Digital Climate Start-ups and their Value Proposition for the Natural Environment as a Key Stakeholder

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Abstract

Climate change (CC) is one of the greatest challenges humanity has ever faced, and despite concerted global efforts over the past two decades to address it, improvements have been disappointing. Notably, the average temperatures over the last decade have reached unprecedented levels, marking the year 2023 as the warmest on record. This alarming trend carries significant consequences for the planet. In this context, there is an increasing effort to understand the significance of involving businesses (and entrepreneurs) in addressing this challenge, as this sector has a great potential to deliver innovation, accelerate technology adoption, develop new business models and technologies, finance initiatives and deploy solutions world-wide. Together with this, it is expected that digitalisation will play a major role in the search for a more sustainable planet, as digital technologies (DT) can achieve the global scale required to make a meaningful impact in the fight against CC. Although the current dominance of sustainability and digitalisation as the drivers for societal changes and the increasing overlap between them, academic research on their interconnectedness is still scarce, providing a fertile ground for management and business academic research.

Thus, this PhD research shows an in-depth study of Business Models (BM) developed by firms that use DT as a core element of their value proposition to tackle CC. It also seeks to contribute to the literature on stakeholder theory as it provides novel insights on the natural environment as a stakeholder. The two research questions (RQ) that guide this investigation are: How do we unpack the value proposition of digital start-ups tackling CC? and how can digital climate start-ups (DCS) improve their value proposition for the natural environment as a key stakeholder? This is an empirical research based on multiple-case study analysis of firms that emerged as a response to CC. It considers mixed methods of study, including semi-structured interviews with CEOs & Founders of 27 firms. Results include an empirical taxonomy framework of DCS, an extended version of the Stakeholder Value Creation Framework for BM Analysis, and a proposal of attributes to improve the value proposition of DCS.

Keywords: Business Models for Sustainability, Digital Climate Start-ups, stakeholder theory, climate change, empirical research.

Disclaimer

I declare that this thesis is a presentation of original work, and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

During this PhD research the following research outputs, in relation to the PhD topic of this thesis, have been produced:

- Candia, J.R., Huaccho-Huatuco, L., Ball, P. (2024). The Competitive Business for Saving the Planet: The Case of Digital Climate Start-ups and their Value Proposition. In: Gondlach, K., Brinkmann, B., Plath, J. and Brinkmann, M. (2024). *Regenerative Futures and Artificial Intelligence. Profit Challenges, solutions, concepts and utopias of Economic Sustainability Goals*. Part 2, paper 13. Springer, to be published Q3 2024.
- Candia, J.R., Huaccho-Huatuco, L., Ball, P. (2023). Challenges faced by data-driven climate change start-ups. *Proceedings of the New Business Models conference - NBM 2023*. University of Maastrich, The Netherlands, 22nd -23rd June 2023. URL: https://pubpub.maastrichtuniversitypress.nl/pub/wqyxwz6h. License: Creative Commons Attribution 4.0 International License (CC-BY 4.0)
- Candia Jorquera, J. R., Huaccho Huatuco, L. D., & Ball, P. D. (2022). Business Models Embedding Ecosystem Services to tackle Climate Change: The case of Digital Climate Solutions. *Proceedings of the Sustainable Business Model Challenges: Economic Recovery and Digital Transformation conference,* 23rd -24th June 2022, Rome. NBM Conferences (newbusinessmodels.org).
- Candia Jorquera, J. R., Huaccho Huatuco, L. D., & Ball, P. D. (2022). Digital Climate Solutions: How emerging enterprises are responding to Climate Change and delivering value to customers and the planet. *Proceedings of the 30th European Operations Management Association conference*, 1-6 July 2022, Berlin (euroma-online.org).

In all these research outputs the PhD candidate was the lead corresponding author and presenter in various conferences.

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Glossary of Abbreviations

BM	Business model
BMfCC	Business model for climate change
BMfS	Business model for sustainability
B2B	Business-to-business (value proposition of BM)
B2C	Business-to-consumer (value proposition of BM)
CC	Climate change, climate crisis
CVP	Customer value proposition
DCS	Digital climate start-ups
DT	Digital technologies
EGD	European Green Deal
EVP	Environmental value proposition
ELMPS	Economics, Law, Management, Politics and Sociology Ethics Committee (ELMPS) of the University of York
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
NBS	Nature based solutions
SDGs	Sustainable development goals
SH	Stakeholders
SMEs	Small and medium size enterprises
SVC Framework	Stakeholder Value Creation Framework for Business Model Analysis.

Glossary of Terminology

Business models for climate change	A business model where the fight against climate change is the fundamental business strategy itself, in essence, it is the driving force of the firm and its decision-making processes.
Business models for sustainability	"A model where sustainability concepts shape the driving force of the firm and its decision making", in other words, sustainability is the business strategy itself, not an add-on component (Stubbs, 2008, p.103).
Climate change mitigation	Climate change mitigation is achieved by limiting or preventing greenhouse gas emissions and by enhancing activities that remove these gases from the atmosphere (IPCC, 2022).
Climate change adaptation	These are the processes and actions that enable people to cope better with increasingly challenging weather and climatic conditions. Considers the process of adjustment to actual or expected climate and its effects (IPCC, 2018). Adaptations may involve the development or adoption of a technology, or it can involve building capacity such as improved risk management or knowledge enhancement (West and Gawith, 2005).
Climate Hypothesis	A declaration by DCS in terms of how are they going to contribute to tackling climate change, when, and by how much.
Data-driven climate start-ups	See definition of digital climate start-ups.
Digital climate start-ups	For the purpose of this study, these are defined as organisations that are developing services that contribute to climate change mitigation or adaptation, where the core of their value offering is based on the internet, considering the use of technologies such as artificial intelligence (AI), machine learning (ML), the internet of things (IoT), blockchain, Big Data (BD), 5G, advanced sensors, digital twins, among others, including a combination of these. Also called Data-Driven climate start-ups.
Digital climate solutions	Solutions that use digital technologies as a core element of their value proposition and that have been developed with the purpose of tackling climate change.
Digital sustainability	The organizational activities that seek to advance the sustainable development goals through creative deployment of technologies that create, use, transmit, or source electronic data (George et al., 2020)
Digital technologies	Products and services based on the internet, and consider the use of technologies such as artificial intelligence (AI), machine learning (ML), the

	internet of things (IoT), blockchain, Big Data (BD), 5G, advanced sensors, digital twins, among others, including a combination of these.
Impact enablers	Economic activities that, by provision of their products or services, enable a substantial contribution to be made in other activities. For example, an economic activity that manufactures a component that improves the environmental performance of another activity.
Impact creators	Economic activities that make a substantial contribution to the fight against climate change based on their own performance. For example, an economic activity being performed in a way that is environmentally sustainable, or the implementation of off-set initiatives for carbon sequestration.
Industry 4.0	The process of the fourth industrial revolution and the digital transformation of the business world. Industry 4.0 nowadays involves the digital transformation of the entirety of industrial and consumer markets, ranging from the emergence of smart manufacturing to the digitization of complete value delivery networks (Schroeder et al., 2019).
Natural environment	The natural, physical surroundings in which human life takes place. Some would call it nature, our living planet, life on Earth or the geophysical world (Lauesen, 2013).
Stakeholders	A stakeholder of an organization is:"...any group or individual who can affect, or is affected by, the achievement of the organization's objectives" (Freeman and Reed, 1983).
Sustainability management	Refers to approaches dealing with social, environmental, and economic issues in an integrated manner to transform organizations in a way that they contribute to the sustainable development of the economy and society, within the limits of the ecosystem (Schaltegger, 2016).
Unpacking value propositions	It refers to the need to understand what is behind the value proposition of digital climate start-ups, i.e. what do they want to achieve and how. It also refers to the understanding of the value proposition of these firms for the natural environment.
Value proposition	For the purpose of this research, value proposition is what the firm will deliver to its customers and other stakeholders, including the natural environment (adapted from Richardson, 2008, p. 138).

Table of Contents

List of Figures

List of Tables

List of Appendices

Chapter 1: Introduction

1.1. About this Research

Climate change, one of the greatest challenges humanity has ever faced, is produced by the emission of six greenhouse gases (GHG), where carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) account for more than half of the total greenhouse effect (Liu, 2019). According to well documented evidence, GHG began to cause warming since the beginning of industrialisation (Hegerl *et al.*, 2019). Indeed, for more than 200,000 years, the atmospheric CO_2 concentration remained stable at approximately 280 parts per million (ppm), maintained by a balance in the biogeochemical carbon cycle (Hashimoto and Hashimoto, 2019). However, since the onset of the industrial revolution, there has been a notable 50% increase in CO_2 concentration, rising from 280 ppm in 1750 to 420 ppm in 2023 (Lindsey, 2023). This substantial rise is causing significant alterations in weather patterns, leading to extreme weather events, shifts in the hydrological cycle, ice melting, rising sea levels, and consequential impacts such as ocean acidification, harm to marine ecosystems, heightened incidences of fires, heatwaves, biodiversity decline, floods, conflicts due to climate migration, food insecurity, heavy rainfall, infrastructure damage, and more (Met Office, 2023). Furthermore, 2023 has been recorded as the warmest year on record, being 1.48°C warmer than the 1850-1900 pre-industrial level, overtaking by a large margin the previous record in year 2016. Global average sea surface temperatures have also remained persistently and unusually high (Copernicus, 2024).

In response to the enduring climate crisis, the global community came together in 2015 to sign the Paris Agreement, a treaty designed to enhance the worldwide effort to combat the threat of climate change. The primary goal is to restrain the rise in global temperatures, striving to keep it well below 2°C and making efforts to limit it to 1.5°C (Segger, 2016). Unfortunately, after eight years, the outcomes have been disappointing, with the current temperature increase standing at approximately 1.1°C, and with the likelihood that the warming will exceed 1.5°C during the 21st century and limiting it below 2°C is proving challenging (IPCC, 2022). Indeed, as per a recent assessment report on global progress toward 2030 targets conducted by the World Resources Institute (Boehm *et al.*, 2023), the evaluation of 42 indicators reveals a concerning picture. Only one indicator, related to the use of electric vehicles, is heading in the right direction. Six indicators are off track but still moving in the correct direction (e.g. reforest 100 Mha., increase ruminant meat productivity per hectare by 27%, relative to 2017.), while a substantial 24 indicators are well off track. Six indicators are moving in the wrong direction (e.g. reduce the percentage of trips made in passenger cars to 35-43%, lower the carbon intensity of global steel production). For the remaining five indicators, there is insufficient data available to assess the rate of change relative to the required action.

In terms of economic sectors, power generation, buildings, manufacturing, transport, agriculture, forest, food production, and other land uses, accounted for almost 85 percent of net anthropogenic GHG emissions globally in 2021 (Boehm *et al.*, 2023). Although reducing GHG emissions and achieving the so-called Net Zero goals from the industrial sector are formidable tasks, they are still considered feasible. This, however, requires substantial and concerted effort from society as a whole, encompassing a change on consumption patterns, demand management, enhancing energy and materials efficiency, promoting circular material flows, developing and implementing abatement technologies, and instigating transformative changes in production processes (IPCC, 2022).

In this context, digitalization is seen as having a great potential to address the challenges of climate change. In fact, tech firms are actively creating environmentally friendly digital applications, and governments are formulating sustainable strategies with digitalization playing a pivotal role, as highlighted by Lenz (2021). According to the World Economic Forum (WEF, 2022a), the digital technology sector is probably one of the most powerful influencers to accelerate action to stabilize global temperatures well below 2°C. Indeed, digital technologies (DT) play a crucial role in devising smart solutions for numerous environmental issues associated with climate change across various sectors like health, agriculture, food security, and manufacturing (Argyroudis *et al*., 2022, George *et al.*, 2019, Eteris, 2020).

Thus, many entrepreneurial actors are actively utilizing digital technologies to tackle significant sustainability challenges. This effort involves not only technological innovations but also the creation of business models that reframe the purpose of these innovations (George *et al*., 2019). According to Gregory and Holzman (2020), digital technologies contribute to the formulation of novel value propositions that encompass environmental, social, and economic dimensions.

Even though the dominance of digitalisation and sustainability (particularly climate change) as drivers for societal changes and the increasing overlap between them, academic research on their interconnectedness is still scarce (Feroz *et al.,* 2021; Kraus *et al.,* 2018, Lenz, 2021, Stuermer *et al.,* 2017, Vilchez, 2023). Many authors emphasise the need to further explore this insufficiently studied area of digitalisation and sustainability (Andersen *et al.,* 2021, Berzina *et al*., 2022, Bohnsack *et al.,* 2022, Hellemans *et al.*, 2021). Furthermore, Lenz (2021) argues for an exploration of the interconnectedness between digitalization and sustainability, as currently discussions on these two dominant processes of social change have been running independently, despite their growing overlap.

Therefore, the context of this research is provided by three current dimensions of society and the intersection of them. These are:

a) The need to move towards more sustainable development strategies and in particular the urgent need to tackle the climate crisis we are facing at planetary level due to the emission of greenhouse gases. This has been called the Sustainability Imperative.
b) The emerging digital technologies and how can they help in the process of effectively tackling climate change. This has been called the Digital Imperative (part of the Fourth Industrial Revolution or Industry 4.0).

c) The role of the private sector (and in particular of entrepreneurs developing digital start-ups) in addressing the climate crisis, through the use of emerging digital technologies and the development of innovative business models and value propositions (business models for sustainability).

As it will be further developed in Chapter 2: Context, there is an important gap of knowledge and research opportunity in terms of analysing the intersection and synergies between new business models aimed at tackling climate change and digital technologies, as seen in the schematic representation of **Figure 1-1**.

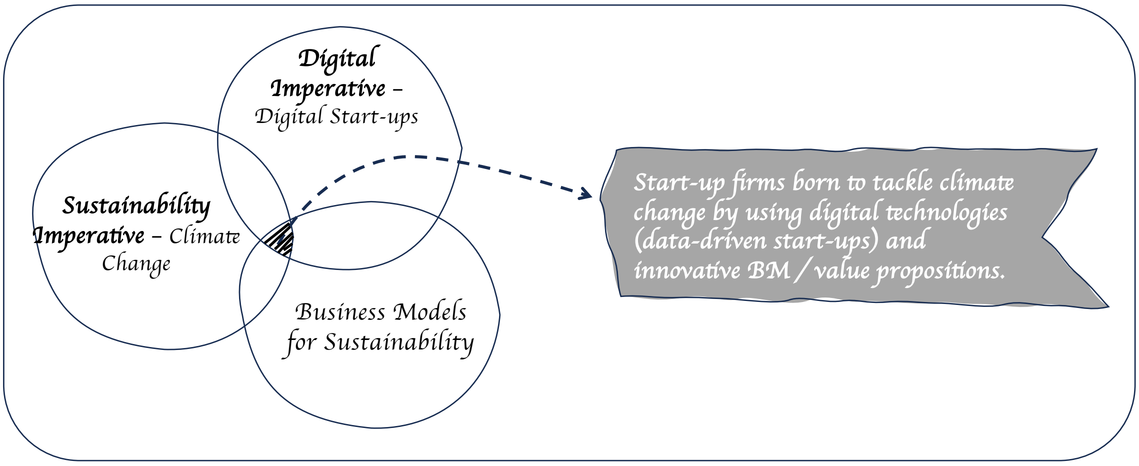

Figure 1-1: Schematic representation of the intersection of the three areas of research (Research Gap).

In this context, the aim of this investigation is to contribute to the research of business models for sustainability, with focus on value proposition and the natural environment as a key stakeholder (the justification for the selection of Stakeholder Theory as the main theoretical lens is presented in Chapter 3: Literature Review). With this aim two main research questions (RQ) were defined, as shown in **Table 1-1**:

Table 1-1: Research questions and objectives

Research Question (RQ)	Objective
RQ1: How do we unpack the value proposition of digital start-ups tackling climate change?	The objective here is to understand the landscape of DCS and what is behind their value proposition, i.e. what do they want to achieve and how, developing a typology of DCS (an empirical Taxonomy Framework).

Research Question (RQ)	Objective
	Additionally, this RQ seeks to contribute to the understanding of the value proposition of DCS for the natural environment, and its relationship with the value proposition for clients.
RQ2: How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?	The objective is to understand the value offering for the natural environment and identifying options for improvement, thus enriching business model research by incorporating stakeholder theory into the analysis of stakeholder relationships within a business model. Attributes necessary to improve the value proposition of Digital Climate Start-ups (DCS) need to be identified.

Thus, the first RQ seeks to unveil the value proposition of Digital Climate Start-ups (DCS), with the aim of contributing to knowledge by suggesting a taxonomy of DCS or a typology of business models, also describing what innovative value propositions are being developed by DCS, what are the driving forces behind, the main digital technologies being used, among others.

The second RQ is explanatory in nature and seeks to extend theory by proposing the explicit incorporation of the natural environment as a key stakeholder in the Stakeholder Value Creation Framework proposed by Freudenreich *et al.* (2020), with the aim of increasing the value creation potential of these businesses.

Figure 1-2 presents a simplified view of the methodology followed in this research, highlighting its four main stages: desk-based analysis, semi-structured interviews, data processing and analysis, and theory analysis (theoretical contribution stage).

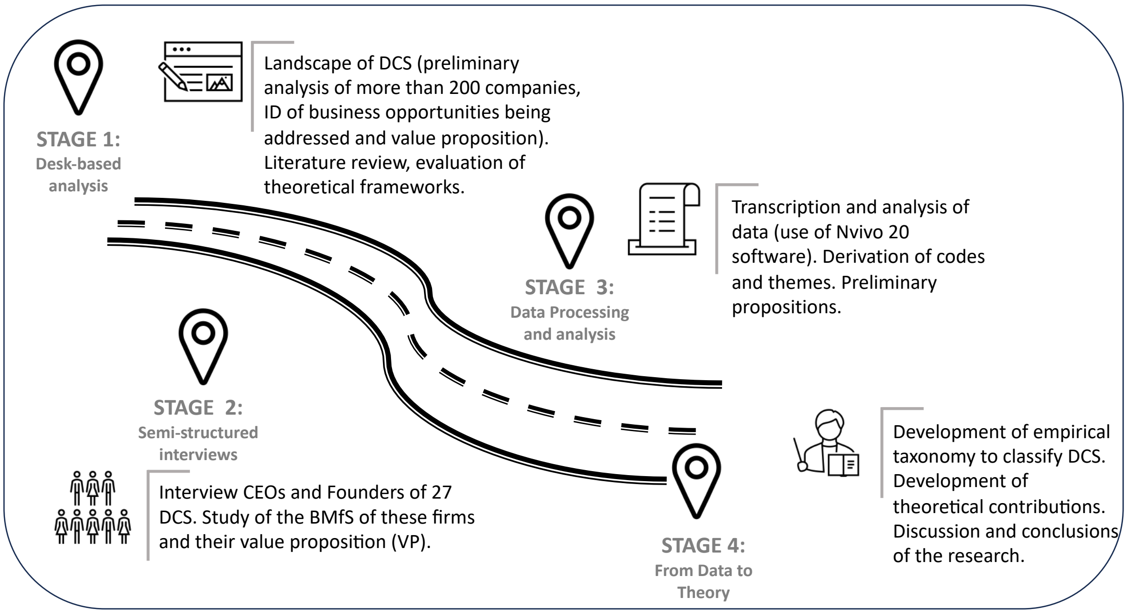

Figure 1-2: Simplified methodology for this thesis research.

1.2. Personal Motivation

My interest in the system view of natural resources, sustainable development, and the role of industries in moving towards sustainability started back in 1990, when I was doing my undergraduate degree at the University of Concepcion, in Chile (a five-year degree in Marine Biology). At that time, I became interested in the environmental management of coastal zones and the pollution produced by industrial development. This was later reinforced by specialised training courses in Sweden and Japan, looking at marine oil pollution and strategies to address this problem. Then in 1998 when I was doing a two-year MSc degree in Resource Management at Lincoln University (in New Zealand), working with Professor Ken Hughey[1], I was introduced to the concept of industrial ecology, and being a biologist by training and a practitioner by career path, I thought it was a great approach to frame industrial development challenges and search for collaborative solutions. I carried out a research project on barriers and opportunities provided by the industrial ecology approach (Candia, 1998). Additionally, with Professor Hughey we did a research project on behalf of the local city council to understand barriers and opportunities for local companies in the city of Christchurch to implement

[1] Prof. Hughey is currently Chief Science Advisor at Department of Conservation (DOC) in New Zealand.

Cleaner Production (CP) practices (Hughey and Candia, 1998), and with Prof. Stefanie Rixecker[2] I looked at socio-cultural perspectives of resource management, diving into the complexities of implementing the sustainable development concept (Candia, 1997). After that I returned to Chile and for the next 5 years became actively involved in the cleaner production concept in a project promoted by the United Nations Industrial Development Organization (UNIDO). In fact, I was co-founder in 1999 of the Chilean Cleaner Production Centre, working with hundreds of Chilean SMEs to promote CP practices, providing training, and developing CP guidelines.

