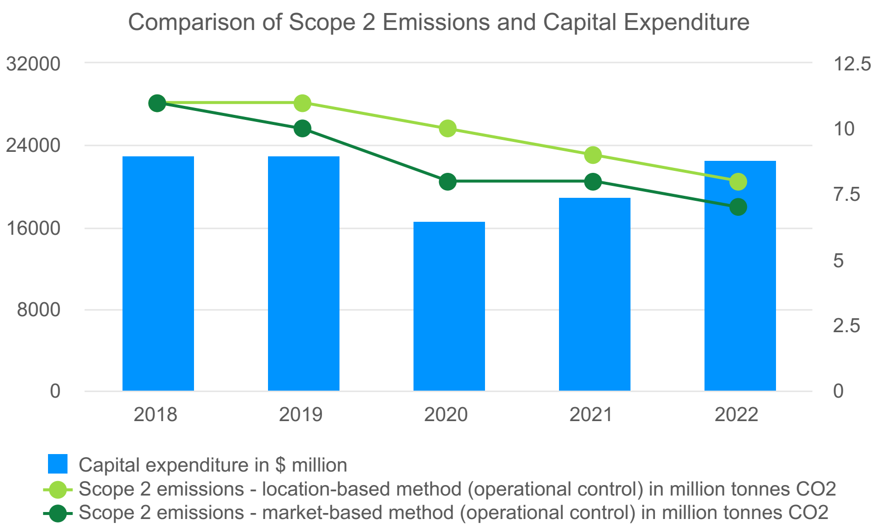
The data provided does not explicitly mention the breakdown of operating expenses or specific details regarding how they relate to Scope 2 emissions.
However, it is worth noting that operating expenses have remained relatively stable during the given period.
While the direct financial implications of operating expenses on Scope 2 emissions are not evident from the provided data, it can be inferred that Shell has managed to maintain stable operating expenses while addressing its emissions impact.

Scope 2 emissions - location-based method and operating expenses:
The decreasing trend in Scope 2 emissions based on the location-based method suggests that Shell has been effectively managing its emissions without incurring significant increases in operating expenses.
This implies that the company may have implemented cost-effective strategies, energy efficiency measures, or renewable energy procurement to reduce emissions without a substantial impact on operating expenses.
Investors can view this as a positive financial implication, as it indicates that Shell has been able to mitigate emissions-related costs while maintaining stable operating expenses.

Scope 2 emissions - market-based method and operating expenses:

The decreasing trend in Scope 2 emissions based on the market-based method, combined with the stable operating expenses, suggests that Shell has been actively addressing its emissions impact while maintaining financial stability.
While the specific relationship between operating expenses and Scope 2 emissions is not explicitly provided, the stable operating expenses may indicate effective cost management in emissions reduction efforts.
Investors may interpret this as a positive sign of Shell's ability to balance environmental responsibility and financial stability.

Overall, the stable operating expenses alongside the decreasing trend in Scope 2 emissions (both methods) suggest that Shell has been effectively managing emissions without incurring significant increases in operating expenses. This implies that the company has implemented cost-effective strategies and potentially invested in energy efficiency measures or renewable energy procurement. Investors can view this as a positive financial implication, indicating Shell's ability to mitigate emissions-related costs while maintaining stable operating expenses and financial stability.



The increase in capital expenditure from 2018 to 2022 indicates that Shell has been investing in its capital assets, potentially including projects aimed at emission reduction, energy efficiency, or renewable energy.
While the data does not provide a breakdown of the specific allocation of capital expenditure, a higher capital expenditure may indicate a financial commitment to addressing emissions and improving the company's environmental performance.

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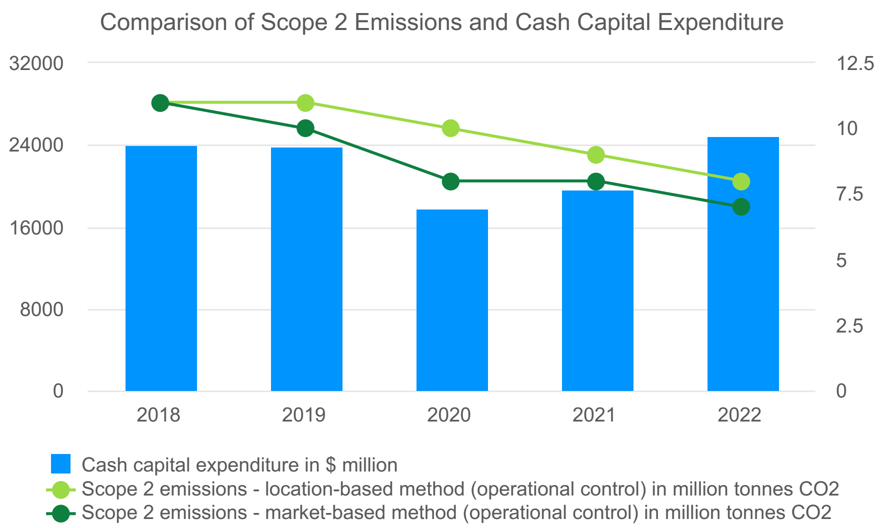
Investors can view this as a positive indication of Shell's proactive approach to sustainability and responsible investment.

Scope 2 emissions - location-based method and capital expenditure:
The decreasing trend in Scope 2 emissions based on the location-based method, combined with the increase in capital expenditure, suggests that Shell has been actively managing its emissions while investing in capital assets.
This indicates that the company may have allocated funds towards emission reduction projects, energy efficiency measures, or renewable energy sources to effectively reduce its emissions.
Investors can view this as a positive financial implication, as Shell demonstrates a commitment to environmental responsibility and potential long-term cost savings through emission reduction investments.

Scope 2 emissions - market-based method and capital expenditure:
The decreasing trend in Scope 2 emissions based on the market-based method, along with the increase in capital expenditure, indicates that Shell has been addressing its emissions impact and investing in capital assets to reduce its carbon footprint.
While the specific allocation of capital expenditure to emission reduction projects is not provided, the increase in investment suggests a commitment to addressing emissions from a market perspective.
Investors may interpret this as a positive sign of Shell's financial commitment to sustainability and reducing its environmental impact.

Overall, the increasing capital expenditure alongside the decreasing trend in Scope 2 emissions (both methods) suggests that Shell has been actively managing emissions while investing in capital assets to address environmental concerns. This demonstrates the company's commitment to sustainability and potential long-term cost savings through emission reduction investments. Investors can view this as a positive financial implication, indicating Shell's proactive approach to environmental responsibility and the potential for improved financial performance.



The increase in cash capital expenditure from 2018 to 2022 indicates that Shell has been allocating financial resources to invest in capital assets and projects.
While the data does not explicitly specify the breakdown of cash capital expenditure, it is possible that a portion of these funds has been allocated to emission reduction initiatives or projects aimed at improving energy efficiency.
Investors can view the increase in cash capital expenditure as a positive sign of the company's commitment to long-term sustainability and responsible investment.

Scope 2 emissions - location-based method and cash capital expenditure:
The decreasing trend in Scope 2 emissions based on the location-based method suggests that Shell has been effectively managing its emissions without incurring significant increases in cash capital expenditure.
This indicates that the company may have implemented cost-effective strategies, such as energy efficiency measures or renewable energy procurement, to reduce emissions without substantial financial investment.
Investors can view this as a positive financial implication, as it suggests that Shell has been able to mitigate emissions-related costs while maintaining stable cash capital expenditure.

Scope 2 emissions - market-based method and cash capital expenditure:
The decreasing trend in Scope 2 emissions based on the market-based method, combined with the increase in cash capital expenditure, indicates that Shell has been actively addressing its emissions impact and investing in capital assets.

While the specific allocation of cash capital expenditure to emission reduction projects is not provided, the increase in investment suggests a commitment to addressing the company's emissions from a market perspective.
Investors may interpret this as a positive sign of Shell's financial commitment to sustainability and reducing its carbon footprint.