Since then, I have worked as an applied researcher in innovation centres, also as a consultant and project manager, in over 400 projects to address issues of sustainable development (SD) and climate change mitigation and adaptation, providing advice to both domestic and multinational companies as well as governmental agencies and NGOs, also giving talks and delivering training courses in several countries. Some of the areas I have been involved with include: looking at organisational strategies for sustainability, development of catchment level water management strategies, eco-industrial parks, cleaner production, sustainable cities, eco-innovation, technology development and technology transfer, circular economy, water footprint, LCA, eco-efficiency, remediation of contaminated sites, risk assessment, ecological footprint, sustainability indicators, water management, water technologies, climate change, Net Zero, among others.

Thus, throughout my professional career I have been exposed to a great diversity of challenges, from evaluating the impact of international development funds on the lifestyle of rural communities in Samoa, to the design of a water management strategy for a city of 7 million people facing dramatic water stress due to climate change; from how to treat millions of litres of complex water contamination on a mining site, to the management of a unique biodiversity area of 60,000 hectares in Patagonia for conservation purposes; from how to start a sustainable tourism business in alliance with indigenous people in the most isolated place on the planet, to how to monitor a fishing

[2] Prof. Rixecker is currently Chief Executive at Environment Canterbury in New Zealand.

fleet of 1,000 vessels in the high sea using digital technologies (30 years ago); from how to start a high performing team from scratch, to overcome the failure of business entrepreneurships; from how to remediate 1,000 legacy sites contaminated with crude oil in the Patagonia (a USD25 million project), to how to deal with conflicting use over water resources by a variety of industries in the Atacama desert; from organising international conferences with thousands of attendees from 19 countries, to creating research and business alliances with highly reputed companies and research centres from Asia, Europe, Oceania, North, and South America. In the last few years, I was also involved in the development of start-up companies and in setting up my own environmental consultancy firm.

In late 2020, I decided to return to academia and be exposed to the state-of-the-art of management research addressing climate change mitigation and adaptation from the business perspective, in the hope I can contribute to the greatest challenge of humanity.

Today, near the end of this PhD journey, I see myself as an explorer of technology-based firms and their connection with the environment (and climate change). I have become interested in studying companies that were born with climate change and sustainability in their DNA, companies for which addressing this challenge is not a nice-to-have-strategy, but instead it is their reason for existing. And through this learning and discovering process, I hope to contribute to advance and stimulate new approaches in the fields of strategic sustainability management and business models for sustainability, inspiring others to follow.

1.3. Structure of this Thesis

This thesis has eight main Chapters. Chapter 1 provides a general introduction, describing the research objective and the research questions, as well as presenting the motivation of the researcher for entering into this PhD journey.

The second chapter provides a general context that justify the relevance of the topic of climate change, and the role of the private sector in tackling this challenge as well as the role that Industry 4.0 can play. This chapter concludes by presenting the research gap that was identified.

Chapter 3 presents the literature review, addressing the two fundamental theoretical approaches that formed part of this research: The business Model for Sustainability approach and the Stakeholder Theory.

Chapter 4 explains the research philosophy behind this investigation, while Chapter 5 provides a detailed description of the four steps followed in the fieldwork methodology.

Chapter 6 presents the results of the research, by addressing each of the research questions, while Chapters 7 and 8 present the discussion and conclusions. Each Chapter also includes a brief conclusion at the end.

Figure 1-3 represents a navigation map for this thesis. The relevant section of the map will be shown at the beginning of each Chapter to facilitate the reading.

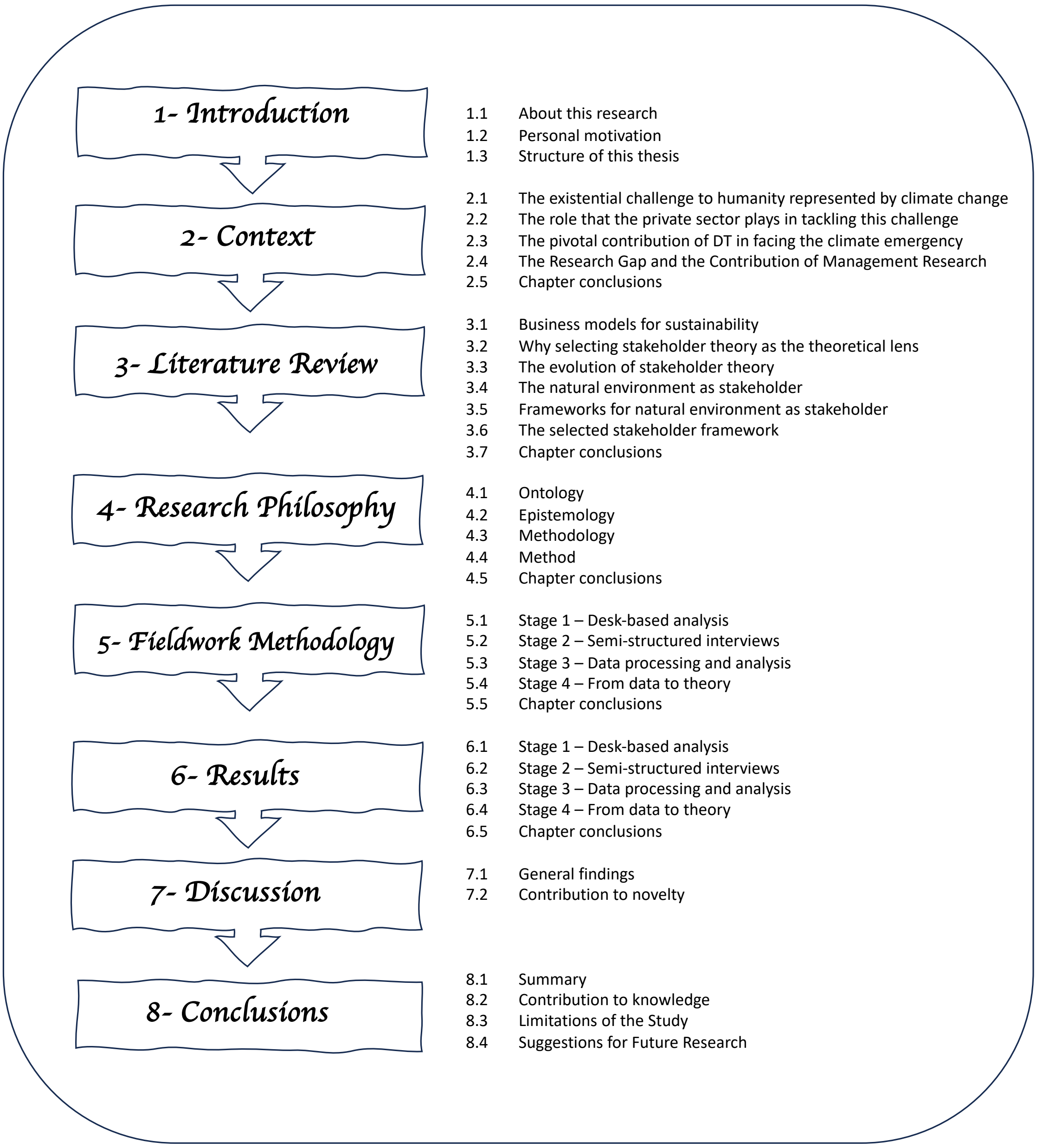

Figure 1-3: Navigation map for this Thesis

Chapter 2: Context for this Research

2- Context

This chapter introduces three key elements that provide the general context of this research:

- The existential challenge to humanity represented by climate change,
- The role that the private sector plays in tackling this challenge, and
- The pivotal contribution of digital technologies in facing the climate emergency.

Thus, the chapter builds up to present the research gap that guided this investigation.

2.1 The existential challenge to humanity represented by climate change

The rapid development and industrialisation of economies as a result of the industrial revolution, brought, together with immense benefits, significant detrimental changes on the natural systems. Thus, some of the main environmental problems in 2023 include issues on: global warming from fossil fuels, poor governance, food waste, biodiversity loss, plastic pollution, deforestation, air pollution, melting ice caps and sea level rise, ocean acidification, unsustainable agriculture, food and water insecurity, fast fashion and textile waste, overfishing, cobalt mining, and soil degradation (Earth.Org, 2023).

In some cases, these impacts are even threatening what has been described as the Planetary Boundaries (Rockström *et al.,* 2009), the limits within which life on the planet can thrive safely. These limits are based on nine Earth-system processes (climate change, stratospheric ozone depletion, ocean acidification, land use change, freshwater use, rate of loss of biodiversity, interference with nitrogen and phosphorous cycles, aerosol loading and chemical pollution) that, if affected, could produce unacceptable environmental effects. An updated analysis concluded that four out of nine of these boundaries have already been transgressed, which are biosphere integrity, interference with the nitrogen and phosphorous cycles, land use change, and climate change (Rockström, 2015), the latest being the focus of this research.

The burning of fossil fuels, in particular, has produced an unforeseen planetary crisis. In fact, the use of this source of energy at great scale started back in 18th Century, with the invention in the United Kingdom of the steam engine powered by coal and the start of the industrial revolution, which main driver was precisely the steam engine. In 1859, the first commercial drilling for oil was done in the United States of America (Kool, 2020), mainly used at that time for kerosene lamps for lighting. A few years later, with the invention in Germany of the first car with an internal combustion engine, the first automobile running on a refined product of crude oil—gasoline— and later the mass production of cars by Henry Ford, the demand for gasoline grew constantly. By the middle of the 20th century, oil became the most used energy source in the United States of America (USA) thanks to gasoline demand. Today the three main fossil fuels (crude oil, natural gas and coal) combined account for the majority of the global energy use at planetary level (Kool, 2020).

This fast growth of the world economies powered by fossil fuels has clearly been key to allow for the development of countries and has since contributed to the improvement of quality of life of hundreds of millions of people around the globe. Unfortunately, as it has been shown by scientists for the past 30 years, the use of fossil fuels has had an unforeseen and critical impact, global warming. According to Professor Robin Perutz, the phenomenon of climate change was anticipated by some scientists as early as in the 18th and 19th Centuries (Perutz, 2021). Based on IPCC data (IPCC, 2018, IPCC, 2022), since the start of the industrial revolution, the average temperature of the planet has increased by near 1ºC (likely to be between 0,8 to 1,2ºC). This may not seem a lot for many, but this "small" increase in practise has produced significant alterations of the natural processes at planetary level, changing patterns of rain, increasing the frequency of flooding, ocean acidification, the continuous rise of sea level, melting of glaciers and ice in the polar zones, producing unforeseen droughts in many parts around the globe, release of methane from melting permafrost, among many others extremely serious impacts (IPCC, 2023).

Just a few years ago, climate scientists stressed the fact that we have just over ten years left to take urgent and drastic actions, if we are to avoid some of the worst impacts from climate change (United Nations, 2019). In response to the crisis, 196 countries agreed to sign the Paris Agreement in 2015, with the commitment to hold the increase of global average temperature to well below 2°C above pre-industrial levels (Wei *et al*., 2016). In addition, in order to face the broader challenges of sustainable development, in 2015 the United Nations member states agreed on the Agenda 2030, an ambitious fifteen years plan with seventeen Sustainable Development Goals (SDGs) and 169 specific targets. The goals and targets address social, environmental, and economic issues. One SDG in particular (SDG 13) is focussed on climate change, specifically aimed at taking urgent action to combat climate change and its impacts. These goals are universal and apply to all countries worldwide and provide a general roadmap to move to a more sustainable planet. According to Cajigal *et al*. (2018), this agenda meant a significant advance with respect to the previous Millennium Goals, particularly on issues of accountability and transparency.

Despite all these international efforts, Greenhouse Gas (GHG) emissions continue to rise[3]. The total global greenhouse gas emissions in 2021 reached 54.6 billion metric tons of carbon dioxide equivalent ($GtCO_2e$), a 3.8% increase in comparison with the previous year (and 40% increase in comparison with 1990 figure), where CO_2 accounts for approximately 75 percent of the total, and is the main driver of climate change (Our World in Data, 2023). The situation for 2022 was not different, with total global greenhouse gas emissions reaching 53.8 $GtCO_2e$. In order to limit global temperature rise to below 2°C aiming for 1.5°C, as committed in the Paris Agreement, countries must

[3] Climate change is produced by the emission of six greenhouse gases (GHG): CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF_6 (sulfur hexafluoride), among which, the role of CO2, CH_4 and N_2O accounts for more than half of the total greenhouse effect (Liu, 2019).

reduce 30 gigatons of GHG emissions annually by 2030 (UNEP, 2023). According to the World Economic Forum (WEF, 2022), global net zero commitments from businesses and governments are projected to decrease GHG emissions by 7.5% by 2030, which is much less that the 55% needed to meet global goals. Filling this gap will require a substantial effort from high emitting sectors around efficiency, circularity, and sustainability (WEF, 2022). To put these numbers into context, ***Table 2-1*** shows emissions of GHG in 2021 and 2022 for selected countries and geographical areas.

Table 2-1: Total GHG emissions in 2021 and 2022 (selected countries)

Geographical Area	GHG Emissions in 2021 ($GtCO_2e$)	GHG Emissions in 2022 ($GtCO_2e$)
China	13,71	15,69
USA	5,93	6,02
European Union	3,8	3,59
India	3,9	3,94
UK	0,42	0,43
Total World Emissions	54,59	53,79

(source: built based on information from Our World in Data website (2023) and EDGAR - Emissions Database for Global Atmospheric Research (2023)).

The results have not been promising, being likely that warming will exceed 1.5°C during the 21st century and being hard to limit warming below 2°C (IPCC, 2022), which call for increase efforts to tackle this unprecedented problem. In fact, as mentioned in Chapter 1: Introduction, 2023 has been recorded as the warmest year on record, being 1.48°C warmer than the pre-industrial levels, with serious consequences for the planet (and society), including increased numbers of wildfires, heatwaves, biodiversity decline, floods, conflicts due to climate migration, food insecurity, heavy rainfall, infrastructure damage, among others (Met Office, 2023, Copernicus, 2024).

Furthermore, according to a recent assessment report of global progress toward 2030 targets carried out by the World Resources Institute (Boehm et al., 2023), out of 42 indicators for the assessment of global progress toward 2030 targets, only one is into the right direction (related to the use of electric vehicles), 6 are off track but still in the right direction, 24 are well off track, 6 are in the wrong direction (e.g. lower the carbon intensity of global steel production), and for the remaining 5 there is insufficient data to assess the rate of change relative to the required action. Thus, a significant and rapid acceleration of efforts is imperative across all sectors to meet the 2030 goals. We must transition from the usual incremental approach to emergency mode to achieve this necessary speed.

Environmental management has evolved from pollution control and risk management in the 1970s, to pollution prevention in the 1980s, to the subsequent implementation of systematic product and process management (the ISO 14000 series), and the emergence of life cycle analysis and industrial ecology approaches (Corbett and Klassen, 2006), together with more recent management strategies such as cleaner production, circular economy, regenerative manufacturing, among many others. In the climate change arena, climate change mitigation and adaptation are the two dominant concepts. In fact, since the late 80s and until a decade ago, the primary response to climate change has been mitigation through reduction of greenhouse gas emissions, where the European Union played a prominent role internationally to reduce greenhouse gas emissions, particularly through ambitious policy emission reduction targets. Only with increasing evidence of climate impacts occurring (e.g. with Arctic Sea ice and mountain glaciers melting, extreme heat waves, floods) has adaptation climbed the political agenda, being today considered an explicit policy response to manage those impacts that are unavoidable (Biesbroek *et al*., 2010).

Mitigation policies focus on either controlling the emissions of greenhouse gases or capturing and sequestering those emissions. Adaptation policies, on the other hand, focus on taking steps to make social and environmental systems more resilient to the effects of climate (Pielke 2004).

There are other concepts that are also relevant in the context of CC. With this purpose the USEPA (2017) has developed a complete Glossary of Climate Change Terms, which include, but are not limited to:

- Adaptive Capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
- Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.
- Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity.

In addition, the Task Force on Climate Related Financial Disclosure (TCFD, 2017) has divided climate-related risks into two major categories: (1) risks related to the transition to a lower-carbon economy, and (2) risks related to the physical impacts of climate change. According to TCFD (2017), efforts to mitigate and adapt to climate change also generate opportunities for organizations, for example, "through resource efficiency and cost savings, the adoption of low-emission energy sources, the development of new products and services, access to new markets, and building resilience along the supply chain. Climate-related opportunities will vary depending on the region, market, and industry in which an organization operates" (p.62).

Finally, due to its complexity, climate change has been mentioned as the best example of a Grand Challenge, i.e., "formulations of global problems that can be plausibly addressed through coordinated and collaborative effort" (George *et al*., 2016, p.1880). Furthermore, climate change is a Grand Challenge that has been characterized as a "super wicked" problem because of the "scale, scope, and time horizon over which mitigation efforts must take place, without central authority" (George *et al*., 2016, p. 1886).

2.2 The role that the private sector plays in tackling this challenge

As a result of the sustainability challenges society is facing, companies around the world are embracing and adopting the SDGs, as it is clear that the business sector has the highest impact on ensuring that the SDGs will be implemented by 2030. In fact, according to Chang *et al.* (2017), sustainable development cannot be achieved without active involvement of firms, as they "play a crucial rule in facilitating sustainable development" (p.48). Similarly, for Smith and Tracey (2016), organizations are recognized as being part of both the problem and the solution, when it comes to sustainability challenges. Many large companies support the SDGs and are using them as part of their policies and sustainability strategies, for example, by indicating to which goals they intend to contribute the most (Howard-Grenville *et al.*, 2014). Also, many business associations have developed guidelines to help their members to move towards these SDGs. An example is the Denmark's water utility SDG agenda for change (The Source Magazine, 2019), an inspirational catalogue to guide water utility companies to move forward regarding the UN SDGs. Other examples include guidelines and tools developed by organisations such UN Global Compact (SDG Industry Matrix), the World Business Council on Sustainable Development (WBCSD), the Principles for Responsible Management Education (PRME), Anthesis Group guidelines, among others.

A study performed by the UNGSII Foundation (2017) showed that different types of companies demonstrate commitment to different SDGs. According to this study, where 100 of the largest and most important companies in the world were analysed, the largest companies focus on issues such as climate change, good health, reduced inequalities, and gender equality, among others.

According to United Nations Global Compact - Accenture (2023), a recent survey of over 2,600 CEOs across 128 countries and 18 industries found that today 98% of CEOs believe it is their role to make their businesses more sustainable, and when it comes to accountability, in 2013 only 19% of CEOs strongly agreed that they were accountable for their firm's sustainability performance, but in 2022 that percentage had increased to 72%, numbers that show that sustainability is clearly at the top of the CEO agenda.

When it comes to climate crisis specifically, internationally there is a growing effort to understand the role and the need to engage businesses to tackle this challenge, as this sector has a great potential to finance projects, develop technologies and innovations, deploy these solutions world-wide, and enhance the scale and effectiveness of climate change adaptation measures (Averchenkova *et al.*, 2015).

In fact, many companies are taking initial steps to adapt their different operations to the climate crisis. Some of the reasons to engage into this include: minimising impacts on their supply chains, improving efficiency on the use of resources as well as improving the production and use of raw materials, and contributing to the efforts made by customers, suppliers and the communities in general, to adapt to climate change. Energy insecurity, raising costs, and legal commitments to meet national net zero targets also add to these pressures, particularly for those energy intensive sectors (Averchenkova *et al.,* 2015).

As an example of concrete actions being taken, in March 2016, the investment committee for California Public Employees' Retirement System (CalPERS), the largest public pension fund in USA, voted to start requiring the corporations it invests in to include people on their boards who have expertise in climate change risk management strategies, in attempt to “make sure that corporate boards have the expertise and competence to adequately understand and address the challenges and risks imposed by climate change” (Farmer, 2016). Furthermore, Standard & Poor noted that it regularly publishes extensive research on the implications of environmental and climate-related risks and that its evaluation of elements of environment, social and governance risks, have become key components of its ratings methodology (Shafroth, 2016). Other initiatives working on the intersection between climate risks and industry performance include the Taskforce on Climate Related Financial Disclosure (TCFD, 2023), Taskforce on Nature-related Financial Disclosures (TNFD, 2023), The Corporate Sustainability Reporting Directive (CSRD, 2023), etc.

While climate change is often perceived by the business community as the most pressing environmental problem of our time, as permanently reflected in the IPCC reports or in the recent Global Risk Report from the World Economic Forum (WEF, 2023), most companies still see the climate crisis as something to be worried about in the long term.

In fact, according to the Global Risks Report 18th Edition (WEF, 2023), environmental risks dominate the annual Global Risks Perception Survey, particularly when asked in a ten years horizon, where six out of the ten main risks are related to environmental problems, including failure to mitigate climate change, failure to climate change adaptation, natural disasters and natural weather events, biodiversity loss and ecosystem collapse, natural resources crisis, and large-scale environmental damage incidents. This yearly report is based on a Global Risks Perception Survey, in which over 1,200 experts across academia, business, government, the international community and civil society assess the risks the world is facing.

Despite this, the immense majority of companies have been unable to grasp the meaning of climate change for their organisations; this may be due to the different time scale of climate change and the businesses, or due to the uncertainty related to the projections of climate change impacts (Howar-Grenville *et al.*, 2014). Nevertheless, as usually occurs in the competitive economy we are in, those few companies that realise this early enough, may introduce changes and develop new key capabilities in a lower-carbon direction, thus transforming climate change into a driver for future competitive advantage; this is the case with the early movers companies (Kolk and Pinkse, 2011, p3).

Thus, the role of the private sector in taking more active actions and initiatives to addressing climate change is still poorly understood, maybe with the exemption of sectors such as insurance, tourism, energy, utilities and the food and beverage industry, as they have had a more visible response so far. But there is still a lack of research on the implications for the private sector, particularly on their supply chains, as climate change is a risk multiplier (Averchenkova *et al.*, 2015).

One key role companies and organisations can play in addressing climate change is through entrepreneurship and innovation. In fact, climate change is seen by many emerging companies as a business opportunity (Seles *et al*., 2018), particularly given the exponential level of development of digital technologies in the last few years (Bongomin, 2020; Marino, 2021; Finance, 2015), which makes possible the development of new value propositions that were unthinkable just three or five years ago.

According to Gregori & Holzmann (2020, p. 1), entrepreneurship has been highlighted as a potential solution to grand challenges such as the climate crisis, while entrepreneurs "are considered to be key actors as they develop and implement financially viable and innovative business models that create positive impact". In their research these authors argue that digital technologies enable novel configurations of sustainable business model components: a blended value proposition, integrative value creation, and multidimensional value capture.

It has also been stated that three emerging trends, circular economy, servitisation, and digitalisation, will be the driving forces for the transformation of companies in order for them to differentiate and meet the demand of their clients and stay competitive (Parida & Wincent, 2019).

When it comes to the UK specifically and its commitments to achieve net zero emissions by 2050, the government wants to meet its reduction target through investing and capitalising on new green technologies and innovation. The UK is in fact the first country to enter legally binding long-term carbon budgets into legislation. This was first introduced as part of the 2008 Climate Change Act. Since then, five carbon budgets have been included into laws. The sixth Carbon Budget in particular will commit the country to one of the most ambitious climate targets in the world, the fastest fall in greenhouse gas emissions of any major economy between 1990 and 2035, as it aims at reducing emissions by 78% from 1990 to 2035, including international aviation and shipping emissions[4] (UK Government, 2021a).

While this target is ambitious, according to the UK Government, the country has already reduced greenhouse gas emissions by 42%, and at the same time has experienced economic growth of 72%. With this strategy of clean growth at the centre of the country's industrial strategy, it is also expected that "green-collar" jobs will grow by 2 million by 2030 (UK Government 2021b). Despite the Government's recent introduction of an adjusted plan, postponing certain measures originally planned for 2030 to 2035 (such as extending the prohibition on the sale of new petrol and diesel cars by five years), according to officials this modification does not diminish their ambition to lead globally in addressing climate issues. The claim is supported by the argument that the country has surpassed expectations compared to other G7 economies (UK Government, 2023).

2.3 The pivotal contribution of digital technologies in facing the climate emergency

The incorporation of digital technologies in businesses is commonly known as Industry 4.0. Originally, Industry 4.0 was conceptualised as the fourth revolution that has arisen in the manufacturing industry, although this conceptualisation has evolved during the past few years to involve the digital transformation of the entirety of industrial and consumer markets (Ghobakhloo, 2020).

It is thought that the use of new digital technologies by both large and small companies could play a significant role in a greener growth and thus contributing to the achievement of the United Nations Sustainable Development Goals (Bican and Brem, 2020, Eteris 2020), especially considering that after many years since the signing of the Paris Agreement, the process is still deficient (Eteris, 2020). It is also believed that digital economy era is a driving force for moving towards SDGs (Schwab, 2016), with 70% of

[4] The Climate Change Committee (CCC) recommended that Carbon Budget 6 should be set at 965 $MtCO_2e$.

the goals being able to be implemented with "already existing digital technology applications" (Eteris, 2020).

European Union countries are promoting that their member states move towards a low-carbon, climate neutral, resource efficient and circular economy (European Commission, 2019). There is also a call in Europe for a "green deal" through a digital agenda, where its digital sector puts sustainability and green growth at the centre of its plans for development (Eteris, 2020). In the case of the UK, this is reflected, for example, in two new strategies from central government called "The Ten Point Plan for a Green Industrial Revolution" (UK Government, 2020a) and in the "UK Research and Development Roadmap" (UK Government, 2020b).

Thus, digitalisation may be seen as a 'problem solver' for climate change, with technology companies developing climate friendly digital applications and Governments working on the development of sustainable strategies where digitalisation is a central element (Lenz, 2021). In line with this, according to the World Economic Forum (WEF, 2022a, p.1), "the digital technology sector is probably the world's most powerful influencer to accelerate action to stabilize global temperatures well below 2°C. Digital technologies could already help reduce global carbon emissions by up to 20% by 2030".

It is expected that digitalisation and the transformation of existing traditional businesses will play a major role in the search for a more sustainable planet (Bican & Brem, 2020). In fact, digital technologies (DT) can contribute to the development of smart solutions to a great number of environmental problems related to climate change in sectors such as health, farming, food security, manufacturing, among others (Argyroudis *et al.*, 2022; George *et al.*, 2019; Eteris, 2020). Specific examples include monitoring of air and water quality, monitoring and optimising the consumption and usage of energy and natural resources (Eteris, 2020). These DT include: artificial intelligence (AI), machine learning (ML), the internet of things (IoT), blockchain, Big Data (BD), advanced sensors, digital twins, deep technologies, among others.

Entrepreneurial actors are already employing DT to address key sustainability challenges, and this is being done not only through technology innovations, but also through the development of business models that give a new purpose to the innovations (George *et al.,* 2019). According to Gregory and Holzman (2020), digital technologies contribute to the development of new value propositions that can combine environmental, social and economic value. According to the same authors, the digital dimension also allows for other elements of value creation, like practices of community development, co-creation, and integration of stakeholders.

It is also thought that digital sustainability has the potential to stimulate innovation and entrepreneurship, having at the same time a great potential for a positive impact on society (George *et al.*, 2019). Although climate tech entrepreneurship and investment seem to be a global phenomenon, as shown in a recent study by Deloitte (2023) that identified that climate tech companies are established across more than 65 countries, most of the initiatives are concentrated in North America (predominantly USA and Canada) and Europe, where the UK is the dominant actor. Worldwide only eight countries concentrated near 75% of climate tech companies (not necessarily digital climate start-ups). These are: Australia (5%), Canada (9%), China (7%), France (4%), Germany (4%), India (3%), the United Kingdom (8%), and the United States (37%). Given their dominance, it is expected that these countries will influence the trajectory and velocity of climate tech development (Deloitte, 2023). Among the technologies included in this study are recycling and waste management, short-duration energy storage, alternative proteins, carbon capture, utilization, and sequestration, long-duration energy storage, electricity management in buildings, and hydrogen production.

To show the relevance of the UK and Europe (the area focus of this research) in the context of the tech ecosystem in general, a study in 2022 showed that the UK tech ecosystem was valued at just under $1tn, placing it third in the world, more than 17x the value a decade before ($53.6bn), and that impact tech companies addressing UN SDGs received $3.5bn in venture capital investment in 2021, nearly 43x that of 2011 (Tech Nation 2022b). In addition, the study found that there were just under five million people working in UK tech start-ups and scaleups, an increase from just under three million in 2019, and more than double from the 2.18 million working in the tech economy in 2011, while tech salaries registered a 36% increase since 2015, while salaries for all jobs increased by just over 10% (Tech Nation, 2022b).

Furthermore, the UK is second only to the USA for the number of firms working to address the climate crisis, with over 5,200 climate tech companies, compared to 14,300 in the USA, 3,656 in Germany, 3,063 in France, 2,504 in Canada, 2,326 in The Netherlands, 2,158 in Italy, 1,959 in Spain, and 243 in Russia, among others (Tech Nation, 2022a). The year 2021 was a record year for climate tech investment, with over $111bn raised by start-ups and scaleups globally, of which $4bn was raised by UK companies, and just under $39bn by USA based companies (Tech Nation, 2022a). Similarly, UK, France and Germany registered significant increase in investments in climate start-ups. Also relevant are Estonia and Sweden. Out of 160 climate tech unicorns (companies valued at over $1bn) that exists worldwide, 6% are based in the UK (Tech Nation, 2022a).

Finally, it is expected that climate tech firms will maintain its dominance as a global innovation leader, as the carbon and energy sector represented 27 percent of all capital invested in European tech firms in 2023, tripling its participation of total investment since 2021. This made it the single largest sector by capital raised, overtaking both fintech and software (Tech.eu, 2024).

In line with this development, the UK government issued a declaration of the 10 Point Plan for a green industrial revolution, aiming to establish 250,000 fresh job positions. The strategy involves a £12 billion investment in environmentally friendly sectors, with the objective of achieving a net-zero carbon economy by 2050. The recently allocated funds in the UK will be granted to innovators, enterprises, and scholars involved in the advancement of technologies within this domain (UK Government, 2020a).

According to Stephen Kelly, chair of Tech Nation Program (a platform to support the growth of highly innovative tech companies in the UK), the fourth industrial revolution can play a massive role in contributing to the UK Net Zero strategy, expecting that digital companies and creative industries will account for as much as 50% of the UK economy by the year 2030[5].

Hence, the two priorities that have shaped the 21st Century agenda, namely the Digital and Sustainability imperatives (George *et al*., 2019), are merging to confront the most significant challenge ever faced by humanity: the climate crisis.

Finally, it needs to be mentioned that not all digital solutions and technologies contribute to the creation of sustainable value, as the aspect of unintended consequences should also be considered, or as expressed by Hellemans *et al.* (2021), they may also have a dark side, leading to unexpected tensions and effects that may risk the creation of value for societal actors. Thus, given that digital technologies have become ubiquitous, sustainability scholars need to get a better understanding of their consequences for sustainable development (Bohnsack et al., 2022).

2.4 The Research Gap and the Contribution of Management Research

According to Daddi (2018), the inclusion of climate change dimension in the strategies of corporations has posed major challenges for organization scholars, gaining increasing relevance in the field of organizations and management. However, some authors have raised unanswered questions about the contribution of these studies to the management theories, as in their view, climate change studies have failed to provide theoretical insights, adopting instead a descriptive and more practical approach (Daddi, 2018, p.456).

Similarly, Wittneben *et al.* (2012) found that many papers adopted a descriptive approach focused on identifying corporate responses to climate change without

[5] Tech Nation website, May 2020. https://technation.io/news/tech-nation-chair-stephen-kelly/

developing a theoretical framework to understand companies' strategies and behaviour. To add to this view, Hahn *et al.* (2010) pointed out the need for novel theoretical approaches to explain the role of business to tackle challenges such as mitigating climate change, alleviating poverty and dealing with migration. Ansari *et al.* (2011) argued that climate change can offer a fertile ground for organization scholars and that management scholars should rethink the current concepts of climate change, especially through the use of institutional, stakeholder and complexity theories.

Reflecting on this, George *et al.* (2019) pointed out that management academics have not fully recognized the immediate importance of climate change and sustainable development in their research. They argue that in light of the widespread scientific agreement on the serious effects of climate change, the management research community should extend its focus beyond academic circles. They should also motivate and direct organizations and their leaders towards a carbon-neutral future. Consequently, it is an appropriate time to engage in the discourse and reshape research to address the societal issues posed by climate change (George, 2016).

Additionally, given the dominance of sustainability and digitalisation as the drivers for societal changes, the need for management research to study the overlap between these two has been highlighted by various authors. Berzina *et al.* (2022) point out that the overlap and integration of sustainability and digitalisation "is an insufficiently explored area, full of potential", where empirical work is needed (Andersen *et al.*, 2021). According to Bohnsack *et al.* (2022), digitalization and sustainability are currently 'hot' topics for policymakers and practitioners and research at the intersection of digitalization and sustainability is only starting. This is also one of the conclusions of the study "Sustainability and Digitalization: Double Strategy Guidelines in National Development", which states that "inherent connections between sustainability and digitalization in the research, development and innovation phase are already providing an active support for quicker SDGs implementation in the states" (Eteris 2020). Howard-Grenville *et al.* (2014) and Huaccho-Huatuco and Ball (2019), also identified these areas as priority areas for further management research.

Even though the relevance and overlap between digitalisation and sustainability (and climate change in particular), academic research on their interconnectedness is still scarce (Feroz *et al.,* 2021, Kraus *et al.,* 2018, Lenz, 2021, Stuermer *et al.,* 2017, Vilchez, 2023), with many authors also emphasising the need to further explore this insufficiently studied area of digitalisation and sustainability (Andersen *et al.,* 2021, Berzina *et al.*, 2022, Bohnsack *et al.,* 2022, Hellemans *et al.*, 2021). In line with this, according to Lenz (2021) there is a need to look at the interconnectedness between digitalisation and sustainability, as so far, the discourses on these two dominant processes of social change have run in parallel to each other, even though their increasing overlapping. Lens (2021) also highlighted that these two areas are increasingly being regarded not just as challenges, but as opportunities for companies using emerging DT, and that this need to address sustainability and digitalisation in an integrated way is also being recognised at the political level, as it is expressed by the German Advisory Council on Global Change (WBGU) in its 2019 report "Towards our Common Digital Future" (Lenz, 2021).

Another dimension to be added to the discussion on digital sustainability, entrepreneurship and climate change, is the need to research into new innovative business models and ecosystems, aspect that has been highlighted as one of the main avenues for future research (George *et al.,* 2019). In fact, there seems to be a broad consensus that sustainable development cannot be achieved without having more sustainable businesses. Despite of this, the business model (a key component of enterprises) have just started to receive attention from sustainability management research (Schaltegger, 2016), where more research is key to understand whether completely new business models (or modified versions of current models) are needed to achieve a more sustainable planet by either reducing their negative impacts on the environment and society or, ideally, creating positive externalities (Schaltegger, 2016).

Gregori & Holzmann (2020) argue that digital technologies enable novel configurations of sustainable business model components: a blended value proposition, integrative value creation, and multidimensional value capture, and consider entrepreneurs to be key actors in the solution to climate change, "as they develop and implement financially viable and innovative business models that create positive impact" (p.1). Similarly, for George *et al*. (2019), entrepreneurial actors are already employing DT to address key sustainability challenges, and this is being done not only through technology innovations, but also through the development of business models that give a new purpose to the innovations.

Thus, there is an important gap of knowledge and opportunity in terms of analysing the intersection and synergies between new business models aimed at tackling climate change and digital technologies (See **Figure 1-1**).

Furthermore, according to George *et al.* (2019), today it is possible to observe in business a convergence of these two topics (digitalisation and sustainability), with consequences for entrepreneurship theory and practice. This aspect of practice is particularly relevant, as a "gap spotting strategy" must be accompanied with an evaluation of the utility in filling this gap (Nicholson *et al.*, 2018), which in the case of this PhD research has been comprehensively explained.

It is therefore an opportune moment to join the debate and promote research aimed at addressing these two imperatives that have taken the agenda for the XXI Century, thus advancing and stimulating new approaches and inspiring other entrepreneurs and corporations to move into this direction. With this aim, the two RQ leading this thesis are:

- RQ1: How do we unpack the value proposition of digital start-ups tackling climate change?
- RQ2: How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?

Now that the research gap has been identified, further exploration of the literature is needed (Chapter 3) to refine the research gap and plan the research in more detail.

2.5 Chapter Conclusions

This chapter covered the main topics that provided the context for this research. To start with, the societal challenge imposed by climate change was explained, briefly presenting its origins, current consequences, and the international efforts that are being taken to deal with it.

Secondly, the role of private companies in tackling this societal challenge was introduced, presenting some examples of initiatives aligned with international pledges, and at the same time presenting some reasons why a more active and widespread involvement is still needed. This section concluded by highlighting the contribution of entrepreneurs, elevating them as key actors in the development of potential solutions to the climate crisis.

Thirdly, the areas of digitalisation and the transformation of existing traditional businesses is discussed, with digitalisation been seen as a 'problem solver' for climate change and with technology start-ups developing climate friendly digital applications, considering it as the world's most powerful influencer to accelerate action to tackle the climate crisis.

Finally, the need to further engage management scholars in the study of challenges imposed by climate change was presented. To the overlapping between sustainability and digitalisation, a third layer was added: business models for sustainability, representing the specific research gap to be tackled in this research.

Chapter 3: Literature Review

3- Literature Review

In this chapter, we introduce the theoretical context that underpins this research. As previously mentioned, this was an empirical and exploratory research focusing on the intersection of digitalization, climate change, and business models (specifically value proposition). This is a nascent area of research where no specific theory has yet been established.

Thus, this chapter starts with a description of business models (BM) and business models for sustainability (BMfS), before presenting the Stakeholder theory and the way they both interact.

3.1. Business Models for Sustainability (BMfS)

There seems to be consensus that a BM is simply a description of how a firm does business, or at least this is a description of the logic that lies behind the processes (Peterovic *et al*., 2001). The concept was first popularised with the emergence of internet, with the dot-coms and the e-commerce companies, and where the start-ups called the attention of investors through new BM, with the expectation of having competitive advantages (Richardson, 2008).

A study carried out by Richardson (2008) showed that different authors have identified different elements conforming the BM, some authors identified three elements (transaction content, transaction structure, transaction governance), others six (value proposition, target markets, internal value chain structure, cost structure and profit model, value network, competitive strategy), while others even eight (customer value, scope, price, revenue, connected activities, implementation, capabilities, and sustainability). In an effort to develop a business model framework that contributed to the strategy of organisations with a simplified logical structure and, at the same time, provided a comprehensive picture of the way a firm does business, Richardson (2008, p.138) captured the common themes and proposed a BM framework around the concept of value, reflecting the logic of strategic thinking about value. These elements are:

The value proposition — what the firm will deliver to its customers, why they will be willing to pay for it, and the firm's basic approach to competitive advantage.

- The offering.
- The target customer.
- The basic strategy to win customers and gain competitive advantage.

The value creation and delivery system — how the firm will create and deliver that value to its customers and the source of its competitive advantage.

- Resources and capabilities.
- Organization: the value chain, activity system, and business processes.
- Position in the value network: links to suppliers, partners, and customers.

Value capture—how the firm generates revenue and profit.

- Revenue sources.
- The economics of the business.

The value proposition typically refers to the benefits a customer gains from a company's (proposed) product or service, and this is the aspect where this research is mainly focussed, although innovation and application of DT also occurs in the other dimensions of the BM.

In the BM framework presented by Richardson (2008), the concept of the value proposition was expanded to encompass not only the product or service the company sells (i.e. the value offering) but also explicitly considers the intended customer or target market. A third aspect of the value proposition under this framework, which is less conventional, involves questioning the company's reason for existence. Beyond what the company offers and to whom, according to Richardson (2008), it is crucial to consider why the market is not already adequately served by existing companies. However, as previously stated, under this research the interest is in the most common understanding of value proposition, which is the value offering, so these concepts (value proposition and value offering) are used interchangeably. **Figure 3-1**, adapted from Richardson (2008) and Bocken (2014), shows the BM framework with the three main components above mentioned, adapted to this research.

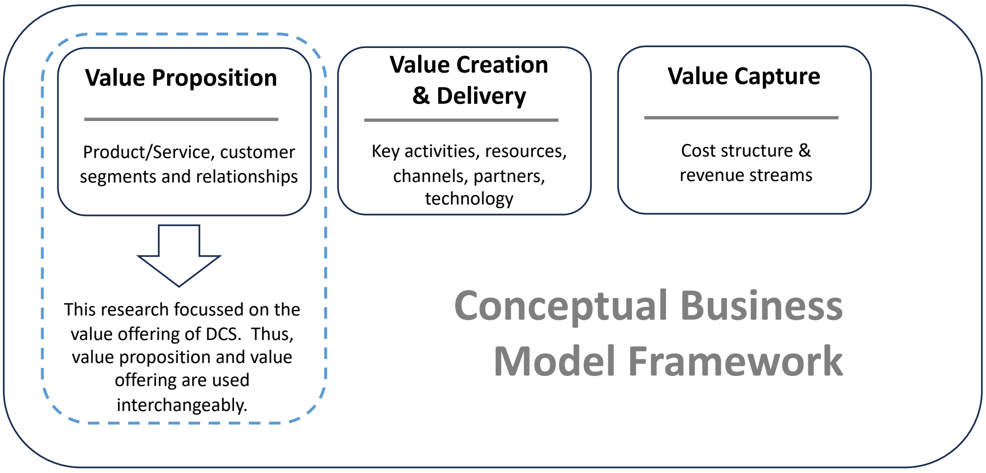

Figure 3-1: Conceptual business model framework, adapted from Richardson (2008) and Bocken (2014)

Teece (2010) states that the essence of a BM is defining the way the enterprise delivers value to customers and seduces customers to pay for this value and transform it into profit. Thus, business models are developed and managed by companies and entrepreneurs in order to create value for their customers.