Overall, the increasing cash capital expenditure alongside the decreasing trend in Scope 2 emissions (both methods) suggests that Shell has been effectively managing emissions without significant increases in financial investment. This demonstrates the company's ability to implement cost-effective strategies to mitigate emissions-related costs. Investors can view this as a positive financial implication, indicating Shell's commitment to environmental responsibility while maintaining financial stability.

Information by Segment

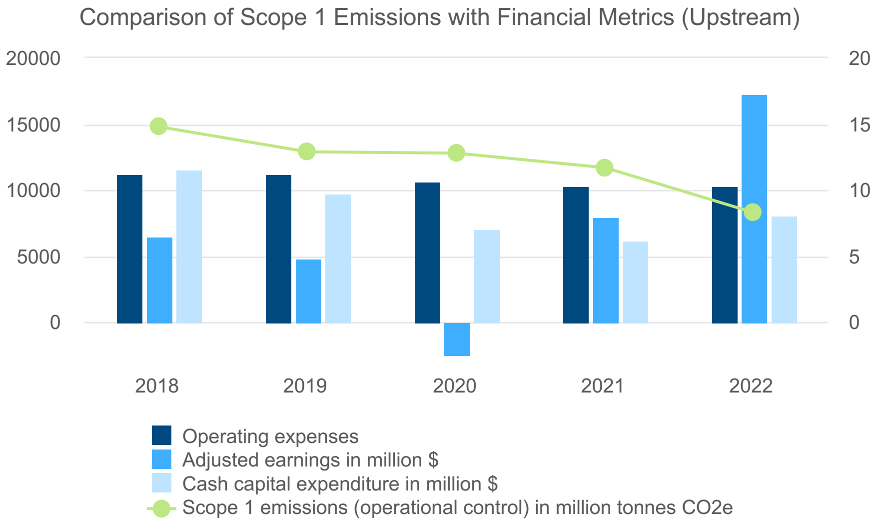
Table 2. Segment Information Data (from 2022 Sustainability and Annual Report)

Metric	Unit	2022	2021	2020	2019	2018
Scope 1 emissions by business						
Upstream	Million tonnes CO2e	8.3	11.7	12.8	12.9	14.8
Integrated Gas	Million tonnes CO2e	14.7	15.5	14.1	16.3	13
Downstream	Million tonnes CO2e	27.3	32.6	35.8	40.2	42.7
Other	Million tonnes CO2e	0.2	0.2	0.2	0.2	0.8
Scope 2 emissions by business (market-based method)						
Upstream	Million tonnes CO2e	0.5	0.6	0.6	1.1	1.4
Integrated Gas	Million tonnes CO2e	1.4	1.4	1.5	1.6	2.4
Downstream	Million tonnes CO2e	5.2	5.6	6	6.9	6.8
Other	Million tonnes CO2e	0.1	0.1	0.1	0.2	0.2
Scope 2 emissions by business (location-based method)						
Upstream	Million tonnes CO2e	0.4	0.6	0.6	1.1	1.2
Integrated Gas	Million tonnes CO2e	2.4	2.6	2.7	2.7	2.4
Downstream	Million tonnes CO2e	5.2	5.5	6.1	7.1	6.8
Other	Million tonnes CO2e	0.2	0.1	0.2	0.2	0.2
Operating expenses						
Integrated Gas	$ million	8828	7271	6816	6968	6381
Upstream	$ million	10364	10324	10650	11209	11297
Downstream	$ million	19745	17848	16819	19230	21236
Other	$ million	540	524	505	486	403
Adjusted earnings						
Integrated Gas	$ million	17882	8805	4011	8574	9407
Upstream	$ million	17319	8015	-2426	4898	6489
Downstream	$ million	7473	5583	6903	6908	7846
Other	$ million	-2805	-3115	-3642	-3918	-2337
Cash capital expenditure						
Integrated Gas	$ million	7734	5861	4494	4596	4324
Upstream	$ million	8143	6168	7099	9845	11629
Downstream	$ million	8669	7448	5972	9060	7855
Other	$ million	287	221	262	418	269

Scope 1 Emissions

To map the Scope 1 emissions data with the provided financial metrics, let's analyze the financial implications for each segment.

Upstream:



Scope 1 emissions (operational control) and Operating expenses:
As Shell's upstream segment reduces its Scope 1 emissions, it can potentially achieve cost savings through improved energy efficiency and operational practices. This can lead to lower operating expenses for exploration, drilling, and production activities. Implementing emission reduction strategies and technologies can optimize resource usage and reduce energy consumption, resulting in improved cost management.

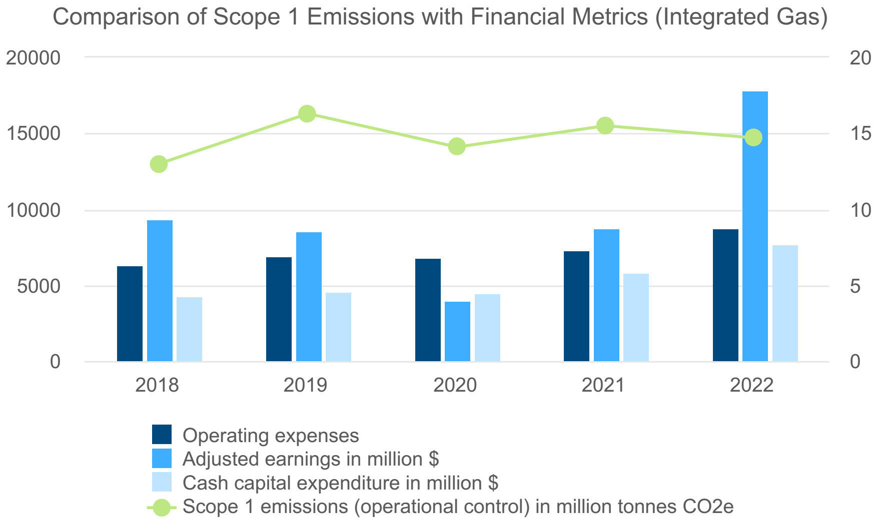
Scope 1 emissions (operational control) and Adjusted earnings:
The reduction in Scope 1 emissions in Shell's upstream segment can positively impact adjusted earnings. By implementing emission reduction measures, Shell can mitigate potential regulatory risks and associated compliance costs. Additionally, as the industry and stakeholders increasingly prioritize environmental sustainability, reducing emissions can enhance Shell's reputation, attract environmentally conscious investors, and potentially improve its upstream segment's earnings performance.

Scope 1 emissions (operational control) and Cash capital expenditure:
Shell's upstream segment's efforts to decrease Scope 1 emissions can influence its cash capital expenditure. By investing in emission reduction technologies and practices,

Shell may allocate capital towards projects that enhance operational efficiency and reduce environmental impact. While this may result in increased short-term expenditure, it positions the upstream segment for long-term sustainability, cost optimization, and potential growth opportunities.

In summary, reducing Scope 1 emissions in Shell's upstream segment can have financial implications such as improved cost management, enhanced earnings performance, and optimized capital expenditure. By aligning financial metrics with emission reduction strategies, Shell's upstream segment can contribute to both environmental sustainability and financial success in the exploration, drilling, and production activities.

Integrated Gas:



Scope 1 emissions (operational control) and Operating expenses:
Similar to the upstream segment, reducing Scope 1 emissions in Shell's integrated gas segment can lead to cost savings through improved energy efficiency and operational practices. By implementing emission reduction strategies and technologies, Shell can optimize resource usage and reduce energy consumption, resulting in lower operating expenses. This can be particularly relevant in the integrated gas segment, which involves liquefied natural gas (LNG) production, as energy-intensive processes are involved.