Traditionally, this value creation process is conceptualised as a unidirectional flow between the businesses and their customers, separating the stakeholders into those who receive the value and those who create it (Freudenreich *et al.*, 2019). Companies, in return, receive the economic compensation for the value delivered.

There has been, however, a growing concern with the *modus operandis* of current capitalist economies and societies, including its organisations, which has been one of the motivations for academic interest in exploring alternative business models (Schaltegger, 2016). In fact, the dominant model for companies is based on the neoclassical economic theory, which states that the primary obligation of corporations is to maximize profits for their shareholders, being social and environmental objectives subordinated to the former goal (Stubbs, 2008). However, given the level of crisis we are facing at a global scale due to the impacts of climate change, it seems clear that this economic approach has serious limitations if society is to avoid the impacts of the climate crisis, being necessary the development of new BM, where sustainability is at the core of the business. Hence, the concept of sustainable business models or business models for sustainability (BMfS) was born as a line of research within BM scholars (Hsien and Evans, 2023).

One of the first academic articles referring to BMfS was Stubbs (2008). She defined a sustainability business model as a model where sustainability concepts shape the driving force of the firm and its decision making (Stubbs, 2008). Under BMfS, sustainability is considered part of the business strategy itself, nor as add-on (Stubbs, 2008).

This model is strongly based on the ecological modernisation perspective, where organisations take into consideration the stakeholders views and interests (including nature and future generations), not just the shareholders views, and where low discount rates are employed to slow down the over-exploitation of natural resources (Stubbs, 2008).

In fact, when talking about BMfS, there is a need to consider that they seek to go beyond delivering economic value to customers, also including other forms of value for a broader range of stakeholders (including the environment). These BM have been defined as business models that create competitive advantage through customer value while also contributing to sustainable development (Ludeke-Freund, 2010).

Similarly, according to Abdelkafi and Täuscher (2016), a BMfS aims at creating value for various stakeholders, including the natural environment. In their research, they emphasised that the core logic of a BMfS is built upon the creation of a reinforcing feedback loop between the created value to the customers, the value captured by the firm, and the value to the natural environment. These authors developed a graphical model based on system dynamics notation in order to conceptualise the relationship between the company, its customers, and the natural environment. This model emphasises the reinforcing feedback loops between the created value to all parties, i.e., the customers, the value captured by the firm, and the value to the natural environment. **Figure 3-2** presents a schematic simplified version of the model. In fact, the actual Abdelkafi and Täuscher (2016) model represents a multilevel system, where the three business model dimensions: customer value proposition, value creation, and value capture, are included, adding a fourth value dimension: environmental value proposition. These are represented by key stocks in the model. To demonstrate the connections between these four key value dimensions, the researchers integrated the business case drivers suggested by Schaltegger *et al.* (2012) as mediating variables. According to Schaltegger *et al.* (2012, p. 102) ". . . the business case drivers have the character of intermediating variables which link the corporate sustainability strategy with the 'architectural' business model level of a firm". Thus, the proposed model identified 18 different connections among its components, analysed the relationship between the stocks and identified reinforcing feed- back loops that lead to system growth.

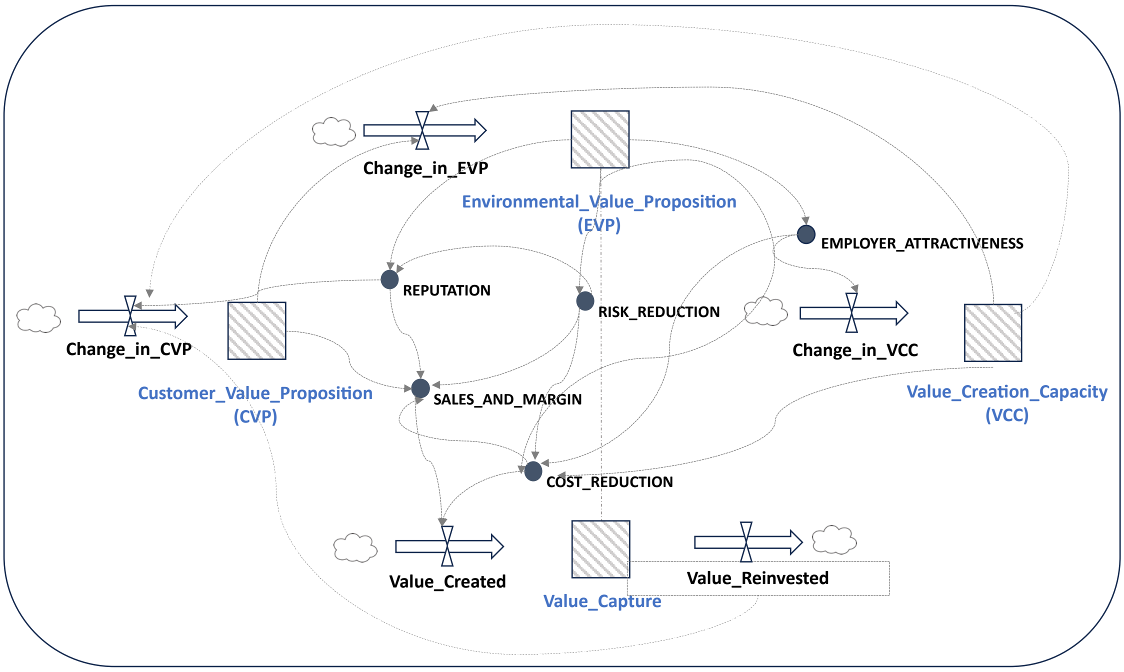

Figure 3-2: Schematic representation of the Stock and flow diagram of generic logic of BMfS developed by Abdelkafi and Täuscher (2016, p.81)

The model developed by Abdelkafi and Täuscher (2016) needed to meet four essential criteria. Firstly, it had to aid entrepreneurs and managers in comprehending the impact their firm had on the natural environment and in identifying ways to minimize this impact. Secondly, the model had to illuminate how the natural environment affects the firm. Thirdly, it needed to clearly define the critical stocks and flows that need to be actively monitored and managed for the performance of the BMfS. Lastly, the model needed to enable the identification of the primary feedback loops both within the firm and between the firm and the environment.

To reinforce this aspect of BMfS needing to create value for various stakeholders, according to Freudenreich *et al.* (2020), BM should be designed, developed, and realised in relationships between a business and its stakeholders. Thus, a theory-based stakeholder value creation framework needs to analyse relationships as a theoretical foundation for the involvement of different stakeholders in business models. Another key component of this framework is a joint purpose that motivates stakeholders to participate in the business model. These two elements constitute a significant distinction between business models viewed through a stakeholder theory lens and those centred merely on a (customer) value proposition. Value co-creation is deemed an essential strategy for companies to manage their stakeholder relationships, thus improving their competitive edge and sustainability (Saha *et al*., 2022, Huang, 2023).

Value creation will also influence the competitiveness of the firm. Competitiveness is concerned with a long-term performance compared to its rivals and is recognised as a multifaceted concept (Man *et al*., 2002). Competitive strategy, as defined by Porter (1985), involves the pursuit of a favourable competitive position within an industry, aiming to establish a profitable and enduring stance against competitive forces (Porter, 1985). Simply put, a competitive strategy enables a company to cultivate a competitive advantage, which lies at the heart of competition and significantly influences performance by enhancing the company's position within its operating environment (Teti *et al*., 2013). Porter's framework delineates competitive strategy into two dimensions: the type of competitive advantage, which can either be cost leadership or differentiation, and the scope of activities, which can be broad or narrow (Teti *et al*., 2013).

Thus, customer value creation represents a strategic commitment with significant economic implications for the firm, as it involves integrating relationship management with innovative offerings tailored for the market (Sanchez-Gutierrez *et al*., 2019). When a company generates value, it allocates it to various stakeholders: dividends for primary stakeholders (i.e., shareholders), salaries for employees, and goods and services for customers, among others (Teti *et al*., 2013). An important consideration here is determining for whom the value should primarily be created and distributed (Mainardes *et al*., 2011). The prioritization of value recipients has sparked considerable debate as it essentially seeks to define the role of firms (Teti *et al*., 2013). In the case of DCS, this debate is expanded even further as the natural environment becomes a primary stakeholder of the firms and should be recipient of the value generated.

Building closer and more collaborative relationships with customers (and stakeholders) facilitates a deeper understanding and fulfilment of their needs through innovative propositions (Preikschas *et al*., 2017). This fosters enhanced differentiation of the firm from its competitors and bolsters competitiveness across various dimensions such as profitability, cost minimization, quality enhancements, product design improvements, and leveraging technology (Sanchez-Gutierrez *et al.*, 2019). In the case of DCS, firms also need a deep understanding of the needs of the various stakeholders that are part of their network, including the natural environment, as will later be shown.

3.2. Why Selecting Stakeholder Theory as the Theoretical Lens?

The utility of theories extends across various stages of the research process. They aid in formulating research questions, directing the choice of pertinent data, interpreting the collected information, and proposing explanations for causes or influences. The significance of theories lies in their ability to offer intricate and comprehensive conceptual insights into phenomena that are inherently complex and elusive—such as understanding how societies function, how organizations operate, and why individuals engage in particular behaviours. Theories provide researchers with different perspectives or "lenses" to examine intricate problems and social issues. This, in turn, focuses their attention on different facets of the data and provides a structured framework within which to conduct their analysis (Reeves et al., 2008).

For this PhD research, there was a broad range of options in terms of the theoretical lenses that could have been used to analyse the information gathered, draw conclusions and develop theoretical propositions. Based on the objectives of this research and its research questions, and following Eisenhardt Method (1989) as explained in the next Chapter, after collecting and exploring the data, together with doing further literature review once the interviews had been concluded, a decision was made to elaborate on existing theory (i.e. working towards extending theory). For that, the theory to be used had to comply with the following criteria:

- The theory needed to explicitly link sustainability to firms,
- The theory needed to allow for a systemic view of the value offering of the firms, beyond the companies' fence,
- The theory had to recognise the natural environment as a potential actor that could benefit from the value offering of companies,
- The theory needed to be used in sustainability management research,

- The theory needed to be used for the study of BMfS (although it may have not been used in the study of the three overlapping areas addressed in this research), and
- The theory needed to be used for looking at climate change in the context of management research.

Thus, a starting point after initial data analysis was deciding about some key aspects of preliminary findings that could help answering the RQs, and so helping in identifying potential research theories. Topics that emerged included the natural environment as stakeholder, the issue of unintended consequences, companies' vision and motivation, among others. As a result, four theories were selected as potential valuable theories to address the objectives of this research (**Table 3-1**), and each of them was evaluated against the selected criteria, as shown in **Table 3-2**. These four theories were Institutional Theory (e.g. looking into DCS's culture and staff commitment), Stakeholder Theory (e.g. looking into the natural environment as stakeholder), Paradox Theory (e.g. looking into potential unintended consequences), and Dynamic Capabilities (e.g. looking into value propositions of DCS and their reconfiguration).

Table 3-1: List of other theoretical lenses that were examined

Theory	Objective	Comments
Paradox Theory	"Paradoxes are persistent contradictions between interdependent elements" (Schad *et al.*, 2016, p.10). This lens shows tensions as inherent within organizational systems and seeks forms to embrace and deal with them (Smith and Tracey, 2016). This theoretical lens is relevant in order to look into the tensions emerging from the value offering of DCS, e.g. the unintended consequences for the environment or local communities.	Although analysing some of the tensions emerging from the use of digital climate technologies is of interest, its relevance in terms of RQ2 (how to improve value proposition of DCS) would have been limited to this aspect, while the objective of RQ2 is broader in scope. In addition, this theory would not contribute to a systemic view of the value offering of the firms.
Dynamic Capabilities	This theoretical lens was originally in the domain of strategic management, and it is defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece *et al.*, 1997, p. 516). It refers to how firms can cope with changing environments (Barreto, 2010). This lens gives the opportunity to study how DCS could reconfigure their resources and capabilities to adapt to rapidly changing environments, particularly given how rapidly digital technologies evolve; and how their competitive advantage is created and maintained (Arndt *et al.*, 2022).	This approach has been subjected to important criticisms, such as the proliferation of definitions producing some confusion, a disconnected body of research pointing in disparate directions (Barreto 2010), and lack of clarity of its main constructs (Kurtmollaiev, 2020), among others. Due to this, after evaluation this approach was discarded.
Institutional Theory	Institutional theory helps to understand organisational culture. It has a well-developed conceptualisation of the type of pressures from the institutional environment working on organizations, which contributes to the understanding of the way the environment affects organizational culture and the mechanisms involved (Zilber, 2012). In the case of DCS, it would be interesting to look into organisational cultural insights of these firms, such as their motivation towards	Although institutional theory was listed as one of the preferred theory in management studies in the area of climate change (Daddi *et al.*, 2018), the emphasis of institutional theory is generally on the formal institutions (e.g. public sector and non-for-profit organisations), which is not the target group of this research. Equally relevant, in this research the objective is to look at the

Theory	Objective	Comments
	including the natural environment as a key stakeholder, the motivation of employees to be part of these start-ups, the culture these firms promoted, decision making processes, among others.	overlapping between BM, DT, and sustainability, so, based on the RQs, the cultural aspect of the organisation was considered to be less relevant.

Table 3-2: Performance of potential theoretical lenses against the selection criteria

	Selection Criteria							
Theory	Relevant to RQ 1	Relevant to RQ 2	Explicitly links sustainability to firms	Allows for a systemic view of the value offering of firms	Recognises the natural env. as a potential stakeholder	Broadly used in sustainability management research	Used for the study of BMfS	Looks at CC in the context of management research
Stakeholder Theory		✓	✓	✓	✓	✓	✓	✓
Dynamic Capabilities			✓	✓		✓	✓	
Institutional Theory			✓		✓	✓		✓
Paradox Theory			✓	✓		✓		

NB:Ticks were allocated by the researcher based on his knowledge of each of these theories and only when it was considered there was a high relevance.

Thus, based on the selection criteria, Stakeholder Theory emerged as the most compelling choice for conducting this research, as this research focussed on the value offering of digital firms, looking at ways this value could be enhanced for a broader range of stakeholders beyond the boundaries of the focal firms (RQ2).

In fact, when linking sustainability to firms, it can be mentioned that formal writing on social responsibility of firms started in the 1950s, with Corporate Social Responsibility (CSR) as a core construct, although it is possible to trace evidence of the business community's concern for society for centuries (Carroll, 1999). According to Chang *et al.* (2017), the main theories linking aspects of sustainability to organisations, in a chronological order, are: 1) Corporate Social Responsibility, 2) Stakeholder Theory, 3) Corporate Sustainability, and 4) Green Economics, forming the main theory landscape of sustainability and firms. Currently, various innovative approaches and new theories have emerged, including Co-evolution Theory and Multi-level Perspective, "reflecting three directions of theory development, namely 1) shifting from "what" to "how", 2) growing use of interdisciplinary approach, and 3) towards broader systems" (Chang *et al.,* 2017, p.49).

Among all of these, stakeholder theory is one of the major, if not the most frequently used, approach in social, environmental, and sustainability management research (Horisch *et al*., 2014; Frynas & Yamahaki, 2013; Montiel & Delgado-Ceballos, 2014). References to 'stakeholders' and stakeholder theory provide a starting point for analyses in a significant number of publications on corporate sustainability and sustainability management, no matter whether they are textbooks, research papers, or policy publications" (Horisch *et al.*, 2014, p.328).

Stakeholder theory is also favoured as a theoretical framework in the examination of business models for sustainability, as indicated by Dembek *et al.* (2018), Norris *et al.* (2020), and Stubbs & Cocklin (2008). This is because these business models aim to propose, generate, and deliver value to all stakeholders extending beyond organizational boundaries, as highlighted by Bocken *et al.* (2014), Freudenreich *et al.* (2020), Lüdeke-Freund & Dembek (2017), Schaltegger *et al.* (2016), and Stubbs & Cocklin (2008).

The focus on stakeholders embraces the assumption that effectively engaging stakeholders is a central element in developing BM that contribute to the societal challenge of sustainability (Stubbs & Cocklin, 2008), and that the capability of a BM to create value depends on ability to successfully harmonise the interest of key stakeholders (Schaltegger *et al*., 2016).

In addition, a study carried out by Daddi *et al.* (2018) showed the most frequently used theories in management studies in the area of climate change (**Table 3-3**), where Stakeholder Theory comes second, after Institutional Theory.

Table 3-3: Organisational and management theories with at least one paper published in the field of Climate Change (adapted from Daddi et al., 2018, p.458)

Theory	References
Institutional Theory	21
Stakeholder Theory	16
Planned Behaviour Theory	13
Transaction Costs	12
Resource-based View	7
Game Theory	6
Organisational Learning Theory	6
Dynamic Capabilities	5
Agency Theory	5

These authors also found that almost all the papers confirmed the theories they used and only a few tried to extend the concepts involved, thus encouraging future authors to be "more courageous" in their approach by updating and broadening the theories explored. Furthermore, Ansari *et al.* (2011) indicate that the Stakeholder Theory is a useful theoretical lens that could prove beneficial for strategy scholars who want to contribute to research on climate change.

Although the Stakeholder Theory was selected as the main theoretical lenses, its links with the other theories above mentioned could be explored in the context of DCS, as these theories can influence each other. For example, connecting Stakeholder and Institutional Theories underscores the pivotal importance of actors or stakeholders and how these entities, along with their relationships, can shape the significance of institutional logics (Herold, 2018). Institutional Theory may also provide good explanations for the adoption of sustainability strategies of DCS. In fact, organisations must actively pursue legitimacy from stakeholders, who in turn require the company's actions to be perceived as acceptable behaviour to legitimate the organisation (Hrasky, 2011). The central premise of Stakeholder Theory is that the long-term survival of a company hinges on the support of these stakeholders, with a core responsibility of management being to address stakeholders' needs and expectations while also reconciling the various interests among them (Herold, 2018).

Similarly, Paradox Theory can inform Stakeholder Theory, and vice versa. Both theories advocate for a multifaceted, long-term, comprehensive, and balanced approach to management. Stakeholder Theory directs attention towards meeting the diverse, and sometimes conflicting, objectives of various stakeholders, while Paradox Theory offers insights into how to navigate the complex task of simultaneously addressing multiple conflicting priorities. Consequently, the former outlines the "what" of effective organizational performance management, while the latter elucidates the "how" (Pinto, 2019, p. 185). These aspects are further elaborated in Chapter 7: Discussion.

3.3. The Evolution of Stakeholder Theory

The notion that the primary (and only) objective of business is to increase profit for shareholders was for a long time an unquestioned assumption above all others business norms. Almost a century ago, the Michigan Supreme Court (in Dodge vs. Ford Motor Company (1919)) established that firms' social responsibility ends at increasing profits for shareholders (Haigh and Hoffman, 2011). Five decades later, Friedman reaffirmed this argument, and added that it was governments' responsibility to solve societal problems. In a seminal article from Friedman (1970), he argues against the notion of social responsibilities for corporations based on three main arguments:

- Only human beings have a moral responsibility for their actions,
- It is managers' responsibility to act solely in the interests of shareholders,
- Social issues and problems should be the concern of governments rather than corporate managers.

In order to support his claims, he provided examples related to taxation, pollution control, inflation, employment, among others. However, given the level of crisis we are facing at a global scale due to the impacts of climate change (among others worldwide challenges), it seemed clear that this economic approach had serious limitations if society is to avoid the impacts of the climate crisis, being necessary the development of new BM, where sustainability is at the core of the business.

Thus, this dominant view started to change particularly since the development of stakeholder theory in the 1980s. As expressed by Freeman (2010), the rejection of the ‘‘financiers first’’ priority rule gave space for the searching for other priority rules to take its place, and so academics focussed in the field of business ethics found in this theory an appealing ground for research, as they regarded the stakeholder theory as an “alternative to bring ethics and justice into business” (Freeman 2010, p. 8).

According to stakeholder theory supporters, “organizations will only be sustainable if the dominant neoclassical model of the firm is transformed, rather than supplemented, by social and environmental priorities” (Stubbs & Cocklin, 2008, p. 103). Traditional definition of stakeholder includes any groups or individuals who can significantly affect or be affected by an organisation´s activities (Freeman and Reed, 1983) and “business can be understood as a set of relationships among groups which have a stake in the activities that make up the business. Business is about how customers, suppliers, employees, financiers (stockholders, bondholders, banks, etc.), communities and managers interact and create value” (Freeman, 2010, p.7).

Under the stakeholder theory lens, firms are viewed as having a responsibility not only towards their shareholders, but also towards other relevant stakeholders of the firm, such as its employees, customers, suppliers, local communities, government agencies, and Non-Governmental Organizations (NGOs) (Crane & Ruebottom, 2011). This implies a collaborative approach that seeks to promote beneficial outcomes for all the parties (not just the firm and its shareholders), in a process of shared value creation with the achievement of common goals (Chang *et al*., 2017).

What constitutes value is, by all means, different for each stakeholder group and it can also be a combination of different types of value (Freudenreich *et al.*, 2020). Given that stakeholders with a legitimate interest in the outcomes expect to receive value from business operations (Casadesus-Masanell and Ricart, 2010; Freeman, 1983; Freeman, 2010; Zott *et al.*, 2011), sustainability outcomes need to be part of the value created for stakeholders and, consequently, become an integral part of the objectives of the firm (Kurucz *et al.*, 2017; Stubbs and Cocklin, 2008).

In a study carried out by Horisch *et al.* (2014), they reviewed the stakeholder literature from the past decades founding that many different versions of stakeholder theory have been developed. Donaldson and Preston (1995) labelled these different versions as descriptive/empirical stakeholder theory, instrumental stakeholder theory, and normative stakeholder theory (**Table 3-4**).

Table 3-4: Different types of Stakeholder Theory (from Donaldson & Preston, 1995, Horisch et al., 2014, p.330)

Type of Theory	Focus	Exemplary Literature
Descriptive/empirical stakeholder theory	Description of how companies are managed; identification of relevant stakeholders	Agle, Mitchell, and Sonnenfeld (1999); Jawahar and McLaughlin (2001); Sangle and Ram Babu (2007); Wallis (2006)
Instrumental stakeholder theory	Effects of stakeholder management on the achievement of corporate objectives	Berman, Wicks, Kotha, and Jones (1999); Johnson and Greening (1999); Jones (1995); Mathur, Price, and Austin (2008)
Normative stakeholder theory	Discussion of the purpose of business; moral justifications of stakeholder theory	Argandoña (1998); Freeman and Gilbert (1988); Goodpaster (1991); Reed (1999)
Integrative stakeholder theory	Considers the descriptive, instrumental and normative aspects of stakeholder theory to be inextricably linked	Freeman (1999); Freeman, Harrison, Wicks, Parmar, and Colle (2010); Jones and Wicks (1999); Schaltegger, Burritt, and Petersen (2003)

This thesis investigates descriptive and empirical aspects of stakeholder theory (the first group), as this approach helps to describe how companies are managed (Horisch *et al.*, 2014) and more specifically understand their value proposition and the way it could be improved for the relevant stakeholders (and the expectations they have related to sustainability).

Finally, according to Freeman (2010), the last 30 years of research on stakeholder theory has led to a rich and varied literature, and the next step is then to see stakeholder theory as a way to redefine how we think about value creation and trade. He adds that "we can make the twenty-first century the century of value creation for stakeholders" (Freeman 2010, p. 9).

3.4. The Natural Environment as Stakeholder

According to Haigh and Griffiths (2009, p.347), the debate surrounding the stakeholder status of the natural environment has developed along five interlinked lines of reasoning:

- The existence of moral obligation between organizations and the natural environment,
- The natural environment's lack of human attributes,
- The dependence of business on the natural environment,
- The adequacy of Freeman's (1984) 'can affect or is affected by' criterion and
- The need for theoretical parsimony.

The more traditional definition of stakeholders does not consider the environment as a valid stakeholder. In fact, subscribers to this definition propose including only those entities that have economic transaction-based relationships with the firms (Orts and Strudler, 2002; Phillips and Reichart, 2000), as, in their view, business transactions are "… characterized by cooperation, mutual benefit, and voluntary acceptance of benefits". They do not recognise the presence of moral obligation between organisations and the natural environment because there may be no mutually beneficial cooperation present (Phillips and Reichart, 2000, p. 187). Furthermore, they do not believe the natural environment has an identifiable interest in organizations, although they have advocated that ethical issues should include valuing its beauty, culture and historical importance (Orts and Strudler, 2002).

However, in recent years the definition by Freeman (1984) has been expanded to include non-humans as stakeholders (Stead and Stead, 2000), thus advocating for a broader view of stakeholders. In fact, many authors have made the case to consider the natural environment as a primary stakeholder (see for example Driscoll and Starik, 2004; Haigh and Griffiths, 2009; Starik, 1995). Starik (1995), for instance, argued that the natural environment is an economic entity and therefore a core stakeholder of organisations. Thus, stakeholders can be defined in a narrow or broad perspective.

Management literature has predominately focussed more on impacts of organizations on the natural environment, and less on the natural environment's impacts on organizations (Winn and Kirchgeorg, 2005). Haigh and Griffiths (2009), instead, highlighted the physical dynamics of the relationship and the growing importance of the natural environment to strategic management, relying on concepts such as its physical force, the dependence of the companies for their entire lifespan and considering it a stakeholder as a matter of practicality.

According to Driscoll and Starik (2004), the attributes given to stakeholders (power, legitimacy, and urgency as proposed by Mitchell *et al*. 1997) are mainly defined from an anthropocentric standing point, and not from an ecological one. This would explain the lack of relevance given to non-human natural environment. They continue to add that the natural environment should take priority among the firm´s stakeholders, and that the stakeholder theory must acknowledge this.

Proponents of this wider definition emphasize that the concept of dependence is crucial yet under-explored, highlighting the intricate link between the survival of organizations and the natural environment. They argue that the biophysical limitations of the natural environment are directly relevant to business strategy (Haigh and Griffiths, 2009). Additionally, there's an acknowledgment of organizations as complex systems (Perrow, 1986), characterized by boundaries that are not rigidly defined (Orts and Strudler, 2002), and that these boundaries are subject to change based on varying circumstances (Orts and Strudler, 2002).

When adopting a more inclusive perspective of stakeholders, which recognizes the natural environment as a legitimate stakeholder in organizations (across various possible categories), we can identify two distinct overarching methods to integrate stakeholder theory within the realm of sustainability. The first method views nature itself as a direct stakeholder. This approach is exemplified in the works of scholars like Starik (1995), Stead & Stead (1996), and Waddock (2011). The alternative method positions human entities — individuals, groups, and organizations — as stakeholders who observe, understand, and respond to changes in the natural environment. This perspective is reflected in the research of Freeman *et al*. (2000), Phillips et al. (2003), Phillips & Reichart (2000), and Schaltegger *et al.* (2017).

There is a distinction between human representatives of the natural environment and the natural environment itself (Haigh and Griffiths, 2009 and Driscoll and Starik, 2004). The former is a human proxy stakeholder advocating for it (for example environmentalist groups and NGOs), but they may create additional layers of interpretation, and companies may concentrate in managing the relationship with them instead of concentrating in the natural environment (Haigh and Griffiths, 2009).

Phillips and Reichart (2000) further emphasise this viewpoint by suggesting that the needs of the natural environment are represented through human proxy stakeholders who advocate on its behalf. However, they also point out that what may be represented are not necessarily the needs of the natural environment itself, but rather those of the proxy stakeholders. Freeman (1984) highlighted the importance of organisations directly interacting with stakeholders, thereby proposing environmentalists as the stakeholders rather than the natural environment itself. Additionally, Freeman (1984) identified the natural environment as part of a non-traditional group of stakeholders, expanding the conventional understanding of stakeholder categories.

In the realm of BMfS research and stakeholder theory, it is observed that the focus is predominantly on humans (human-centred), as highlighted by Hausdorf (2023). This emphasis revolves around human stakeholders, including customers, suppliers, employees, partners, shareholders, investors, or local communities, as noted by Freudenreich *et al.* (2020), Norris *et al.* (2021), and Stubbs & Cocklin (2008).

Nevertheless, there is a growing trend among scholars to acknowledge nature as a non-human stakeholder in their investigations, as seen in the works of Fobbe & Hilletofth (2021), Lüdeke-Freund *et al.* (2020), Velter *et al.* (2020), and Vladimirova (2019).

Although this research leaves a detailed discussion on the distinction between these two views to the existing research, the conceptual framework later presented builds on the second approach where sustainability interests are represented by human stakeholders, highlighting how the natural environment is central to strategic management, and what the implications could be for business, policy and future research.

3.5. Frameworks for the Natural Environment as Stakeholder

Based on Mitchell *et al*. (1997) framework, the identification of stakeholders should consider the attributes of power, legitimacy and urgency as central elements in order to determine their level of relevance, this is: (1) the stakeholder's power to influence the firm, (2) the legitimacy of the stakeholder's relationship with the firm, and (3) the urgency of the stakeholder's claim on the firm.

Based on the presence of these attributes, the authors proposed seven categories of stakeholders: definitive stakeholders, dominant, dormant, dependent, discretionary, dangerous and demanding (**Figure 3-3**).

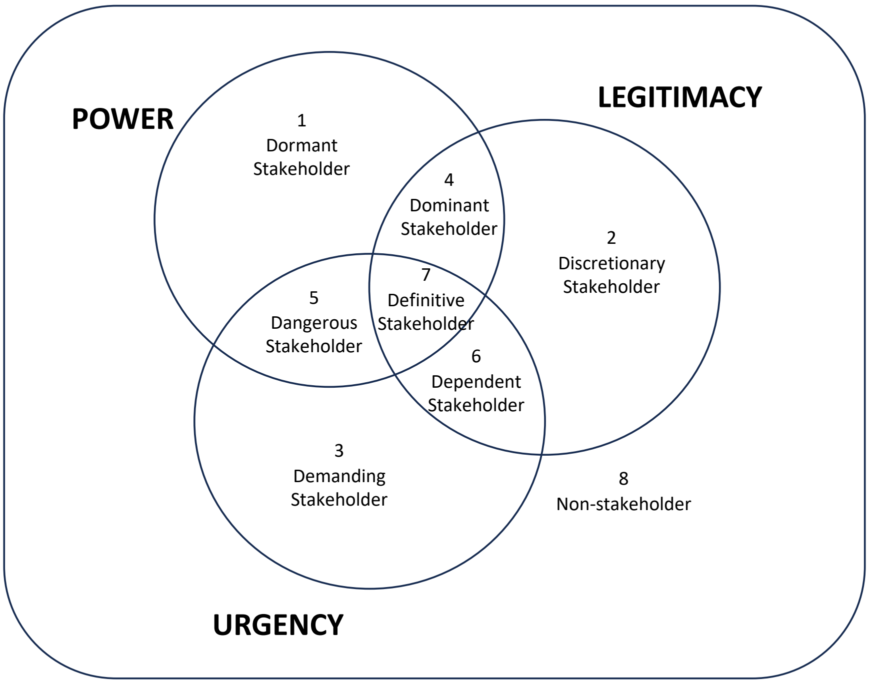

Figure 3-3: Stakeholder typology: one, two or three attributes present (Mitchell et al., 1997, p. 874)

According to their framework, the environment would be classified as a dependent stakeholder, this is "stakeholders who lack power but who have urgent legitimate claim" (Mitchell *et al.*, 1997, p. 877). These stakeholders depend on others dominant stakeholders to carry out their will. In other words, the natural environment is not relevant to managers unless other dominant stakeholders decide to exercise their power to support the protection of the natural environment (Driscoll and Starik, 2004).

Driscoll and Starik (2004) expanded this framework by adding the attribute of proximity (in space and time) and making the case for the natural environment to be considered a primordial stakeholder of the firm and hence should be of high importance to all managers.

They proposed a broad view of stakeholders, as shown by the definition by Mitchell *et al.* (1997, p. 854) of stakeholders as '. . . those entities to whom managers should pay attention'.

For Driscoll and Starik (2004, p.69), "the natural environment should be seen as the primordial and primary stakeholder of all firms, deserving of immediate attention by management researchers and practitioners", although most of the time this is not the case. As discussed before, managers and firms define their stakeholders under a socio-economic lens, giving more relevance to aspects of the market, supply chain, shareholders, competitors, governmental agencies, among others (Cyert and March, 2015).

Haigh and Griffiths (2009) made the case of the natural environment as a primary stakeholder by demonstrating it has power, legitimacy, urgency and proximity, particularly in the context of impacts produced by climate change (the natural environment is an easily identifiable primary stakeholder when bringing into the discussion the issue of climate change). According to these authors, the natural environment is a non-traditional but extremely relevant stakeholder. "Climate change enables us to view the organization–natural environment relationship in a less anthropocentric light, and with respect to its inherent properties" (Haigh and Griffiths, 2009, p.357). They approached the stakeholder issue from a strategic rather than moral or ethical perspective, as climatic events such as "increasingly frequent anomalous extreme weather, can damage business infrastructure, resources, products and market, overshadowing moral and ethical aspects of the debate" (p.347). **Figure 3-4** presents this view.

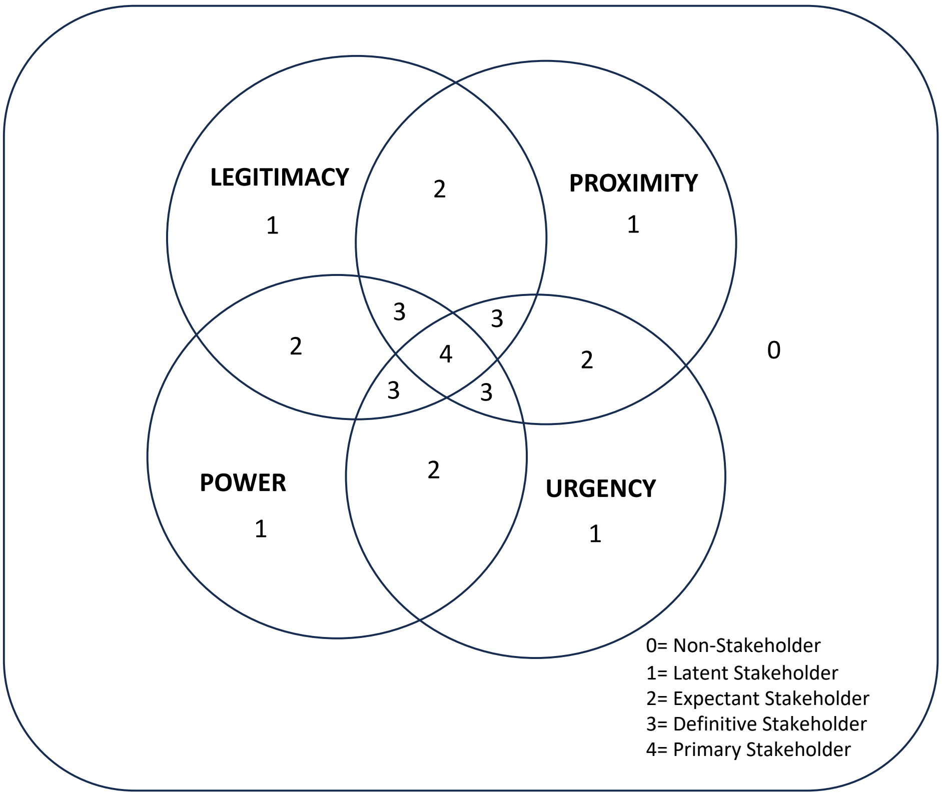

Figure 3-4: Combined Stakeholder Identification Framework (Haigh and Griffiths, 2009, p. 353)

In Starik's view (1995), dependence is a concept that has been overlooked. Organisations depend on the environment for the provision of raw materials, water, air, energy, and their physical location (Clarkson *et al.*, 1994; Stead and Stead, 2014), making the natural environment a core economic stakeholder (Starik, 1995).

In the case of some DCS, their value offering is based on the maintenance or improvement of the natural ecosystems. In other words, for these types of firms the natural environment is an economic entity and therefore a core stakeholder (although there is no economic transaction-based relationship). They also recognised the moral obligation due to the level of impacts of climate change. According to Bazin and Ballet (2004), when the natural environment is included as a stakeholder of the firm, it needs to have an ethical status, otherwise the theory runs into complications. They added that humans have an interest in preserving life, which depends on the natural environment.

3.6. The Selected Stakeholder Framework

Selecting Stakeholder Theory as the theoretical lens for this research was a valuable first step, yet it was still too broad. Hence, there was a need to apply a more specific theoretical proposition (framework) which could be further developed through this PhD thesis. To this aim, continuing with the set of criteria presented in Section 3.2, specific emphasis was made in two of them:

- The framework needed to specifically emphasise the role of the natural environment as a primary stakeholder,
- The framework needed to specifically target the value proposition/offering.

Thus, according to Geissdoerfer *et al.* (2018), the main idea of the BMfS concept is to modify the conventional business model by incorporating sustainability into the value chains of an organisation. In fact, transitioning towards BMfS entails looking beyond the boundaries of an organisation, and it needs innovation activities to create sustainable values for the stakeholders. The traditional conceptualisation and understanding of business models is therefore insufficient to address the challenges faced by companies (Goni *et al.* 2020).

A study carried out by Goni *et al.* (2020) reviewed the existing literature on BMfS, by comparing the presence/absence of nine features: sustainability, value chain, core values, value creation, organisational values, circular economy, performance management, IT, and stakeholder engagement. The objective was to analyse existing frameworks developed for BMfS, identifying gaps and new features that need to be included. Under stakeholder engagement, in particular, the authors considered the aspects of partnership, participation, consultation and communication, defining this feature only from human-centred perspective (i.e., insufficient according to the two criteria above mentioned). In fact, the authors defined stakeholder engagement as the "process in which an organisation involves people who influence decisions about the business operations of an organisation" (p.895). In another study of BMfS by Comin *et al.* (2020), it was found that there is a strong focus on service-oriented business models and a call for user involvement in the value creation process, i.e. a user-centric perspective, where the client can be part of a co-creation process. Although still insufficient for the aim of this study, the aspect of co-creation is of high value, as will be shown later.

Evans *et al.* (2017), on the other hand, presented a unified perspective drawing on multiple bodies of literature, including business model innovation, sustainability innovation, networks theory, stakeholder theory and product service systems (Evans *et al.,* 2017). In their study, they treated society and nature as stakeholders of the firm, in line with Haigh and Griffiths (2009)'s definition of the natural environment as a primary stakeholder, highlighting their importance as key elements for the conceptualization of BMfS (Stubbs and Cocklin, 2008, Evans *et al*., 2017). In fact, Haigh and Griffiths (2009) demonstrated that the natural environment has an economic stake in organizations, as it can 'affect or is affected by' the business. Identifying all the value flows among stakeholders, including the natural environment and society as primary stakeholders, can reveal opportunities for business model innovation (Evans *et al.*, 2017). The work performed by these authors presented five propositions, of which the following three are of relevance to this study (p.601):

- Proposition 1. Sustainable value incorporates economic, social and environmental benefits conceptualized as value forms.
- Proposition 2. BMfS require a system of sustainable value flows among multiple stakeholders including the natural environment and society as primary stakeholders.
- Proposition 4. BMfS require a systemic consideration of stakeholder interests and responsibilities for mutual value creation.

Identifying the potential value flows among stakeholders, including the natural environment and society as primary stakeholders, can open valuable opportunities for innovation within the BMfS context (Evans *et al*., 2017). It must also be emphasised that the scope of value goes beyond economic transactions, looking into relationships, exchanges and interactions that take place among the various stakeholders (Allee, 2011).

Thus, a framework that complied with these two emphasised criteria, and to some extend with the above mentioned propositions by Evans et al. (2017), was the Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) developed by Freudenreich *et al*. (2020). In fact, by developing this framework, the authors looked to contribute to business model research by applying stakeholder theory to stakeholder relationships in a business model context, with focus on value creation (in this case, value creation refers to a broad definition of value, including value proposition, value capture and value delivery). The authors considered relationships among stakeholders (and not just the clients) as a core aspect of business models, highlighting the "active role that each stakeholder plays in value creation processes" (p.16). They also emphasised the relevance of applying stakeholder theory as this shifts the focus from developing a value proposition considered relevant by customers to creating multiple outcomes (a value portfolio), each of which are valued by different stakeholders. The authors also proposed that any analysis of a BMfS should be preceded by a detailed analysis of its stakeholder network, according to the framework they developed.

In a review of research on stakeholder theory carried out by Parmar *et al.* (2010), the authors identified six key groups as members of a business's stakeholder network: customers, suppliers, employees, financiers, communities, and managers. The SVC Framework reduced these to five stakeholder groups, by combining managers in the employee stakeholder group. In relation to the community group, according to authors, a more suitable term for this group is societal stakeholders (instead of communities) because "it represents perceived needs in society and the natural environment and the relationship of members of this group to the focal business is not governed by contract" (Freudenreich *et al.*, 2020, p. 10). **Figure 3-5** shows a simplified version of the SVC Framework as developed by Freudenreich *et al.* (2020).