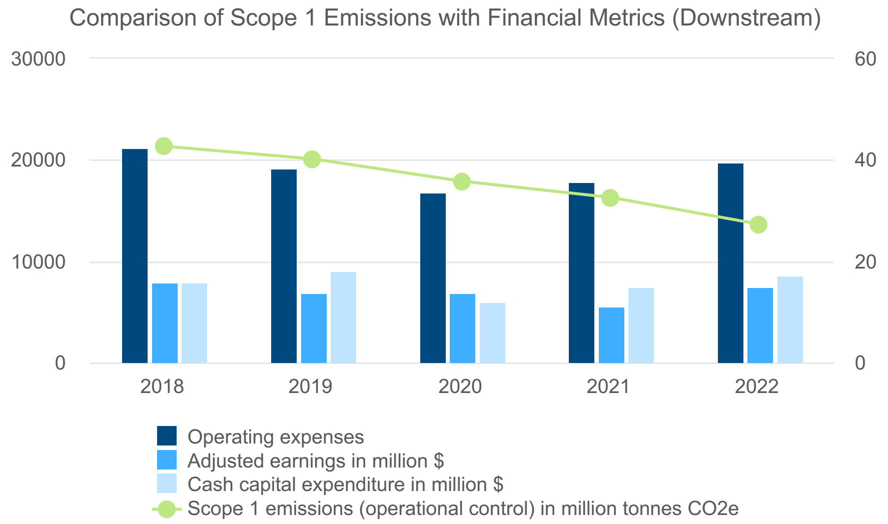
Scope 1 emissions (operational control) and Adjusted earnings:
The reduction in Scope 1 emissions in Shell's integrated gas segment can positively impact adjusted earnings. By implementing emission reduction measures, Shell can

mitigate regulatory risks and associated compliance costs. As environmental sustainability becomes increasingly important to stakeholders, reducing emissions can enhance Shell's reputation, attract environmentally conscious investors, and potentially improve the integrated gas segment's earnings performance. Furthermore, as the demand for cleaner energy sources like natural gas grows, a low-emission integrated gas segment can capture market opportunities and drive profitability.

Scope 1 emissions (operational control) and Cash capital expenditure:
Efforts to decrease Scope 1 emissions in Shell's integrated gas segment can influence its cash capital expenditure. By investing in emission reduction technologies and practices, Shell can allocate capital towards projects that enhance operational efficiency and reduce environmental impact. This may involve implementing carbon capture and storage (CCS) technologies or adopting more efficient LNG production processes. While these investments may lead to increased short-term expenditure, they position the integrated gas segment for long-term sustainability, cost optimization, and potential growth opportunities, as demand for cleaner energy sources continues to rise.

In summary, reducing Scope 1 emissions in Shell's integrated gas segment can result in improved cost management, enhanced earnings performance, and optimized capital expenditure. Aligning financial metrics with emission reduction strategies allows Shell to contribute to environmental sustainability while pursuing financial success in the production of liquefied natural gas and related activities.

Downstream:



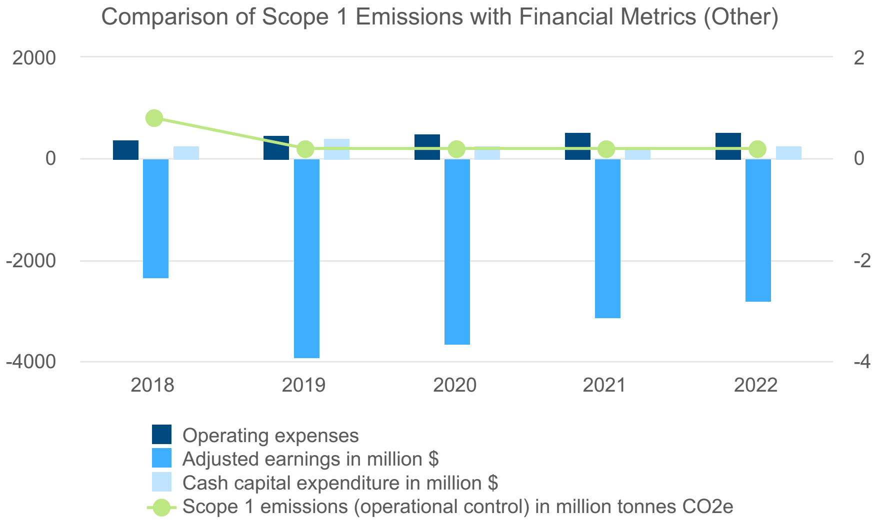
Scope 1 emissions (operational control) and Operating expenses:
Reducing Scope 1 emissions in Shell's downstream segment can potentially lead to cost savings through improved energy efficiency and operational practices. By implementing emission reduction strategies and technologies, Shell can optimize resource usage and reduce energy consumption, resulting in lower operating expenses. This can be particularly relevant in downstream activities such as refining and marketing, where energy-intensive processes are involved.

Scope 1 emissions (operational control) and Adjusted earnings:
The reduction in Scope 1 emissions in Shell's downstream segment can positively impact adjusted earnings. By implementing emission reduction measures, Shell can mitigate regulatory risks and associated compliance costs. Additionally, as environmental sustainability becomes increasingly important to consumers and stakeholders, reducing emissions can enhance Shell's reputation, attract environmentally conscious customers, and potentially improve the downstream segment's earnings performance. Furthermore, by transitioning towards cleaner fuels and renewable energy sources, Shell can capture market opportunities and drive profitability.

Scope 1 emissions (operational control) and Cash capital expenditure:
Efforts to decrease Scope 1 emissions in Shell's downstream segment can influence its cash capital expenditure. By investing in emission reduction technologies and practices, Shell can allocate capital towards projects that enhance operational efficiency and reduce environmental impact. This may involve upgrading refineries to improve energy efficiency, implementing carbon capture and storage (CCS) technologies, or expanding renewable energy infrastructure. While these investments may result in increased short-term expenditure, they position the downstream segment for long-term sustainability, cost optimization, and potential growth opportunities in a changing energy landscape.

In summary, reducing Scope 1 emissions in Shell's downstream segment can contribute to improved cost management, enhanced earnings performance, and optimized capital expenditure. By aligning financial metrics with emission reduction strategies, Shell's downstream segment can support environmental sustainability while pursuing financial success in refining, marketing, and other downstream activities.

Other:



Scope 1 emissions (operational control) and Operating expenses:
The corporate segment of Shell may not directly generate significant Scope 1 emissions as it primarily encompasses the company's administrative and management functions. However, by implementing emission reduction strategies within its operations, the corporate segment can contribute to overall cost savings through improved energy efficiency and operational practices. This can involve adopting sustainable practices within corporate offices, implementing energy-saving measures, and encouraging employee engagement in environmental initiatives.

Scope 1 emissions (operational control) and Adjusted earnings:
While the corporate segment's Scope 1 emissions may not have a direct impact on adjusted earnings, reducing emissions within the corporate operations can enhance Shell's reputation and contribute to its overall earnings performance. By demonstrating a commitment to environmental sustainability through emission reduction measures, Shell can attract environmentally conscious investors, stakeholders, and customers, thereby strengthening its brand and potentially positively impacting its financial performance.

Scope 1 emissions (operational control) and Cash capital expenditure:
Efforts to decrease Scope 1 emissions within the corporate segment can influence cash capital expenditure by directing investments towards sustainable infrastructure, technologies, and practices. This can include initiatives such as energy-efficient office buildings, renewable energy installations, and carbon offset programs. While these investments may result in increased short-term expenditure, they align with the broader

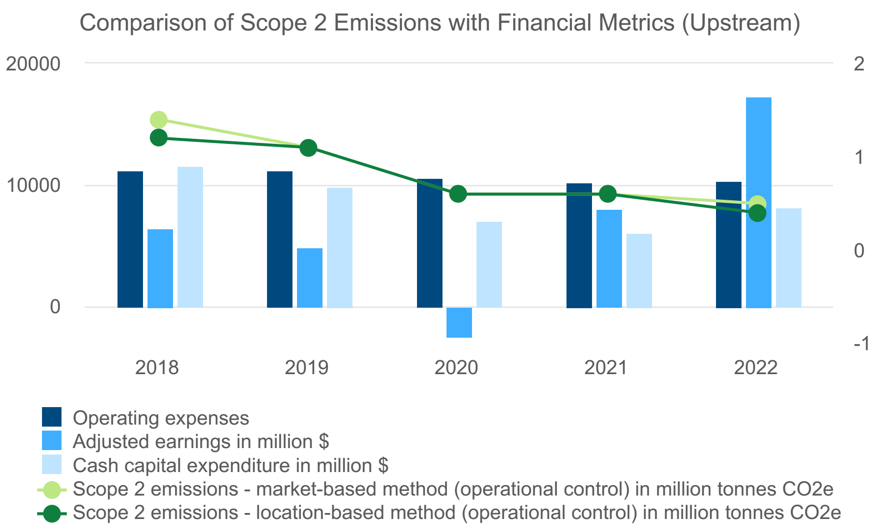
environmental objectives of the company and can contribute to long-term sustainability and cost optimization.