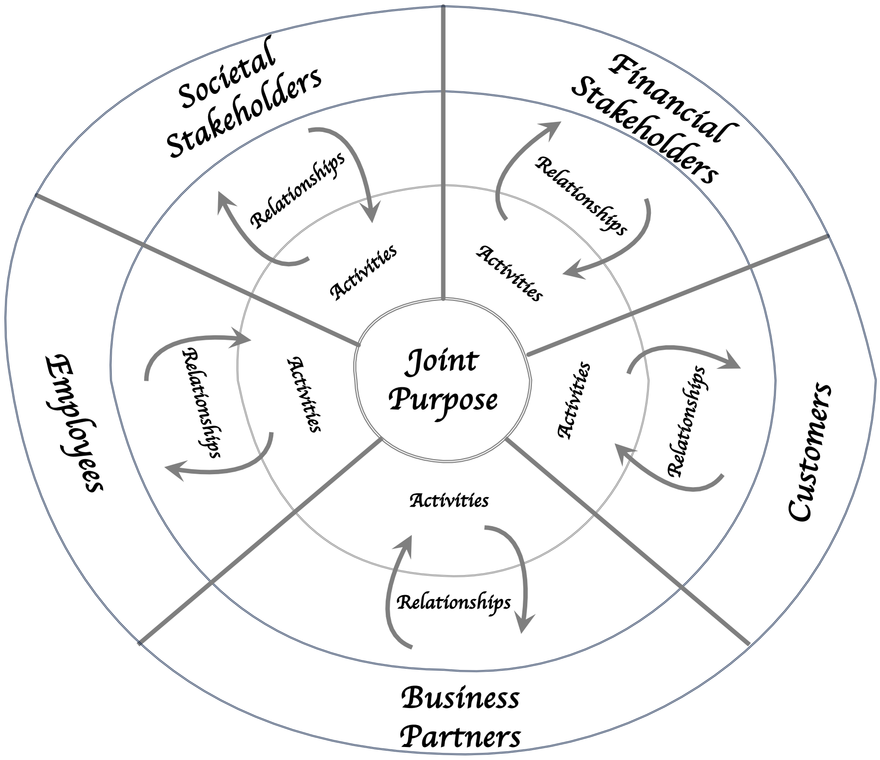

Figure 3-5: Simplified version of the SVC Framework (Freudenreich et al., 2020, p.9)

Figure 3-5 shows how the focal business engages with each stakeholder group through different activities, and that they are all united by a central joint purpose. The arrows show that value can be created in both directions, in a permanent exchange process. The framework also shows that the value portfolio may differ from one group to another. The inner circle represents the value created for the focal company while the external circle represents that value is also being created for each specific group of stakeholders. Under this framework, each stakeholder is not only a recipient of a value, but also an active contributor to the development of the value portfolio (i.e. stakeholders make an active contribution to value creation activities). For example, while traditionally customers are seeing as recipients of the outcome of the value creation processes, under the stakeholder theory lens customers are active participants in the business model. In fact, they do not just pay for a product or service but also provide other values to the business, for example: personal data and information about consumption preferences, they may also be involved in value creation processes, for example, by individualizing product designs or participating in open innovation initiatives (Freudenrich *et al.*, 2020), such as focus groups.

Thus, under this approach, the development of the value proposition of BMs needs to consider the role of multiple stakeholders (the value creation network) to contribute to and benefit from the value being created, risking losing their business partners and legitimacy if this is not achieved (Freudenreich *et al*., 2020). This conclusion from the business model literature is reinforced by updated interpretations of Freeman (1984) stakeholder theory (Freudenreich *et al*., 2020). Garriga (2014, p. 491), for example, defines stakeholders "as groups or individuals who contribute, whether substantially or not, to the value creation process of the business". Value is therefore created jointly by and exchanged between the focal business and its stakeholders (Figge and Schaltegger, 2000); therefore, by applying stakeholder theory the focus shifts from "producing something customers consider valuable to creating multiple outcomes, each of which is perceived to be valuable in different ways by its recipient stakeholders" (Freudenreich *et al.*, 2020, p.16).

Figure 3-6 shows the concept of value creation according to more traditional BM perspectives as well as the Stakeholder Perspective on value creation. In the first case the value flows between the focal business and its customers, while the second is more concerned with value being created for multiple stakeholders.

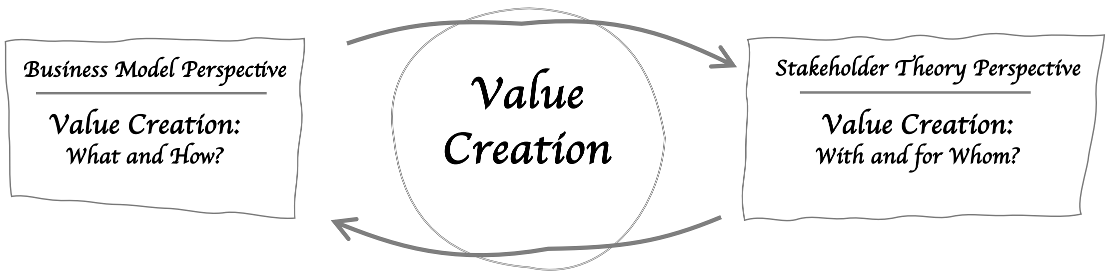

Figure 3-6: Business model and stakeholder theory perspectives on value creation (Freudenreich et al. 2020, p.4)

In their analysis, however, the natural environment was not discussed in detail, as they solely focussed on human stakeholders (e.g. societal stakeholders, financial stakeholders, business partners, employees, and customers). In fact, under societal stakeholders the authors included the "perceived needs in society and the natural environment" (p.10), adding that the relationship of members of this group to the focal business are not governed by contracts.

However, in the case of DCS, given the nature of their business and objectives, value is explicitly expected to be created for the natural environment by, for example, protecting a forest and its biodiversity. In return, society receives benefits from the environment, like ecosystem services in general or carbon sequestration in particular. This outcome of the BM is expected to also have other positive impacts in the local community and, given the global nature of the CC challenge, on human society as a whole. This aspect of recognising the natural environment as a key stakeholder in the context of BM of DCS is a central element of this research, as for this type of business the SVC Framework seems incomplete. Hence RQ2 in this PhD research is “How can Digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?”.

3.7. Chapter Conclusions

This chapter started by introducing the concept of business models (BM) and business models for sustainability (BMfS). It was shown that BM research presents several forms to describe and classify BM. In particular, the approach by Richardson (2008) was presented, consisting of: value proposition, value creation and value capture. It was also shown how the traditional understanding of BM has evolved to BMfS, a model where sustainability concepts become the driving force of firms and their decision-making processes.

Thus, scholars propose a shift of the conceptualisation of the value creation process, traditionally seen as a unidirectional flow between the businesses and their customers, separating the stakeholders into those who receive the value and those who create it, to a process that seeks to go beyond delivering economic value to customers, also including other forms of value and for a broader range of stakeholders (including the environment).

The Stakeholder Theory was presented as the selected theoretical lens for this research, providing elements that justified its use. The evolution of this theory over time was outlined, making the case that organizations will only be more sustainable if the dominant neoclassical model of the firm is transformed, rather than supplemented, by social and environmental priorities.

The next section addressed the debate surrounding the stakeholder status of the natural environment, as the more traditional definition of stakeholders does not consider the environment as a valid stakeholder. Indeed, subscribers to this traditional definition propose including only those entities that have economic transaction-based relationships with the firms.

In the last decades management scholars have expanded the definition of stakeholders to include non-humans, thus advocating for a broader view of stakeholders. In fact, many authors have made the case to consider the natural environment as a primordial or primary stakeholder. Hence, two different general approaches to apply stakeholder theory in the context of sustainability can be identified: considering nature as a stakeholder by itself or alternatively considering human beings (or organisations) as stakeholders who analyse and interpret nature.

The chapter ended by presenting Stakeholder Theory research frameworks used in the context of sustainability, and the selected Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) developed by Freudenreich *et al.* (2020).

Chapter 4: Research Philosophy

4- Research Philosophy

The decision to investigate a subject in a particular way invariably involves a philosophical decision about what is considered important (Easterby-Smith *et al.*, 1991). Therefore, the research philosophy is inherent in the study and must be addressed before the design of the research strategy and methodology.

Scientists and philosophers have long grappled with the challenge of understanding and interpreting our world. There are both descriptive and prescriptive approaches. Descriptively, theories in cognition, perception, and thought process explain how humans process stimuli and comprehend them. Prescriptively, there are two main methods for making sense of the world: reductionism and systems theory. Reductionism suggests that the most effective way to understand new phenomena is by analysing the functions or characteristics of its individual components. For instance, to understand the human body's workings, one would study each of its parts (like organs, muscles, tissues, bones, and cells) and their individual properties (Miller and Rice, 1967). Conversely, systems theory concentrates on the interactions among these parts. Rather than dissecting an entity like the human body into its separate elements (such as organs or cells), systems theory examines the organisation and interconnections of these parts, arguing that the system's characteristics are defined by the organization and interactions of its components (Miller and Rice, 1967). In the context of management, a system is essentially a collection of distinct yet interconnected parts functioning collaboratively to achieve a unified objective. Take an organization as an example: it comprises various departments, sections, and units, each made up of individual and group members. These components are independent in nature, yet they work in concert to fulfil a shared objective, with the ultimate goal of realising the organisation's vision. In summary, while Systems Theory represents an abstract philosophical concept, it also embodies a deeply empirical and research-oriented approach within the field of management science (Miller and Rice, 1967).

Thereby, the philosophical debate in management research is concerned with the ontological and epistemological foundations of the research, where ontology is the "assumptions that we make about the nature of reality" (Easterby- Smith *et al*., 1991, p.31). while epistemology is about what represent knowledge or evidence (Mason, 2012).

Mason (2012) suggested a framework of five questions that researchers must address at the outset of their investigation. The first two questions refer to the need to define the ontology and epistemology of the research, while the remaining three are concerned with the topic of study and the research questions. Similarly, O'Gorman and MacIntosh (2015) identified four key components in research methods for business and management: ontology, epistemology, methodology and method, as shown in **Figure 4-1.**

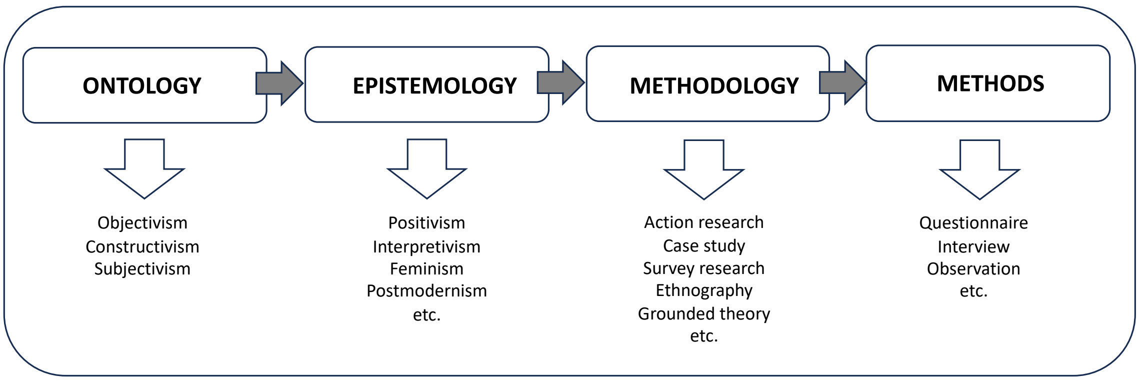

Figure 4-1: General framework for management research (adapted from Gray, 2021, and O'Gorman and MacIntosh, 2015)

4.1. Ontology

When looking into the ontology of a research, the central question is "What is the nature of the social reality I want to investigate?" (Mason, 2012). This PhD research looks into climate change as a business opportunity (i.e. business-based solutions to this socio-ecological problem), by studying emerging private enterprises that are developing digital solutions aimed at addressing the challenges imposed by the climate crisis into our society. More specifically, the aim of the research is to look into the interconnectedness between these digital solutions and climate change, and the innovative business models and value propositions being developed (with focus on the natural environment as a stakeholder). Therefore, the interconnectedness took the form of the value propositions for various stakeholders (including the natural environment), aspects of subjective nature.

4.2. Epistemology

The second question put forward by Mason (2012) related to the epistemological position, this is: “What may represent knowledge or evidence of the entities I want to investigate?”.

The above ontological definition is well suited for qualitative research, as it is about understanding the aspect of interconnections and value for multiple stakeholders. In addition, as this research is proposing the study of a new phenomenon with not enough previous research (i.e. the analysis of the interface between digital technologies, BM, and climate crisis), applying a qualitative methodology seemed to be the most adequate avenue (Bican and Brem, 2020). In the same sense, applying a qualitative research design was expected to enable an adequate study and description of the complex relationships of the business model components, their exemplification, and the materialization of multiple institutional logics (Gregory and Holzman, 2020).

Qualitative research allows to engage and explore the way institutions work and the significance they generate; through qualitative research it is possible to better understand how things work in the particular context under study. In words of Mason (2012, p.1), it allows as to “engage with things that matter, in ways that matter”.

Thus, this research was conducted under an interpretivist philosophical lens (a branch of epistemology, an answer to the objective world of positivism). The reason behind this choice of approach was that interpretivist as philosophical position is concerned with how the social world is interpreted, understood, experienced, produced, or constituted (Mason, 2012). People were the primary source of data (mainly CEOs and founders of start-ups), and the aim was to explore their understanding about the value they generate for stakeholders, with focus on the natural environment. The underlying idea of the interpretivist approach is that the researcher is part of the research, interprets data and as such can never be fully objective and removed from the research.

Interpretivists focus on unique, context-specific settings and recognize that both reality and knowledge are shaped by individuals in those environments, not entirely objective. This philosophical stance is more subjective and prone to biases, making it less generalisable compared to the way positivist research can be (Gray, 2021; O'Gorman and MacIntosh, 2015).

4.3. Methodology

Research in the social sciences is broadly divided among deductive, inductive, and abductive research designs (Thompson, 2022). This research is primarily empirical phenomenon-driven research with an inductively-oriented data analysis process (interpretation is grounded in the data) based on multiple case studies, where semi-structured interviews are the primary source of data. Secondary data was collected from publicly available reports, company documents, web sites, and newspaper and journal articles.

As previously mentioned, the topic of this research is well suited for a qualitative methodology, as it is about understanding the aspect of interconnections. As proposed by Ormston *et al.* (2014, p. 12), "social research should explore "lived experiences" in order to reveal the connections between the social, cultural and historical aspects of people´s lives and to see the context in which particular actions take place".

The justification for this methodology also rests on the phenomenon´s importance and the lack of visible theory and empirical evidence (phenomenon-driven research questions). As defined by Barratt *et al.* (2011, p. 329), this research "primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon". In the same line, as this research is proposing the study of a new phenomenon with scarce previous research (i.e. the analysis of the interface between digital technologies, BM, and climate crisis), applying a qualitative methodology seems to be the most adequate avenue to explore the topic (Bican and Brem, 2020). Applying a qualitative research design enables an adequate study and description of the complex relationships of various business model components and their exemplification (Gregori and Holzman, 2020).

In qualitative research, the design of a research strategy is an ongoing process grounded in the process itself, and in the results obtained along the process. This is because qualitative research is "characteristically exploratory, fluid and flexible, data-driven and context-sensitive" (Mason, 2012, p.24), making it almost impossible to write an entire blueprint strategy from the beginning.

Although this was primarily inductive research, the abductive approach was also used in order to construct empirically based theorisation, particularly for the development of second order categories, as later explained. In fact, Thomson (2022) defined a step-by-step guide to abductive thematic analysis by specifying eight steps:

- Step (1) Transcription and Familiarisation
- Step (2) Coding
- Step (3) Codebook
- Step (4) Development of Themes
- Step (5) Theorising
- Step (6) Comparison of Datasets
- Step (7) Data Display
- Step (8) Writing Up

Steps 1 to 4 were part of the inductive approach (the first half of this research). Step 5 (abductive approach) was also key in order to select the most appropriate theoretical lenses and thus define the expected contribution to theory (RQ2); it was also relevant in the context of RQ1, as it allowed the definition of literature informed categories.

This is a key step that distinguishes the abductive approach from other guidelines on qualitative analysis. Unlike deductive methods, the idea here was not to test the collected data by fitting it into already existing theoretical frameworks, but instead, "the clustering and explanation of themes should be guided, but not determined by existing theoretical understanding" (Thompson, 2022, p.1415). In fact, according to Tavory and Timmermans (2014), qualitative researchers navigate complex waters, as they have to navigate between a rich descriptive account and narratives, but may be not sure how to think theoretically about their work. Equally problematic can be trying to adjust their findings to predefine theoretical account, both of these approaches falling short of the expectations of high-level qualitative investigation. Thus, a more appropriate approach can be to conduct the analysis in two parts, where one part is an empirical observation of the social world while the other is a theoretical proposition. These two parts should in the end intertwine and amplified each other (Tavory and Timmermans, 2014). Thus, finding a balance between the theory and observations (i.e. deductive versus inductive approaches) is a complex challenge, or as put by these authors, "the relation among theory, observation, and method thus remains and Achilles heel of qualitative research" (Tavory and Timmermans, 2014, p.3). Therefore, the abductive data analysis approach aims to find a middle ground between inductive and deductive methods. Thus, in the second part of this research abductive analysis was used in order to construct empirically based theorisation, providing a way to "think about research, methods and theories that nurture theory construction, without looking it into predefined conceptual boxes" (p.4).

The nature of what constitutes a theory and what does not is a longstanding debate (Sutton and Staw, 1995; Weick, 1995). Theories are frequently characterized by their ability to explain relationships between phenomena that were previously misunderstood or not understood at all. However, there is no unanimous agreement on the exact definition of a theory. A theory can be viewed either as a final product or as part of a continuum, and continuous efforts are being made to delineate the various phases of this continuum (Ridder, 2017, p.293).

Finally, according to Ridder (2017), there needs to be clarity as to whether a case study design (the selected method) aims at creating, elaborating, extending, or testing theory, to clearly identify what the potential contribution is (in the case of this research, its aim is to extend theory).

4.4. The Method

Research in social sciences can be carried out in different ways, including case studies, surveys, experiments, histories, and archival analyses such as statistical or economic modelling (Yin, 2014). Case study is a preferred method when dealing with questions of "how" and "why" (Yin, 2014). Case study research can include single or multiple cases, drawing a single set of "cross-case" conclusions. It can also include qualitative or quantitative evidence and embrace different epistemological orientation, e.g. relativist or realistic orientation (Yin, 2014). It also must be considered that with case study research an investigator's goal is to expand and generalise theories (analytic generalisation) and not to enumerate frequencies (statistical generalization) (Yin, 1992).

Classical case study approaches prioritise detailed examinations of a single case, taking into account the context to derivate insights that can lead to the formulation of new theories. Dyer and Wilkens (1991) assert that when multiple cases are compared, the result often is more superficial descriptions, which may undermine the ability to provide detailed, contextually rich narratives. Whereas traditional case studies strive to tell compelling stories, multiple cases method focuses on the creation of well-defined constructs and the exploration of their interrelations, as discussed in Ridder's work (2017).

Case study research scientifically investigates a real-life phenomenon within its environmental context, where these contextual conditions are not controlled by the researcher (Ridder, 2017) and the focus of the research is a contemporary topic (Yin, 2014). A case study method is particularly valuable to address theory-building research and to demonstrate that the existing research does not properly address the investigated propositions (Eisenhardt & Graebner 2007, Cosenz 2020), thus, it is first and foremost about theory building (or in the case of this research, extending theory).

In case study research, unlike in experimental research, the surrounding context is not isolated or manipulated; instead, it is integral to the investigation. Case studies typically use non-random sampling, as they don't select a sample to represent a broader population. Instead, a case is selected based on its intrinsic interest, as argued by Stake (2005), or for theoretical reasons, as Eisenhardt and Graebner suggested (2007), rather than following the statistical logic of quantitative research (Ridder, 2017).

According to Eisenhardt and Graebner (2007), solid empirical research is founded on a thorough review of existing literature, the identification of an unexplored area (the research gap), and the formulation of research questions aimed at filling this gap. However, when adopting the strategy of constructing theory from case studies, researchers must additionally explain why their research questions are more suitably addressed through theory building rather than theory testing. There's an underlying presumption that theory building from case studies is not as exact, impartial, or methodical as large-scale hypothesis testing.