In summary, while the corporate segment of Shell may not directly generate substantial emissions, implementing emission reduction strategies and practices within the segment can contribute to cost savings, enhance the company's reputation, and align with its broader sustainability goals. By integrating emission reduction measures into the corporate operations, Shell can foster a culture of environmental responsibility and contribute to the financial success of the organization as a whole.

Scope 2 Emissions

To assess the financial implications of Scope 2 emissions based on the provided data, let's analyze the financial metrics for each segment.

Upstream:



Scope 2 emissions:

When we examine the Scope 2 emissions data, we see that both the market-based and location-based emissions have shown a consistent decline over the five-year period. This downward trend indicates Shell's efforts to reduce its environmental impact and transition to a more sustainable energy model.

Operating expenses:

Operating expenses have generally decreased over the years.

The declining trend in operating expenses suggests that Shell has implemented cost-saving measures, operational efficiencies, or other strategies to optimize its expenses. The reduction in Scope 2 emissions might have played a role in driving down operating expenses, such as through energy efficiency initiatives or the utilization of renewable energy sources. This aligns with Shell's commitment to environmental sustainability while also potentially contributing to cost savings.

Adjusted earnings:

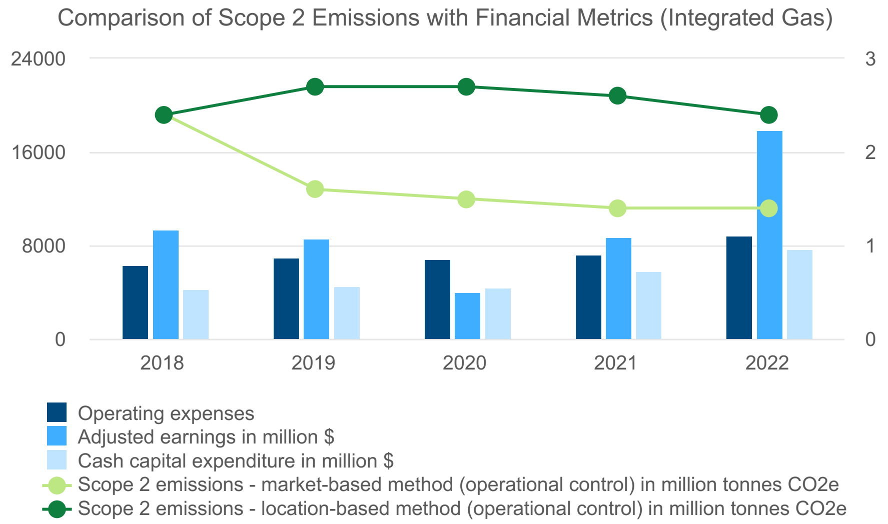
Adjusted earnings have exhibited significant fluctuations during the five-year period.

It is important to note that the financial performance of Shell is influenced by various factors beyond Scope 2 emissions, such as oil prices, market conditions, and global events (e.g., the COVID-19 pandemic).
While the Scope 2 emissions may have some impact on adjusted earnings through cost management and potential reputational benefits, other factors play a more significant role in determining the financial performance of the upstream segment.

Cash capital expenditure:
Cash capital expenditure has generally declined over the five-year period..
This reduction indicates Shell's focus on capital discipline, cost control, and efficient allocation of capital resources.
While the correlation between Scope 2 emissions and capital expenditure is not as direct as with operating expenses, it is possible that Shell's sustainability efforts, including emission reduction initiatives, have contributed to more efficient resource allocation and potential cost savings in capital projects.

In summary, the analysis of Scope 2 emissions in relation to the financial metrics for upstream segment reveals several points. The consistent decline in emissions indicates the commitment to reducing its environmental impact. The correlation between Scope 2 emissions and operating expenses suggests potential cost savings through energy efficiency and sustainable practices. However, the financial performance, as reflected in adjusted earnings, is influenced by multiple factors beyond emissions.

Integrated Gas:



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Scope 2 Emissions:
The market-based and location-based Scope 2 emissions for the Integrated Gas segment have generally remained consistent or slightly decreased over the five-year period. This indicates Shell's commitment to managing and reducing its environmental impact within the segment.

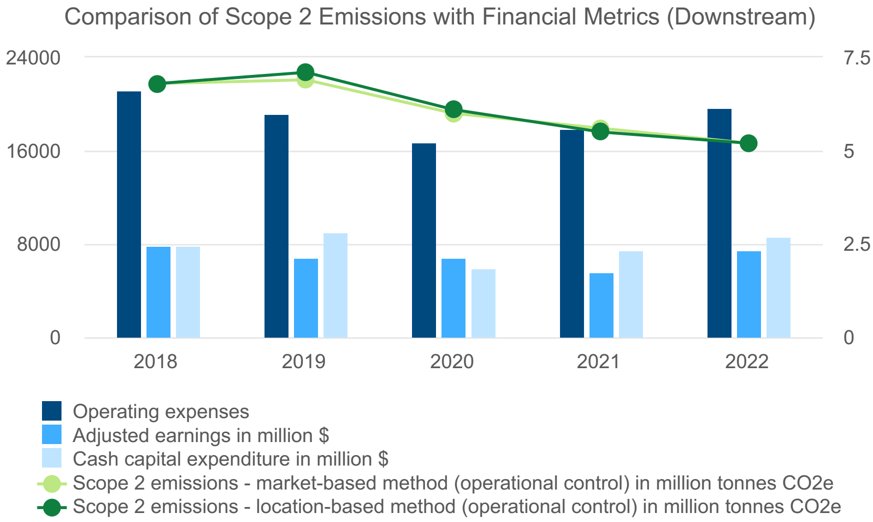
Operating Expenses:
Operating expenses in the Integrated Gas segment showed some fluctuations, with a slight increase in 2019, a decrease in 2020, and subsequent increases in 2021 and 2022. The correlation between Scope 2 emissions and operating expenses suggests potential cost-saving opportunities through energy efficiency and sustainable practices.

Adjusted Earnings:
Adjusted earnings for the Integrated Gas segment exhibited significant fluctuations, reflecting various factors beyond Scope 2 emissions, such as market conditions, oil prices, and global events. While emissions reduction initiatives and sustainability efforts may contribute to cost management and potential reputational benefits, other factors play a more significant role in determining the financial performance of the segment.

Cash Capital Expenditure:
Cash capital expenditure in the Integrated Gas segment generally increased over the five-year period, indicating Shell's focus on capital investment and expansion. While the correlation between Scope 2 emissions and capital expenditure may not be as direct as with operating expenses, Shell's sustainability efforts could contribute to more efficient resource allocation and potential cost savings in capital projects.

In summary, the analysis reveals that Shell's Integrated Gas segment has made efforts to reduce Scope 2 emissions, but the financial performance of the segment is influenced by a multitude of factors beyond emissions reduction initiatives.

Downstream:



Scope 2 Emissions:
The market-based and location-based Scope 2 emissions for the Downstream sector have generally shown a decreasing trend over the five-year period. This indicates Shell's efforts to manage and reduce its environmental impact within the sector.

Operating Expenses:
Operating expenses in the Downstream sector exhibited fluctuations, with a decrease from 2018 to 2019, a further decrease in 2020, and subsequent increases in 2021 and 2022. The correlation between Scope 2 emissions and operating expenses may suggest potential cost-saving opportunities through energy efficiency and sustainable practices.

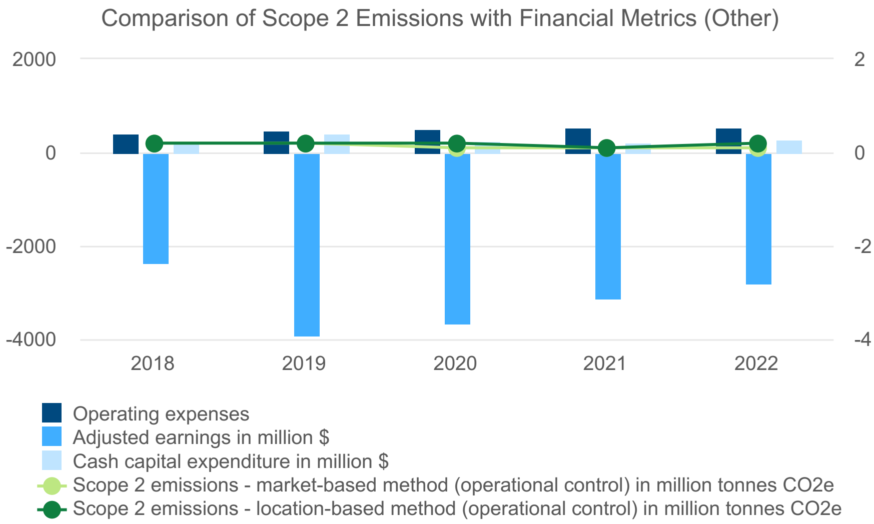
Adjusted Earnings:
Adjusted earnings for the Downstream sector showed fluctuations, reflecting various factors beyond Scope 2 emissions, such as market conditions, refining margins, and global events. While emissions reduction initiatives and sustainability efforts may contribute to cost management and potential reputational benefits, other factors play a more significant role in determining the financial performance of the sector.

Cash Capital Expenditure:
Cash capital expenditure for the Downstream sector exhibited fluctuations over the five-year period, reflecting Shell's investment and capital allocation decisions. While the correlation between Scope 2 emissions and capital expenditure may not be as direct as

with operating expenses, Shell's sustainability efforts could contribute to more efficient resource allocation and potential cost savings in capital projects.

To summarize, the analysis demonstrates that the Downstream sector of Shell has demonstrated a consistent decrease in Scope 2 emissions while experiencing fluctuations in its financial metrics. While Shell's endeavors to reduce emissions can aid in cost management and enhance its reputation, it is important to note that the financial performance of the sector is impacted by numerous factors beyond emissions reduction initiatives.

Other:



Scope 2 Emissions:
The market-based and location-based Scope 2 emissions for the Corporate segment have generally shown a decreasing trend over the five-year period. This indicates Shell's efforts to manage and reduce its environmental impact within the Corporate segment.

Operating Expenses:
Operating expenses for the Corporate segment showed fluctuations over the five-year period. The correlation between Scope 2 emissions and operating expenses suggests potential cost-saving opportunities through energy efficiency and sustainable practices, which could contribute to the overall reduction in expenses.

Adjusted Earnings:
Adjusted earnings for the Corporate segment exhibited fluctuations during the five-year period. It's important to note that adjusted earnings are influenced by various factors beyond Scope 2 emissions, such as corporate investments, financial strategies, and market conditions. While emissions reduction initiatives and sustainability efforts may contribute to cost management and potential reputational benefits, other factors play a more significant role in determining the financial performance of the Corporate segment.

Cash Capital Expenditure:
Cash capital expenditure for the Corporate segment showed fluctuations over the five-year period. While the correlation between Scope 2 emissions and capital expenditure may not be as direct as with operating expenses, Shell's sustainability efforts could contribute to more efficient resource allocation and potential cost savings in capital projects.

In conclusion, the analysis indicates that Shell's Corporate segment has successfully reduced its Scope 2 emissions over time, demonstrating a commitment to environmental responsibility. However, it is important to note that the financial performance of the segment is influenced by a range of factors beyond emissions reduction initiatives. While these efforts may contribute to cost management and enhance Shell's reputation, other variables play a significant role in shaping the overall financial metrics of the Corporate segment.

D INTERVIEW QUESTIONS

D.1 Original UTAUT Questionnaire

Performance expectancy:

- I would find the system useful in my job.
- Using the system enables me to accomplish tasks more quickly.
- Using the system increases my productivity.
- If I use the system, I will increase my chances of getting a raise.

Effort expectancy:

- My interaction with the system would be clear and understandable.
- It would be easy for me to become skilful at using the system.
- I would find the system easy to use.
- Learning to operate the system is easy for me.

Social influence:

- People who influence my behavior think that I should use the system.
- People who are important to me think that I should use the system.
- The senior management of this business has been helpful in the use of the system.
- In general, the organization has supported the use of the system.

Facilitating conditions:

- I have the resources necessary to use the system.
- I have the knowledge necessary to use the system.
- The system is not compatible with other systems I use.
- A specific person (or group) is available for assistance with system difficulties.

D.2 Complete Interview Questionnaire

Control questions:

1. What is your current role and main functions?
2. How many years of professional experience do you have in your field?
3. How familiar are you with enterprise architecture modeling?
4. How familiar are you with producing carbon/financial reports?
5. How familiar are you with XBRL reporting standard?

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?
2. Do you think the reference architecture accurately reflects the processes in the organization?
3. How confident are you that the reference architecture will be compatible with existing systems in the organization?
4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?
5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?
2. Were there any sections or aspects of the report that you found particularly useful or informative?
3. Were there any sections or aspects of the report that you found confusing or unclear?
4. Did the report provide enough detail and transparency regarding the carbon and financial data?
5. How would you rate the usability and user-friendliness of the report?

UTAUT questions (for the evaluation form):

- Performance expectancy:

  1. I believe that using the reference architecture will improve the accuracy and efficiency of carbon and financial reporting processes.
  2. I expect that using the reference architecture will enable better decision-making regarding sustainability and financial strategies.
  3. The example report showcases how the reference architecture enhances the organization's ability to track and report carbon emissions and financial data effectively.
  4. The example report provides valuable insights into the relationship between carbon performance and financial outcomes, demonstrating the capabilities of the reference architecture.

- Effort expectancy:

  5. The reference architecture is designed in a way that is easy to understand and navigate.
  6. Learning and implementing the reference architecture will not require excessive time and effort.
  7. The example report highlights the intuitive and user-friendly nature of the reference architecture.
  8. Based on the example report, I feel confident that I can quickly become proficient in using the reference architecture.

- Social influence:

  9. Key stakeholders in the organization would strongly support adopting and implementing the reference architecture.
  10. Senior management would actively encourage the use of the reference architecture.
  11. Colleagues would perceive the reference architecture as valuable for both carbon and financial reporting.
  12. The organization would provide the necessary resources and support to facilitate the reference architecture implementation.

- Facilitating conditions:

  13. The organization has sufficient resources (financial, technological, and human) for the successful implementation of the reference architecture.
  14. Adequate training and support are available to help users utilize the reference architecture effectively.
  15. The reference architecture integrates smoothly with existing systems and tools within the organization.
  16. Clear guidelines and documentation can be provided to address any difficulties or challenges that may arise during the implementation process.

E INTERVIEWS PROTOCOL

E.1 Interview 1

Control questions:

1. What is your current role and main functions?

   A: The interviewee 1A is a Senior Group Reporting and Data Analyst. He checks whether the services provided by the service provider are in line with Shell's expectations, prepares the annual report, and ensures its format meets the required standards.

   B: The Interviewee 1B is an Accounting Policy Analyst. This role encompasses similar functions but additionally involves conducting a thorough review of the XBRL tagging performed by the service provider. The interviewee 1B primarily checks the prepared file for readiness to be tagged and then reviews the tagged data.

2. How many years of professional experience do you have in your field?

   A: The interviewee 1A has 15 years of overall professional experience, with 4 years of experience in the current role.

   B: The interviewee 1B has 23 years of overall professional experience, including 5 years of experience in working with XBRL.

3. How familiar are you with enterprise architecture modeling?

   A: The interviewee 1A has some familiarity with the topic, as he was working as a process expert in the tax department, where he closely collaborated with the system team involved in building architecture.

   B: Interviewee 1B is not familiar with the topic.

4. How familiar are you with producing carbon/financial reports?

   A: The interviewee 1A is only familiar with producing financial reports.