The task of defending inductive case study research partially depends on the nature of research question posed. For questions aimed at expanding upon current theories, as noted by Lee *et al.* (1999), a researcher must situate the inquiry within the existing theoretical framework and then argue why inductive theory construction is essential (Eisenhardt and Graebner, 2007). On the other hand, when dealing with questions driven by phenomena, a researcher must highlight the significance of the phenomenon in question and the absence of any convincing current theories covering it. Such research questions are intentionally broad to allow the researcher greater flexibility. The rationale here is built upon the significance of the phenomenon itself, coupled with a gap in both theory and empirical data to explain it (Eisenhardt and Graebner, 2007).

Ridder (2017) made a comparison among case study research highlighting the main differences among the four principal methods. **Table 4-1** presents the main results obtained in the study.

Table 4-1: Portfolio of case study research design: differences in underlying elements (Ridder, 2017, p. 292)

	Case Study Research Designs			
	No theory first	Gaps and holes	Social construction of reality	Anomalies
Representative scholars	Eisenhardt (1989)	Yin (2014)	Stake (1995)	Burawoy (1998)
The case	Research question; A priori constructs, variables; No assumed relationships	Research question; Existing theory; Proposition; Framework	Curiosity in the case; Understanding of research issues	Curiosity; Existing theory; Anomalies; Internal contradictions; Gaps, silences
The data	Theoretical sampling; Qualitative data as the primary choice	Purposeful sampling; Qualitative data as the primary choice	Purposive sampling; Thick descriptions; Holistic comprehension	Theoretical sampling; Dialogue of observer and participants; Participant observation
The analysis	Emerging constructs and relationships	Pattern-matching as a primary choice; Analytic generalization	Learning from the case; Categorical aggregation	Social processes; Structuration; Reconstruction of theory

As explained before, the epistemological orientation of this research is relativist or interpretivist, acknowledging multiple realities having multiple meanings, with findings that are observer dependent (Yin, 2014, p. 17), and with no initial theory having been defined. Thus, the selected research method was multiple cases (i.e., several cases of climate start-ups were chosen, analysed, and compared), where the Eisenhardt Method (1989) was the method that best fit the objectives of the research.

The Eisenhardt Method's unique contribution is theory building from multiple cases (Eisenhardt, 2021), and "it relies on Yin's work (1984) on cases (and replication logic) and Glaser and Strauss' (1967) iterative process of constant comparison of data and theory (and theoretical sampling and saturation)" (Eisenhardt, 2020, p.148). The method also follows the ideal of 'no theory first' to "capture the richness of observations without being limited by a theory" (Ridder, 2017, p.286), which differentiates from, for example, Yin's method (2014) which focusses on specifying gaps in existing theory with the ultimate goal of advancing theoretical explanation (Ridder, 2017).

Eisenhardt's approach is recognized as a paradigmatic example that enhances the conceptualisation and operationalisation stages in the process of building theory. On the other hand, Yin's approach is noted for refining theories that are already conceptualized and operationalised to some extent, though minimally. Welch *et al.* (2020), crafted a typology of theorising methods in case study research, using 'contextualization' and 'causal explanation' as two key dimensions. Within this framework, they categorised different approaches to case studies: Eisenhardt's work exemplifies inductive theory-building, Stake's approach aligns with interpretive sensemaking, Yin's methodology corresponds with the natural experiment mode, and the approach by Ragin and Bhaskar represents contextualised explanation (Ridder, 2017).

The selected Eisenhardt method is not rigid, leaving space for a wide variety of research possibilities. It is, according to Eisenhardt (2020, p.155), "ontologically (i.e. nature of reality) and epistemologically (i.e. how that reality is known) flexible". The method offers advantages over "alternative methods like arm-chair theorising and analytic modelling, bringing the theory builder into close and even intimate contact with phenomena" (p.157). There are, however, some fundamental features that need to be met (Eisenhardt, 2020), corresponding to:

First, it addresses research questions for which there is little theory and/or empirical evidence and the research questions are likely to provide fertile opportunities for theory building. In the case of this research, the overlap between digitalisation and sustainability (with focus on climate change and the natural environment as a key stakeholder) is indeed an area of incipient development, as has been presented in the Literature Review chapter. Thus, it was expected that the case studies would show the role of the natural environment as a key stakeholder in this context.

A second element is that this method emphasises a careful selection of case studies, i.e. theoretical sampling, as opposed to random sampling (Ridder, 2017). This means that cases are selected based on the likelihood that the phenomenon under study is likely to occur, and where the similarities and differences across cases are likely to improve theory building. Here several options are available, including matched pair design (i.e. the researcher chooses two cases with similar features), racing (i.e. cases begin at the same time with similar initial conditions like founders, location, and funding), polar types (i.e. cases are chosen for being in the extremes), among others. These examples of case design involve similar cases that may reveal different processes or outcomes. In this particular research, however, the selection of cases was based on choosing several cases with the same focal phenomenon (DCS) in purposefully different settings (a variety of digital technologies, industry sectors, business models, and countries), thus improving generalisability (i.e. transferability) of the emergent theory across settings. The emphasis in data collection is on interviews, archives, and participant observation (Ridder, 2017). Ridder (2017) also indicates that case study researchers usually triangulate data as part of their data collection strategy, resulting in a detailed case description. This is particularly relevant in single case study research. In this research, however, the emphasis was more on the cross-case comparison (still, some triangulation was obtained from semi-structured interviews, materials provided by informants, public data from websites, business publications, and by the preliminary validation workshop).

A third element is that the method needs to be explicit about developing (and defining) constructs and measures during the analysis, as these elements are essential components of any theory and ensure that the emergent theory is well grounded and testable (categorisation and abstraction are core elements of theory building). In this research the terms "concepts" and first and second order themes were preferred instead of constructs and measures. As defined by Gioia *et al.* (2013, p.16), "by 'concept,' we mean a more general, less well-specified notion capturing qualities that describe or explain a phenomenon of theoretical interest".

A fourth element is that the Method "emphasises explicit theoretical arguments (i.e. mechanisms) that support why particular emergent relationships between constructs are likely to hold" (Eisenhardt, 2020, p.151). Following the categorisation by Ridder (2017) on a continuum of theory development, this research falls into the category of "developing theory" (as opposed to theory building or theory testing), and in particular under theory extension, as it was expected that pre-existing constructs would be extended to other groups or other contexts (Ridder, 2017). In fact, in theory building the research strategy focuses on drawing out concepts and their interrelations directly from the data. Conversely, in theory development, the research strategy shifts to pinpointing new components and connections within an initial theoretical framework. The goal here is to uncover mechanisms that offer a more precise explanation of the phenomenon under investigation (Ridder, 2017, p.299).

Fifth, the implementation of this method considers the definition of boundary conditions to clarify the scope of the theory, i.e., the domains to which it is likely to apply.

The last element is that this method emphasises analysis using "constant comparison between the theory and data (Glaser and Strauss, 1967), replication logic (Yin, 1984), and cross-case analysis (Eisenhardt, 1989)" (Eisenhardt, 2020, p.152).

In summary, the main reasons for the selection of the Eisenhardt method (1989) included:

- Case studies offer the opportunity of a holistic view of a process, as opposed to a reductionist and fragmented view. The whole is not identical with the sum of its parts; consequently, the whole can only be understood by treating it as the central object of the study (Patton and Appelbaum, 2003).
- Multiple cases also create more robust theory because the propositions are more deeply grounded in varied empirical evidence. Thus, theory development and theory building from multiple cases typically yields more robust, generalisable, and testable theory than single-case research (Eisenhardt, 1989).

- The case study allows an investigation to retain the holistic and meaningful characteristics of real-life events (Ying 1984; Patton and Appelbaum, 2003).
- The justification for cases studies also rests on the phenomenon´s importance and the lack of visible theory and empirical evidence, i.e. phenomenon-driven research questions (Eisenhardt, 2007).
- Also research using cases typically answer questions that address how and why in unexplored research areas (Yin, 2014).
- Usefulness of the research for management practices and the business community (pragmatic view).
- The method was chosen for its explanatory functions, and not just descriptive or exploratory.

4.5. Chapter Conclusions

In this chapter the philosophical approach to this research was explained. Starting with a description of the nature of the social reality that is being investigated (the ontology of this research), and a definition of what represent knowledge of the entities to be researched (the epistemology).

Later, methodological aspects were introduced, explaining the rationale behind the selection of an inductive approach. This approach was complemented with the abductive data analysis approach, thus providing balance into this investigation (finding a middle ground between inductive and deductive methods).

Finally, the chosen research method was presented, the Eisenhardt method (1989) for multiple case studies, a method that is ontologically and epistemologically flexible, providing a justification for its selection and its strengths in comparison with other qualitative methods. Six fundamental features of the selected method were described.

Thus, having provided the philosophical context for this research, the next chapter presents the field methodology in detail, and the way data was collected, processed, and analysed.

Chapter 5: Fieldwork Methodology

5- Fieldwork Methodology

After describing in the previous Chapter the research philosophy behind this investigation, including general aspects of its ontology, epistemology, methodology and method, this Chapter presents a detail description of the steps followed (the so-called Fieldwork Methodology). In fact, this empirical research was based on multiple data collection strategies, where the primary source of information were on-line semi-structured interviews of company representatives (one representative per organisation) between July 2021 and January 2023, also including secondary data collection mechanisms (e.g. analysis of publicly available information), discussions with scholars in the study field, and an intermediate validation workshop. Figure 5-1 shows the main stages of the methodology, while in the following pages a detailed description of each of these stages is provided. The relevant section of the methodology will be shown at the beginning of each Section to facilitate the reading.

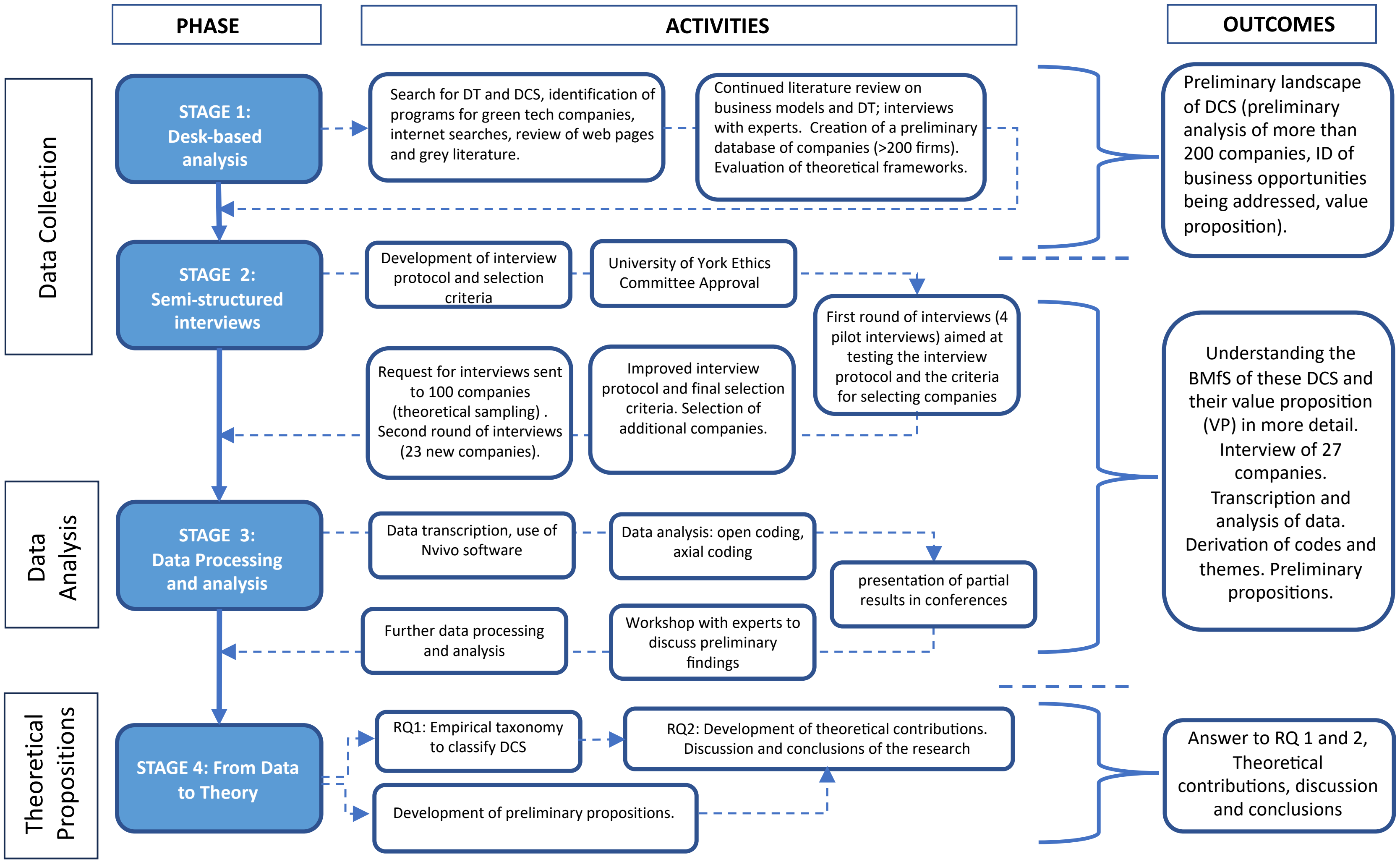

Figure 5-1: Fieldwork Methodology

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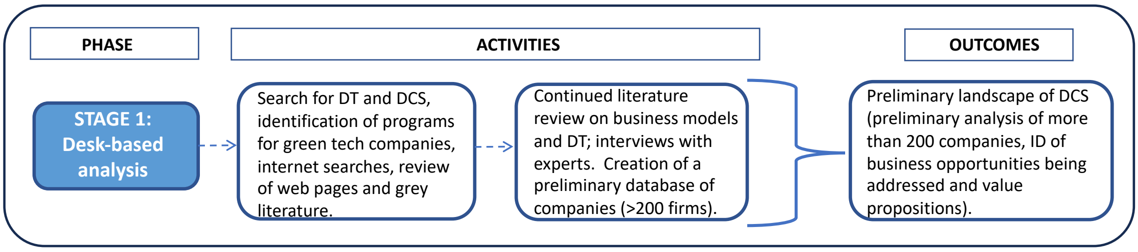
5.1. Stage 1: Desk-based Analysis



As shown in **Figure 5-1**, this research started with a desk-based analysis of digital climate start-ups. To identify these companies, the main sources of information were country programs supporting green start-ups, particularly: Tech Nation Program, Carbon 13, and Tech Zero (all of them from the UK), WSA (Austria), and EIT Climate-KIC (from The Netherlands). **Table 5-1** provides a description of each of these five initiatives. Not all the start-ups that were part of these initiatives could be classified as digital climate start-ups, hence an analysis to discriminate those that were relevant was made.

Table 5-1: Description of programs supporting climate start-ups.

Program	Website	Description
Tech Nation Program	https://technation.io/	UK Net Zero Tech Nation Program is a publicly and privately funded organisation, a platform to support the growth of highly innovative tech companies in the UK. This organisation has a specific programme called Net Zero, which is aimed at innovative tech companies working towards climate change, early-stage scaleups that operate across key sectors, including electricity & energy, transport & mobility, agriculture, food systems, manufacturing and building technology. The Net Zero program started in 2019 and counts with 4 cohorts of companies (Net Zero Cohort 1, 2 and 3, plus the most recent Net Zero X). It was initially selected to provide a coherent sample of highly innovative tech companies that are working towards climate change.
Carbon 13	https://carbonthirteen.com/	Based at the University of Cambridge, Carbon13 works with founders to build start-ups that can reduce CO_2e emissions by millions of tonnes. Each of the 70+ founders on the seven-month programme is focused on tackling the biggest challenges of Net Zero and achieving a meaningful impact on emissions.

Program	Website	Description
		Carbon13 selects, supports and invests in people through their venture building programmes, focused specifically on building scalable climate ventures that will reduce and remove emissions on a global scale.
Tech Zero	https://techzero.technation.io/	A climate action group for tech companies of all sizes committed to fighting the climate crisis. They believe that by joining forces, they can make faster progress to net zero.
Climate KIC	https://climaccelerator.climate-kic.org/	EIT Climate-KIC (Knowledge and Innovation Community - KIC), an organisation based in The Netherlands, working to accelerate the transition to a zero-carbon, climate-resilient society. EIT Climate-KIC is supported by the European Institute of Innovation and Technology, with the aim to identify and support innovation that helps society mitigate and adapt to climate change. In particular, they have an Entrepreneurship Programme aimed at measuring and improving the positive climate impact of start-ups.
World Summit Awards	https://wsa-global.org/	WSA is a unique awards system, selecting and promoting local digital innovation to improve society. Combining an ongoing series of international events and activities with a global network of start-ups, social entrepreneurs, mentors, jurors, speakers, experts, government leaders, academia and civil society, WSA is an international platform for cutting edge examples of how ICTs can impact society in a positive way. WSA is conducted by ICNM, an Austrian not-for-profit organisation based in Salzburg and Vienna, Austria.

In addition, serval other sources to identify relevant DCS were used, for example: www.eu-startups.com, www.reuters.com, www.forbes.com, www.startus-insights.com, etc. This analysis was complemented with general internet searches for "digital start-ups tackling Climate Change" and interviews with two scholars working in this field[6].

[6] The researchers were: Prof. Jonatan Pinkse, Professor of Strategy, Innovation and Entrepreneurship at Alliance Manchester Business School, and Dr. Simon JD Schillebeeckx, academic and entrepreneur working on digitalisation and sustainability, Singapore Management University.

The main objective of this stage was to map the diversity of digital solutions available in the market in order to uncover the landscape of DCS, thus obtaining a preliminary understanding of business opportunities being addressed and value propositions being developed to tackle climate change with the support of digital technologies. Three introductory questions were used as a guidance for the collection of information during this Stage:

a) What digital technologies were utilised and for what objectives?
An initial interest of this research was to understand the type of DT that were used by DCS and the role these technologies play in the fight against CC. It was expected that this element would also contribute to the characterisation of DCS, hence, to unpack the value proposition of these firms (ie. RQ1).

b) What market needs were tackled by DCS?
A second aspect to be analysed during Stage 1, which is closely related to the previous one, was understanding the market needs being addressed by DCS, based for example on the clustering of digital climate solutions.

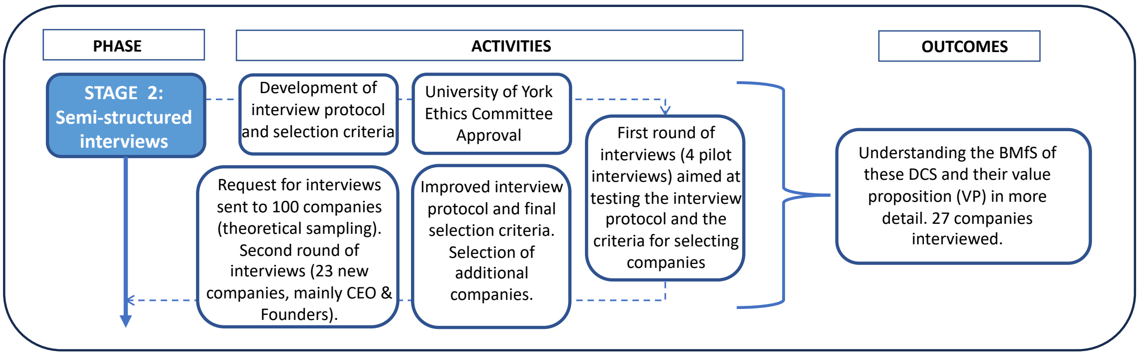
c) How did firms define their value proposition?
Having a better understanding of the digital technologies being used and the business niches being targeted by DCS, the final aspect of this exploratory stage was to understand the business model of these firms (focussing on their value proposition) and how the natural environment was part of this.

A dataset in MS Excel format was built to facilitate the collection of relevant information regarding the companies and their value proposition. The companies incorporated in the dataset were classified based on two major characteristics of their value proposition: promoting climate mitigation or climate adaptation. These categories were later further expanded into sub-categories designed to describe specific characteristics of the companies (i.e. develop the taxonomy aspect). The remaining fields of the dataset included: company name, city, digital/non-digital offering, type of offering (e.g.

software, product, etc), climate change native/non-native, sector being targeted, subsector, mitigation/adaptation solution, considered Nature Based Solutions, description of value proposition. These fields where filled-in by researching the websites of every company. **Appendix 1** presents an example of the initial dataset (later expanded to include additional fields), also including a full list of companies initially reviewed.

With this initial search of companies and preliminary understanding of business niches, climate change goals, and value proposition, it was possible to select companies to be contacted with the aim of interviewing their executives and thus gain further insights into their BM. This is further described in the next section.

5.2 Stage 2: Semi Structured Interviews



5.2.1) Interview Protocol and Selection Criteria

Stage 2 started by developing a preliminary interview protocol composed of 13 questions, as shown in **Table 5-2**. These questions related to four categories: BM of the start-up, climate change and the company's ecosystem, climate change and the impact of the organisation, and a set of general questions.