   B: The interviewee 1B is also only familiar with creating financial reports.

5. How familiar are you with XBRL reporting standard?

   A: The interviewee 1A is familiar with the standard, but not with the tagging process itself.

   B: The interviewee 1B is also only familiar with the standard itself.

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?

A: The interviewee 1A mentioned that although the overview is not immediately clear, more time spent carefully reading and understanding the content within the boxes would be helpful. He also noted that he lacks the carbon part knowledge and modelling architecture knowledge, which makes it difficult to grasp the full picture.

B: The interviewee 1B also acknowledged his limited experience in the subject matter but appreciated the effort and work put into the architecture. The interviewee 1B mentioned that although he couldn't fully assess the flow and incorporation of all components, it demonstrated author's dedication to the project.

2. Do you think the reference architecture accurately reflects the processes in the organization?

   A: Overall yes, but the interviewee 1A emphasized that validation steps continue throughout the process, including the final validation of consolidated data in the annual report.

   B: The interviewee 1B agreed with the interviewee 1A.

3. How confident are you that the reference architecture will be compatible with existing systems in the organization?

   A: Compatible to a certain extent. The interviewee 1A explained that data is collected from multiple source systems, and is loaded into financial consolidation software. There is a manual adjustment process process for data that require additional information or adjustments. The data undergo a submission process, involving individual company focal points, where manual adjustments are made before the final submission. The consolidated results are then checked for data validation and logical integrity. The interviewee 1A emphasized that the process involves multiple people and systems, and while automation is maximized, it cannot be fully automated due to the complexity and involvement of various stakeholders.

   B: No additional comments.

4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?

   A: The interviewee 1A believes that the reference architecture should adequately address the reporting requirements for financial data. He understands that the goal is not to replicate the current steps but to reflect the existing process, which the architecture seems to do. He acknowledges that the architecture includes an additional step for integrated reporting. While it may not be an exact replica of the current process, it captures the essence of the financial reporting process and can be considered applicable and suitable. The interviewee 1A also notes that the steps for financial reporting and carbon reporting are similar, indicating that the architecture's approach would likely address both types of reporting effectively.

   B: No additional comments.

5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

   A: The interviewee 1A highlighted the complexity of data processes and the presence of many manual steps during data loads, consolidation, and validations.

   B: The interviewee 1B agreed with the interviewee 1A's response and added that resources would also be a challenge due to the additional processes introduced by the reference architecture.

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?

   A: The interviewee 1A expressed his impression of the report, stating that he was impressed with the work done. He acknowledged that editing a taxonomy and tagging the data is a significant achievement, which usually takes the involvement of multiple people and service providers in the process. The interviewee 1A believes that the report could be valuable for investors and suggests that it could be presented to organizations like the ISSB for further development and integration into carbon reporting. He overall views the report as looking good and providing added value. However, he highlights the limitation of not having a standardized carbon taxonomy for data comparison across different companies. The interviewee 1A suggests that encouraging other companies to use the same taxonomy could address this limitation.

   B: The interviewee 1B also shared his positive impression of the report, mentioning its usefulness for investors and highlighting the potential for the report to be part of the team developing carbon reporting standards. He emphasized the value it brings and believes it looks good overall. He also pointed out the need for standardized carbon taxonomy.

2. Were there any sections or aspects of the report that you found particularly useful or informative?

   A: The interviewee 1A agrees with interviewee 1B's assessment and confirms that the concept and layout of the report are clear.

   B: The interviewee 1B finds the general data comparison with graphs, implications for investors, and segment analysis sections of the report to be particularly useful and informative. He appreciates the inclusion of tables for data points related to the graphs, as it ensures proper tagging.

3. Were there any sections or aspects of the report that you found confusing or unclear?

   A: No additional comments.

   B: The interviewee 1B stated that more time is needed to properly read the report's content. Therefore, no specific comments or confusion regarding the report's content were highlighted.

4. Did the report provide enough detail and transparency regarding the carbon and financial data?

   A: No additional comments.

   B: The interviewee 1B acknowledges that it is difficult for him to provide specific comments on how to make the data more transparent. He points out that he has not seen the data before, making it challenging to provide precise feedback. However, when he looks at the tables shared, he finds it structured and understandable. He can comprehend the information presented, indicating that it meets the requirement of transparency.

5. How would you rate the usability and user-friendliness of the report?

   A: The interviewee 1A suggests that the addition of graphs to the report would enhance its user-friendliness. He mentions that people generally prefer graphs over tables, making the information more accessible and visually appealing.

B: The interviewee 1B confirms that the report is usable and user-friendly. He sees it as being understandable, and he expresses that the layout and overall presentation of the report are indeed user-friendly. However, the interviewee notes that he cannot make a judgment on the content since he has not fully read it yet.

E.2 Interview 2

Control questions:

1. What is your current role and main functions?

   A: In his role as the lead data architect for the Carbon and Environment domain portfolio at Shell, the interviewee 2A is responsible for ensuring proper data design and defining the rules for data placement within the portfolio's applications. He oversees how data flows through the landscape and how it is organized across the various applications. Essentially, his main function is to establish and manage the structure of data within the carbon and environment portfolio.

2. How many years of professional experience do you have in your field?

   A: The interviewee 2A has 10 years of experience in data architecture and a total of 14 years of overall work experience.

3. How familiar are you with enterprise architecture modeling?

   A: The interviewee 2A has in-depth knowledge of the topic.

4. How familiar are you with producing carbon/financial reports?

   A: The interviewee 2A is not familiar with the actual production of reports, but he is aware of the requirements related to report production that are relevant to his role as a data architect.

5. How familiar are you with XBRL reporting standard?

   A: The interviewee 2A has high-level knowledge of the standard.

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?

   A: The interviewee 2A suggests that the reference architecture is clear and easy to understand. However, he provides feedback on the need to label the data flows between the applications in the architecture. He mentions that organizing the diagrams well can help derive a lot of information, and suggests adding a few words on each line to indicate what data goes where in the interfaces between applications. He also appreciates the summary data model that was created and suggests using objects or attributes from the data model to highlight their placement in the flows between applications.

2. Do you think the reference architecture accurately reflects the processes in the organization?

A: The interviewee 2A believes the architecture accurately reflects the current processes in the organization. He mentions that while there may be some additional details behind it, the bottom line is clear. He explains that there is currently a separate process for financial reporting and non-financial reporting, and they only can come together at the final steps of the process. Therefore, he considers the architecture to be a proper reflection of the current state.

3. How confident are you that the reference architecture will be compatible with existing systems in the organization?

   A: The interviewee 2A states that the architecture is compatible with existing systems at Shell to a large extent. He mentions that the current architecture reflects the existing process and application landscape, and that the architecture fits within the existing systems, as expressed by the utilization of applications within the portfolio. However, he clarifies that the role of Wdesk is not positioned as a central system for consolidation or reporting. Instead, it is considered a specific add-on for generating reports in XBRL format. He suggests that for the architecture to be fully deployed, additional value needs to be added, such as using the transformed reporting format earlier in the chain. This would allow for reporting solutions on both ends, covering financial and non-financial reporting.

4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?

   A: The interviewee 2A explains that the architecture does address reporting requirements for financial data to some extent. The focus of the solution is on bringing together financial and carbon emissions data, which is a relatively new and important requirement. The solution incorporates the reporting needs for carbon data and aims to ensure that the data is properly shaped and combined.

5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

   A: The interviewee 2A highlights several challenges and limitations associated with the adoption and use of the solution. One major challenge lies in properly accounting for carbon emissions, as it differs from traditional financial reporting. There is a risk of double counting, and certain information may be unavailable or not in a format that can be directly handled, leading to the use of assumptions or defaults. Additionally, the complexity of carbon accounting increases when dealing with Scope 3 emissions, where visibility and traceability across the supply chain can be challenging. The accounting process for carbon emissions involves variations in regulations and industry-specific calculations, making it less mature compared to financial reporting. Ensuring accuracy, transparency, and avoiding the omission of crucial data are significant challenges in carbon accounting.

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?

   A: Interviewee 2A provides a positive impression of the report, mentioning that it is well-formatted with the exception of some final formatting details. He finds the report useful beyond a single report and suggests that the structured data could be utilized for transformations, especially when data is reused across multiple reports. He emphasizes the value of having a structured data architecture in the sustainability space where reports often have partial overlaps. The interviewee 2A acknowledges the benefits of easier data exchange, combining data sets, and performing validations with linked text data to underlying sources. He also mentions the traceability and quality check advantages of structured data compared to regular PDF documents.

2. Were there any sections or aspects of the report that you found particularly useful or informative?

   A: The interviewee 2A does not mention any specific sections and acknowledges that his limited knowledge in the subject matter makes it difficult for him to provide a more detailed assessment.

3. Were there any sections or aspects of the report that you found confusing or unclear?

   A: The interviewee 2A does not mention any specific sections and acknowledges that his limited knowledge in the subject matter makes it difficult for him to provide a more detailed assessment.

4. Did the report provide enough detail and transparency regarding the carbon and financial data?

   A: The interviewee 2A agrees that tagging the carbon and financial data in tables and explaining the connections provides more transparency. He thinks that by doing so, it becomes easier to link the data to the underlying dataset and enables further drill downs for detailed analysis.

5. How would you rate the usability and user-friendliness of the report?

   A: The interviewee 2A believes that the report is usable and user-friendly. He mentions that the usability may vary depending on the audience, but overall, he finds it easy to understand and interact with. He emphasizes that it is important for users to be able to click on data and understand what information is presented underneath.

E.3 Interview 3

Control questions:

1. What is your current role and main functions?

   A: The interviewee 3A is currently the IT Manager for Environment and Carbon. His role involves being accountable for IT services and projects related to environment and carbon, as well as overseeing the carbon foundations, which include environmental reporting, carbon footprint, carbon intensities, and collaboration with finance. He also mentioned his involvement in sustainability proof of stability and tracking sustainability across the entire supply chain.

2. How many years of professional experience do you have in your field?

   A: The interviewee 3A has 24 years of professional experience in various roles related to IT, and he has been in his current role for close to two years.

3. How familiar are you with enterprise architecture modeling?

   A: The interviewee 3A rated his experience as 2 out of 5.

4. How familiar are you with producing carbon/financial reports?

   A: The interviewee 3A only has experience with producing carbon reports, and he rated his experience as 4 out of 5.

5. How familiar are you with XBRL reporting standard?

   A: The interviewee 3A rated his experience as 1 out of 5.

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?

   A: The interviewee 3A finds the information clear and easy to understand. He also confirms that the models provided are very easy to understand.

2. Do you think the reference architecture accurately reflects the processes in the organization?

   A: The interviewee 3A believes that the architecture accurately reflects the current reporting process.

3. How confident are you that the reference architecture will be compatible with existing systems in the organization?

   A: The interviewee 3A expresses confidence in the compatibility of the architecture with existing systems.

4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?

   A: The interviewee 3A believes that the architecture addresses reporting requirements and suggests presenting it to a broader group, including finance colleagues.

5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

   A: According to the interviewee 3A, the main challenge and limitation that could affect the adoption of the process is the outsourcing of the whole Wdesk work. He raises concerns about the effort required to implement the process and automate it, as well as the need to assess the number of hours, licensing, and level of automation integration necessary.

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?

   A: The interviewee 3A's overall impression of the integration of the reports is very positive. He finds it highly useful, especially considering the ongoing discussions about integrating these reports over the past six months. He suggests conducting a demo for other contributors who will be working with the reports in the future.

2. Were there any sections or aspects of the report that you found particularly useful or informative?

   A: According to the interviewee 3A, he found the entire report informative. He appreciated the two options presented in the report, particularly the exploration of automation and increased requirements on disclosure.

3. Were there any sections or aspects of the report that you found confusing or unclear?

   A: The interviewee 3A did not have any major concerns or confusions about the report, suggesting that minor tweaks could be made but that the descriptions were generally good. He discussed the challenge of ensuring data quality and the need for expert verification. He agreed with the suggestion of making sure the source data is clear upfront rather than checking it afterwards.

4. Did the report provide enough detail and transparency regarding the carbon and financial data?

   A: The interviewee 3A found the question interesting regarding the existence of an externally accepted metric that measures emissions per dollar of capital or a similar concept. He suggested that combining different sources of information could help derive such metrics. The interviewee suggested double-checking with other organizations like KPMG for any forward-looking documents that might address this issue. Overall, the interviewee found the input valuable and it sparked further thoughts on reporting possibilities.

5. How would you rate the usability and user-friendliness of the report?

   A: The interviewee 3A mentioned that the overall usability and user-friendliness of the report is very high. He finds it easy to read and mentioned that it makes complete sense, even without a voice-over. He expressed his intention to bring the document into projects on carbon and financial convergence, using it as a pre-read for people and a source for thought.

E.4 Interview 4

Control questions:

1. What is your current role and main functions?

   A: The interview 4A is a Senior Solution Data Finance. Her role involves designing and aligning solution architectures, overseeing data architecture, and collaborating with various teams and stakeholders to ensure the effective implementation of projects within the finance domain.

2. How many years of professional experience do you have in your field?

   A: The interviewee 4A has 19 years of overall experience in data and analytics, and she has been in her current role for approximately one year and two months.

3. How familiar are you with enterprise architecture modeling?

   A: The interviewee 4A has in-depth knowledge of the topic. Her experience spans different aspects of working with data within a modern framework.

4. How familiar are you with producing carbon/financial reports?

   A: The interviewee 4A has experience working on carbon and financial reporting projects, including emissions reporting and taxonomy compliance. She handles carbon and financial data, such as scope emissions, sales data, emission factors, and financial metrics.

5. How familiar are you with XBRL reporting standard?

   A: The interviewee 4A is not familiar with the standard.

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?

   A: The interviewee 4A confirmed that she finds the architecture clear and easy to understand.

2. Do you think the reference architecture accurately reflects the processes in the organization?

   A: The interviewee 4A mentioned that the presented architecture may not completely accurately reflect the process specific to Shell, but it can be applicable to different organizations. She stated that, in general, it is clear and understandable.

3. How confident are you that the reference architecture will be compatible with existing systems in the organization?

   A: The interviewee 4A expressed confidence that the presented architecture would be compatible with existing systems, both within Shell and in the broader world. She emphasized the importance of aligning the architecture with governance frameworks and enterprise architecture. The interviewee 4A also mentioned the consideration of regulations for reporting, particularly in relation to carbon, and noted that Shell has specific rules and standards for architecture. She confirmed that the architecture aligns with those standards and regulations.

4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?

   A: The interviewee 4A responded affirmatively, stating that she believes the reference architecture adequately addresses the reporting requirements for both carbon and financial data.

5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

   A: The interviewee 4A highlighted several challenges and limitations that could impact the adoption and use of the proposed architecture. These include the need for alignment with the organization's strategic direction, compliance with existing rules and regulations, integration with the current landscape, and the impact on automation capabilities. It is crucial to ensure that the architecture aligns with the organization's goals, justifies the need for new applications, seamlessly integrates with existing systems, and enhances automation rather than creating additional overhead.

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?

   A: The interviewee 4A's overall impression of the report is positive. She acknowledges that the report effectively tells the story of the carbon and finance aspects and provides meaningful data and insights. She appreciates the intention to convey the trends and their implications. Overall, she finds the report to be good and aligned with its purpose.

2. Were there any sections or aspects of the report that you found particularly useful or informative?

   A: According to the interviewee 4A, the useful sections of the report include the graphs and tables that effectively convey the trends and information related to financial metrics. She appreciates how these sections translate the data into meaningful insights for stakeholders.

3. Were there any sections or aspects of the report that you found confusing or unclear?

   A: According to the interviewee 4A's feedback, while certain sections were useful, there were no clear definitions of the metrics used in the report, indicating a lack of clarity in that aspect.

4. Did the report provide enough detail and transparency regarding the carbon and financial data?

   A: As for the transparency of carbon and financial data, the interviewee 4A believes that there is enough detail and transparency in the report, especially in terms of the logical model discussed. She understands the purpose behind the model and acknowledges the inclusion of relevant KPIs. Overall, she finds the report to be informative and well-structured in conveying the desired information.

5. How would you rate the usability and user-friendliness of the report?

   A: The interviewee 4A rated the final report, with its combination of text and graphs, as user-friendly and easy to navigate.

E.5 Interview 5

Control questions:

1. What is your current role and main functions?

   A: The interviewee 5A's role is the Group Carbon Reporting Lead, and her main function is to inform the Executive Committee about the company's performance on carbon metrics at the group level. She provides regular updates on these metrics, which have externally stated targets. Her role focuses on management information rather than end-of-year external reporting.

2. How many years of professional experience do you have in your field?

   A: The interviewee 5A has 25 years of overall experience, primarily in the financial reporting. In the specific area of carbon reporting, she has been working for the past 10-12 years.

3. How familiar are you with enterprise architecture modeling?

   A: The interviewee 5A has no experience in the topic.

4. How familiar are you with producing carbon/financial reports?

   A: The interviewee 5A has in-depth experience with producing both financial and carbon reports.

5. How familiar are you with XBRL reporting standard?

A: The interviewee 5A has no experience in the topic.

Reference Architecture:

1. Do you think the reference architecture is clear and easy to understand?

   A: The interviewee 5A acknowledges that the explanation of the reference architecture was clear and easy to understand. She raises some points to consider, particularly regarding the sensitivity of data and the challenges it presents. The interviewee 5A emphasizes the importance of aligning reporting bases and boundaries for financial and emissions data. She also suggests exploring the potential integration of Wdata. The interviewee 5A highlights the need for clear communication, consideration of data sensitivity, and alignment of reporting bases within the architecture.

2. Do you think the reference architecture accurately reflects the processes in the organization?

   A: The interviewee 5A believes that the reference architecture accurately reflects the consolidation process between the two systems. She also mentions that the data models for financial reporting and reporting of Scope 1 and 2 emissions are different, indicating the need to reconcile them for effective integration. The interviewee 5A feels that the architecture presented is simplified and emphasizes the importance of aligning the finance and emissions data on the same basis.

3. How confident are you that the reference architecture will be compatible with existing systems in the organization?

   A: The interviewee 5A finds it possible to implement the first option of the architecture, but expresses uncertainty about the compatibility of the second option of the reference architecture with existing systems. She raises the question of timing and suggests that implementing option 2, as described, would not be possible until the existing financial reporting system has been replaced.

4. Do you feel the reference architecture adequately addresses the reporting requirements for carbon emissions and financial data?

   A: The interviewee 5A agrees that the architecture addresses the reporting requirements for carbon and finance data. However, she emphasizes that the focus is currently on reporting carbon data on the same basis as financials. She acknowledges the importance of integrating the two types of data and mentions the need for automation and insightful reporting. She also brings up the challenge of aligning data hierarchies and ensuring comparable levels of detail in both sets of information. She suggests that the architecture, once combined with the necessary alignment work, can address their requirements.

5. In your opinion, what challenges or limitations could affect the adoption and use of the reference architecture?

   A: Based on interviewee 5A's answers, the challenges and limitations identified include the complexity of aligning data hierarchies between carbon and financial reporting, the timing constraints in implementing the proposed architecture with existing systems, and the requirement for automation and insightful reporting. Additionally, she mentions the importance of addressing the basis of consolidation and ensuring comparable levels of detail in the integrated data.

Example XBRL report:

1. Could you describe your overall impression of the demo XBRL report?

   A: The interviewee 5A's overall impression of the report is positive, describing it as well laid out and useful. She acknowledges the potential of such a report to provide valuable metrics to foreign investors, especially if consistently presented by all companies. The interviewee 5A appreciates the clear and presented look of the report, emphasizing its positive attributes.

2. Were there any sections or aspects of the report that you found particularly useful or informative?

   A: The interviewee 5A mentions that she found the usage of graphs in the report to be particularly useful. She emphasizes the value of using simple and straightforward graphs, such as trend lines and bars, as they effectively convey the story. The interviewee 5A encourages to continue incorporating graphs in combination with clear explanations, as she believes it makes a lot of sense.

3. Were there any sections or aspects of the report that you found confusing or unclear?

   A: No specific mention is made regarding confusing sections of the report, but the author needs to continue incorporating graphs in combination with clear explanations, as the interviewee 5A believes it makes a lot of sense.

4. Did the report provide enough detail and transparency regarding the carbon and financial data?

   A: The interviewee 5A believes that the report provides enough detail and transparency for the carbon and financial data. She acknowledges that the users of the report will ultimately determine if it is sufficient in terms of detail. However, she notes that the report effectively brings the two types of data together in one place, allowing for explanations of the relationship between carbon and financial metrics. This transparency helps in understanding the reasons behind fluctuations and changes in these metrics.

5. How would you rate the usability and user-friendliness of the report?

   A: The interviewee 5A rates the usability and user-friendliness of the report as highly favorable. She believes that the report is user-friendly and easy to navigate for readers. However, she clarifies that the challenge lies not in preparing the report but rather in the way of using it.

F EVALUATION FORM RESULTS

F.1 Numeric Results

ID	1A	1B	2A	3A	4A	5A	Average	St. Dev.
1	4	2	4	4	4	4	**3.7**	**0.82**
2	4	4	4	4	4	4	**4.0**	**0.00**
3	3	3	5	4	4	4	**3.8**	**0.75**
4	3	3	5	5	4	4	**4.0**	**0.89**
5	3	3	5	5	5	5	**4.3**	**1.03**
6	2	1	4	4	4	3	**3.0**	**1.26**
7	2	3	5	4	5	5	**4.0**	**1.26**
8	3	3	4	5	4	4	**3.8**	**0.75**
9	4	4	3	3	4	4	**3.7**	**0.52**
10	4	4	2	3	4	4	**3.5**	**0.84**
11	4	2	5	4	4	3	**3.7**	**1.03**
12	3	3	3	4	4	4	**3.5**	**0.55**
13	3	1	5	4	4	3	**3.3**	**1.37**
14	3	1	2	3	4	3	**2.7**	**1.03**
15	3	3	5	4	4	2	**3.5**	**1.05**
16	3	3	4	4	4	5	**3.8**	**0.75**

Table F.1: Evaluation Form Numeric Results

F.2 Textual Results

ID	1A	1B	2A	3A	4A	5A
1	Somewhat agree	Somewhat disagree	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree
2	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree
3	Neither agree nor disagree	Neither agree nor disagree	Strongly agree	Somewhat agree	Somewhat agree	Somewhat agree
4	Neither agree nor disagree	Neither agree nor disagree	Strongly agree	Strongly agree	Somewhat agree	Somewhat agree
5	Neither agree nor disagree	Neither agree nor disagree	Strongly agree	Strongly agree	Strongly agree	Strongly agree
6	Somewhat disagree	Strongly disagree	Somewhat agree	Somewhat agree	Somewhat agree	Neither agree nor disagree
7	Somewhat disagree	Neither agree nor disagree	Strongly agree	Somewhat agree	Strongly agree	Strongly agree
8	Neither agree nor disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	Somewhat agree	Somewhat agree
9	Somewhat agree	Somewhat agree	Neither agree nor disagree	Neither agree nor disagree	Somewhat agree	Somewhat agree
10	Somewhat agree	Somewhat agree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Somewhat agree
11	Somewhat agree	Somewhat disagree	Strongly agree	Somewhat agree	Somewhat agree	Neither agree nor disagree
12	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree	Somewhat agree	Somewhat agree	Somewhat agree
13	Neither agree nor disagree	Strongly disagree	Strongly agree	Somewhat agree	Somewhat agree	Neither agree nor disagree
14	Neither agree nor disagree	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Neither agree nor disagree
15	Neither agree nor disagree	Neither agree nor disagree	Strongly agree	Somewhat agree	Somewhat agree	Somewhat disagree
16	Neither agree nor disagree	Neither agree nor disagree	Somewhat agree	Somewhat agree	Somewhat agree	Strongly agree

Table F.2: Evaluation Form Textual Results