Table 5-2: Interview protocol Version 1.0

Climate Digital Solutions - Digital Technologies and Innovative Business Models for Enhanced Climate Action - Preliminary Interview Protocol with Companies (Version 1.0)

Regarding BM

1. What would you say is the main innovation of your offering? Is it the technology? BM? Both? Can you describe it? (distinctive characteristic)
2. Has this BM evolved/change since its creation?
3. Could you please describe the ecosystem of your business? (suppliers, customers, partners) (how does a climate intelligence ecosystem look like?)

Climate Change and your ecosystem

4. What do you see is the main impact of your company on addressing CC? how can we measure it? (mitigation, adaptation, both)
5. How do you see this convergence between tackling climate change and digitalisation? (do you agree with the convergence? What is the potential? How do you see the contribution of AI to tackling CC? do you think it can make a difference? How?
6. What type of companies is your technology (or organisation) mainly targeting?
7. Do you have examples of actions taken by your customers to effectively address climate change issues as a result of engaging with your technology (or service)? (mitigation, adaptation, increase of resilience; efficiency gains from the optimisation of existing processes in agriculture, on roads, in energy networks, and in manufacturing)
8. Is your solution also contributing to address others sustainability challenges? (17 SDGs, have you mapped that? e.g. Is it addressing issues related to water, ecosystems, food supply, human health, cities?)

Climate Change and your company

9. Where do you think is the focus of your company in terms of contributing to tackling CC?
10. Do you have an assessment of the carbon footprint of the company? Do you have an offset strategy in place? (e.g. do you purchase renewable energy?

Final questions

11. Is there any specific result from this investigation that you would considered of special interest?
12. Would it be possible that you give me contact details of some other actors of your ecosystem? (food and agriculture, renewable energy, infrastructure)
13. Any other comments you may have?

In order to test and refine this preliminary interview protocol, a first round of interviews (pilot phase) was performed where four companies were selected in July 2021. Before conducting the pilot interviews, an application was made to the Economics, Law, Management, Politics and Sociology Ethics Committee (ELMPS) of the University of York. The ELMPS application was aimed at ensuring that the research complied with the

University codes of practice, ethical guidelines on research integrity and the General Data Protection Regulation (in line with University Data Management Policy) as well as other relevant professional guidelines from the School or funding organisation. The application included: a participant information sheet, a consent form for participants, a DIPA (Data Protection Impact Assessment) screening questions, plus the main application form where details of the research and the pilot interviews were provided. Full documentation can be seen in **Appendix 2**.

In this stage, the preliminary criteria for selecting the four companies were (where at least three of these four criteria needed to be met):

- Companies with a value proposition oriented to tackle CC,
- Companies with value proposition based on digital technologies,
- Companies that provided services (B2B or B2C) or products,
- Companies based in the UK.

After these pilot interviews, the interview protocol was revisited based on logic of the sequence of questions, clarity of the questions, and whether there was enough coverage of the topics necessary to inform the research questions.

As a result, the interview protocol was improved by eliminating some questions, reformulating others, and expanding it to accommodate a total of 25 questions including aspects of: Strategy, value proposition, performance (KPIs), technology, barriers and nature-based solutions. **Table 5-3** shows a shorter version of the 2.0 interview protocol while **Table 5-4** explain the rationale behind the questions and their contribution to the RQ. **Appendix 3** contains a full example of the 2.0 interview protocol.

Table 5-3: Interview protocol Version 2.0

Climate Digital Solutions - Digital Technologies and Innovative Business Models for Enhanced Climate Action - Final Interview Protocol with Companies (Version 2.0)

A) General Aspects:

B) STRATEGY - General Introductory Questions

1. Why is your company in business? What specific market needs is your company's addressing?
2. To what segments? (target audience, beneficiaries), sector specific or sector agnostic.
3. Who are its ideal customers?
4. Is it B2B, B2C? Focussing on Mitigation or Adaptation? carbon management?
5. Is this a software company? is a climate technology?
6. At what stage is your business? (e.g. development, entering the market, scaling, mature)

C) VALUE PROPOSITION

1. How would you describe your company's value proposition? (for both customers and the planet)
2. What would you say is the main innovation of your BM? Can you describe it?
3. How does the company capture value? (revenue model, how do you monetise your offering)
4. What was the rationale/motivation behind the development of the Business Model?
5. What is the company's vision for the next ten years?
6. How relevant is Science for your offering and how is it used?

D) PERFORMANCE: KPIs

1. How do you measure performance in your company? What are criteria for success?
2. Are climate change objectives part of your KPIs?
3. Do you have a way to quantify the expected Climate Change outcomes?
4. Do you have examples of the CC impacts you want to reduce?
5. Do you have a particular method/tool to forecast the benefits to be achieved when tackling CC?

E) TECHNOLOGY & BARRIERS:

1. In terms of the digital component that are part of your value proposition: Could you list what are the main technologies being used? (IoT, blockchain, etc.)
2. Is there any unintended consequence due to the use of these technologies?
3. How does your company proof its technology?
4. What would you say are the main barriers for success for your company?
5. Can you think of any external variables can influence the results you are expecting?
6. How scalable is your technology?

The idea behind this refined version of the interview protocol was to further focus the research by, for example, eliminating questions about a broader set of stakeholders (e.g. the business ecosystem question) and focussing on the planet as stakeholder, plus customers and the focal business. Other questions that were eliminated referred to actions taken by customers to effectively address climate change, and whether the firm was contributing to address others sustainability challenges, among others.

Table 5-4 Justification of the final interview protocol

Category	Description	Objective	RQ
General aspects	Interviewee name, position in the company, numbers of employees, year of foundation.	General aspects about the company.	RQ1
Strategy	Description of market needs being targeted, services provided, customer segments, stage of development.	Obtain a general understating of the company's strategy	RQ1 & RQ2
Value proposition	Description of the company's value proposition (for both customers and the planet), main innovation, value capture, rationale/motivation behind the development of the company, vision, the role of science in their offering, criteria for success, among others	Understand the firms' value proposition for both customers and the planet, as well as other elements of the BM. Understand the future vision of the company.	RQ1 & RQ2
Performance (KPIs)	Description of the type of KPIs used by the firms and their criteria for success, climate change objectives used, method for forecasting climate impact.	Understand whether climate change KPIs were part of their criteria for success, and the way these were incorporated.	RQ1
Technology, unintended consequences, and barriers	Description of digital technologies being used, identification of potential unintended consequences of these technologies, proof of technology, main barriers, the use of Nature-Based solutions, among others.	General questions about the technology component, including barriers and unintended consequences.	RQ1

NB: as a remainder, the two RQ are:

- RQ1 - How do we unpack the value proposition of digital start-ups tackling climate change?
- RQ2 - How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?

Similarly, the selection criteria of companies were expanded. As expressed by Yin (2014, p.28), it was expected that applying these new set of criteria will favour the selection of cases that will "most likely illuminate the research questions". Thus, five criteria were proposed, where all of them needed to be met:

a) Start-up companies with an environmental value proposition specifically oriented to tackling CC.
b) Start-up companies with value proposition based on digital technologies (data-driven firms).
c) Start-up companies that provide services to others (B2B or B2C) (as opposed to manufacturers of products).
d) Start-up companies based in the UK or Europe.
e) Start-up companies that cover one of the eight economic sectors defined by the European Green Deal (EGD) taxonomy.

Criterion e) was added to align this research with the main green development strategy across Europe, the European Green Deal (EGD). The sectors considered by the EGD are the following eight policy areas (European Commission, 2019):

- A zero-pollution ambition for a toxic-free environment,
- Accelerating the shift to sustainable and smart mobility,
- Building and renovating in an energy and resource efficient way,
- "From 'Farm to Fork': designing a fair, healthy and environmentally-friendly food system",
- Mobilising industry for a clean and circular economy,
- Supplying clean, affordable and secure energy,
- Preserving and restoring ecosystems and diversity,
- Pursuing green finance and investment and ensuring a just transition.

Finally, it is worth to mention that the portfolio of case study companies was not meant to be a representative sample of the European/UK climate start-up ecosystem, instead the objective was to provide a diverse group of climate digital stat-ups with the potential to contribute to the challenge of climate change.

5.2.2) Selecting case study companies

This stage was aimed at obtaining deeper insights into the value propositions being developed by DCS (i.e. the aspect covered in Stage 1). In this case-oriented research, the sampling strategy was theoretical sampling, in other words, cases were selected based on the fact they were theoretically significant in relation to the objectives of the research (Marx *et al*., 2014). Furthermore, given that the purpose of the research is not test theory, but to extend theory, then theoretical sampling is appropriate, i.e., cases are chosen for theoretical reasons, as opposed to statistical (Glaser & Strauss, 1967). Or as expressed by Eisenhardt (1989), in case-study research, cases are usually selected by applying specific criteria, as opposed to selecting a random or stratified sample.

To this aim, based on the final five criteria outlined in Section 5.2.1, companies were selected from the following sources:

- The initial mapping exercise (Section 5.1), thus covering a diversity of cases (e.g. a variety of countries, digital technologies, business niches, and sectors)
- Based on referrals from the programmes mentioned in Section 5.1 (e.g. Tech Zero program, EIT Climate-KIC) and detailed in **Table 5-1** and,
- Other sources (e.g. web searches, experts on the field, contacts in relevant seminars and conferences).

For the first round of interviews (pilot phase), the interviews were conducted on-line via the platform Zoom, lasting in average 45 minutes. The interviewees were CEO & Founders or high-level executives of these firms, as there was a need to count with knowledgeable agents (Gioia *et al.*, 2012). Companies' names were anonymised (use of code names based on the alphabet, Companies A to D) and only a generic description has been provided. The same was done for individual participants, using their job title and not their name (e.g. CEO of Company C). This first round of interviews took place in July 2021.

For the second round of interviews, nearly 100 companies (out of the universe of over 200 companies listed in the dataset developed during this investigation) were initially contacted either via e-mail or Linked-In (**Appendix 4**). Some of these companies were also contacted with the help of representatives from Climate KIC or Tech Zero (see **Appendix 5** for an example). Over 30 companies answered positively, but in the end only 23 new companies were available for interviews on Zoom. It must be remembered that the Eisenhard method is not about a specific number of cases, indicating that between 4 and 10 cases are commonly used (Eisenhardt, 1989), but a specific number of cases is not inherent to the method. Instead, the final number is dictated by theoretical aspects like case design and data saturation, as well as by pragmatic factors like data availability and time (Eisenhardt, 2020). As it will be shown, in this particular case the final number of cases was the result of a combination of the above, i.e. data saturation and availability as well as resources (myself as sole researcher full-time), and the emphasis was more on covering and comparing a broad set of cases than going deep into each of them.

As with the pilot interviews, before conducting the second round of interviews, Ethics approval was sought from the University of York by submitting a new application to the Ethics Committee. Full documentation can be seen in **Appendix 2**. The interviewees were CEOs, Founders or Senior Executives of the selected companies. **Appendix 6** provides a full list of the 27 interviewed firms (both from the first and second round of interviews) and duration of interviews.

Having high-level interviewees was a key condition for the interviews, given the strategic nature of the questions contained in the interview protocol. Thus, the objective was to interview “knowledgeable agents”, as described by Gioia *et al.* (2012), i.e. “…people in organizations that know what they are trying to do and can explain their thoughts, intentions, and action” (p.17). This was also particularly relevant given that only one representative per each company was interviewed, with probably limited triangulation, but where the emphasis was more on cross-case superficial comparison more than one in-depth case analysis (the idea was to capture process differences across cases (Eisenhardt, 2020)). Hence, cross-case analysis was used in this research as an approach to enhance the generalisability of the findings.

The second round of 23 new interviews took place between February 2022 and January 2023 and, as in the first round, the interviews were conducted on-line via the platform Zoom, recorded and lasted 45 minutes approximately. In all cases the companies' names were anonymised (use of code names, from Company E to Company AA) and only a generic description has been provided. The same was done for individual participants, using their job title and not their name (e.g. CEO in Company X) so it is expected that it would not be possible to uncover the identity of the individual.

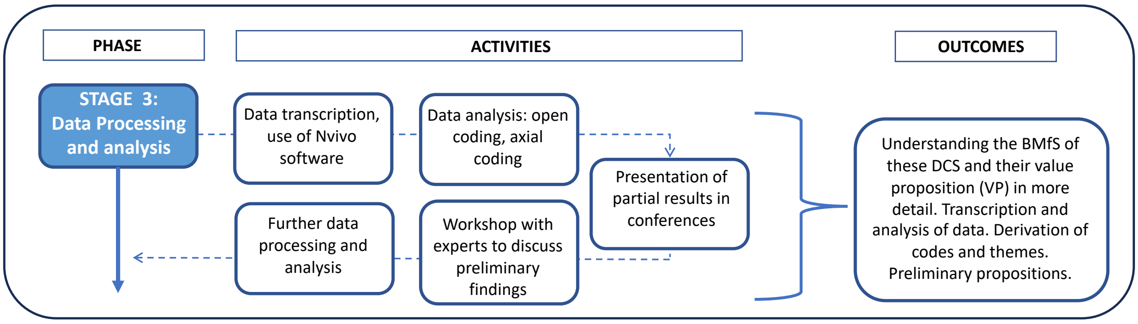
In addition, secondary data from these 27 companies was collected. The main source of information was the websites of each of these firms, looking at description of their value offering, together with other information considered relevant (e.g. KPIs, type of digital technologies used, etc.). In some cases, when available, also public reports, newspaper, and journal articles were used. The video interviews were recorded for the purpose of data analysis.

5.2.3) Unit of Analysis

The unit of analysis was the BM of organisations, specifically their value proposition. In this sense, the business model is considered to be an "excellent unit of analysis for studying and advancing common managerial and entrepreneurial approaches as well as stimulating and revitalizing old and new business philosophies" (Schaltegger, 2016).

Furthermore, when it comes to stakeholder theory, as expressed by Freeman *et al.* (2010), "it is essential to note that the unit of analysis for stakeholder theory is not the company itself but the relationships between an organization and its stakeholders" (Horisch *et al.* 2014, p.329).

5.3. Stage 3: Data Processing and Analysis



5.3.1) Data Transcription

For the third stage, data processing and analysis, the interview recordings were transcribed for thematic analysis. The Zoom platform provides a useful function to help the transcription process of the interviews. All interviews were carried out in English language and no translation was needed.

Transcribed data was transferred to Nvivo 20 software, which is considered a useful tool for organising and systematically analysing qualitative data (Edhlund and McDougall, 2019). This tool allowed the identification of the connections within the data obtained in the interviews.

As part of the process, a memo was created in NVivo to record decisions made during the analysis stage. This helped to provide clarity during the analysis process as new codes and categories emerged.

5.3.2) Coding and Categorising

As explained by Saldaña (2013), coding is a form of exploration and problem-solving that "lacks specific formulas or algorithms to guide the process" (p.8). Qualitative codes play a crucial role in capturing the essence and essential elements of the research narrative. When grouped based on similarity and regularity, these codes actively support the creation of categories, facilitating the analysis of their connections. In other words, coding enables the researcher to organize and group similarly coded data into categories or families based on the fact they share characteristics (Saldaña, 2013), for that the researcher uses "classification reasoning plus your tacit and intuitive senses to determine which data "look alike" and "feel alike" when grouping them together" (Lincoln & Guba, 1985, p. 347).

Coding is more than just assigning labels; it involves connecting concepts. It serves as a bridge that takes you from the data to the concept, and from that concept, it guides you to all the data related to that specific idea (Richards & Morse, 2012). Coding is also a cyclic process, requiring re-coding in order to generate categories and themes. As such, in order to turn raw data into conceptual ideas, the analysis of the empirical material takes place in several phases, moving from coding of raw data to theoretical constructs (Gioia *et al.*, 2012).

The process started with open coding, i.e., a brainstorming approach where the researcher is open to data exploration Mason (2012). Data was break down forming categories ("parent" codes and "child" codes) to help understand the phenomenon under study. This was an inductive process, where codes were produced based on interpretative and reflexive reading (instead of more literal reading).

According to Saldaña (2013), a code in qualitative research is usually a word or short phrase that symbolically assigns an attribute to a portion of language-based data. The portion of data to be coded can range from a single word to a full paragraph to an entire page of text, thus, coding can be understood as the "critical link" between data collection and their explanation of meaning, it seeks to "represent and capture a datum's primary content and essence" and we need to take into account that "coding is not a precise science; it is primarily an interpretive act" (Saldaña, 2013, p.4). This process of adding new codes was designed to conclude once saturation was achieved (i.e., when no significant number of new codes were emerging from the reflexive reading of the interviews). This would also indicate whether the size of the sample was adequate or not.

The objective of this initial systematic overview of the data is to establish whether and how well the data addresses the research questions. The data was not treated as variables, but instead, in words of Mason (2012, p.157), as "unfinished resources or products", as this will support a wider range of analytical and explanatory logics. The data gathered from the interviews was not anticipated to consist of clear and neatly labelled variables. Instead, it was expected to involve loosely organized and flexible groupings of incomplete resources, primarily designed as a retrieval mechanism. In terms of the creation and application of indexing categories, the intend was to generate ideas and propositions based on the data (instead of testing of hypothesis), which meant that indexing categories were generated based on ongoing interpretation of data. In words of Charmaz's (2006), coding "generates the bones of your analysis. ... [I]ntegration will assemble those bones into a working skeleton" (p. 45). The main stages of the analysis are shown in **Figure 5-2**.

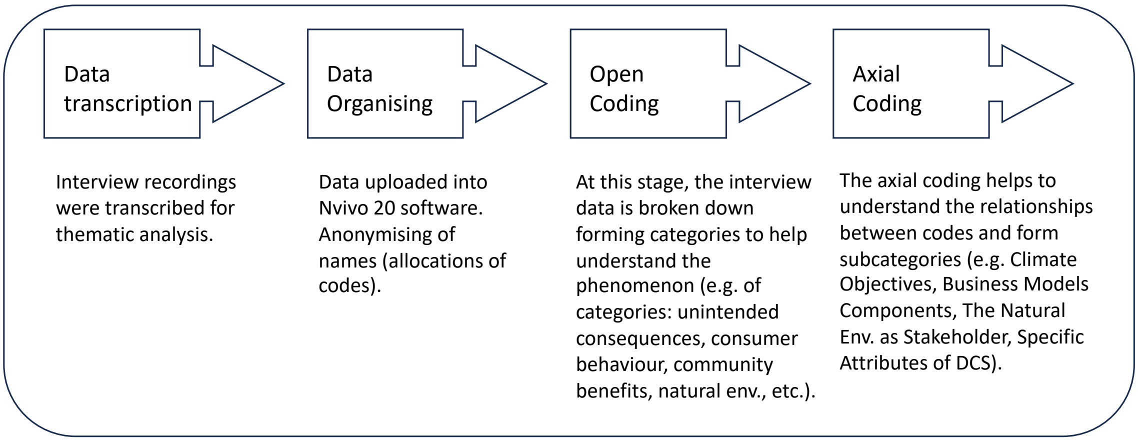


Figure 5-2: Stages for data analysis

In further analysis of the first-order codes and transcripts, axial coding (or secondary coding) helped to understand the relationships between codes and formed subcategories, thus generating themes in this research. In the axial coding stage more theoretically informed second-order themes and sub-themes were identified, categorizing the various types of DCS and strategies, drawing largely on labels used in the climate change and BMfS literature. That is, codes that included similarities or possible relations were grouped into a particular theme or category closely aligned to the literature. In this stage step the initial aim of coding was to give meaning to the data with the purpose of creating a categorisation of DCS (a taxonomy). As introduced in Section 4.3 (Research Philosophy: Methodology), this part of the research was abductive, resulting in the identification of various theoretically informed types of value proposition. Literature used to inform this process included sources such as IPCC (2018) (mitigation vs adaptation), Climate-KIC (enablers vs direct impact) (Impact Forecast, 2023), carbon removal vs carbon avoidance, BMfS, stakeholder theory, among others. Codes that included similarities or possible relations were grouped into a particular theme or category closely aligned to the literature. This categorisation was key to tackle RQ1.

Finally, third-order aggregate dimensions were developed. It became apparent that firms tended to mention elements that in their view were relevant for the success of their value proposition and their impact, such as transparency, collaboration, etc. These dimensions were key to tackle RQ2, as it will be explained in Chapter 6: Results.

5.3.3) Continuous Validation Mechanisms

As the data was being processed and analysed and preliminary results obtained, early feedback mechanisms were implemented, namely: presentation of partial results in conferences, an intermediate workshop with independent experts, monthly discussions with the research supervisors and six Thesis Advisory Panel (TAP) Meetings. The feedback obtained was iteratively incorporated in the data processing and analysis, as shown in **Figure 5-3** below.

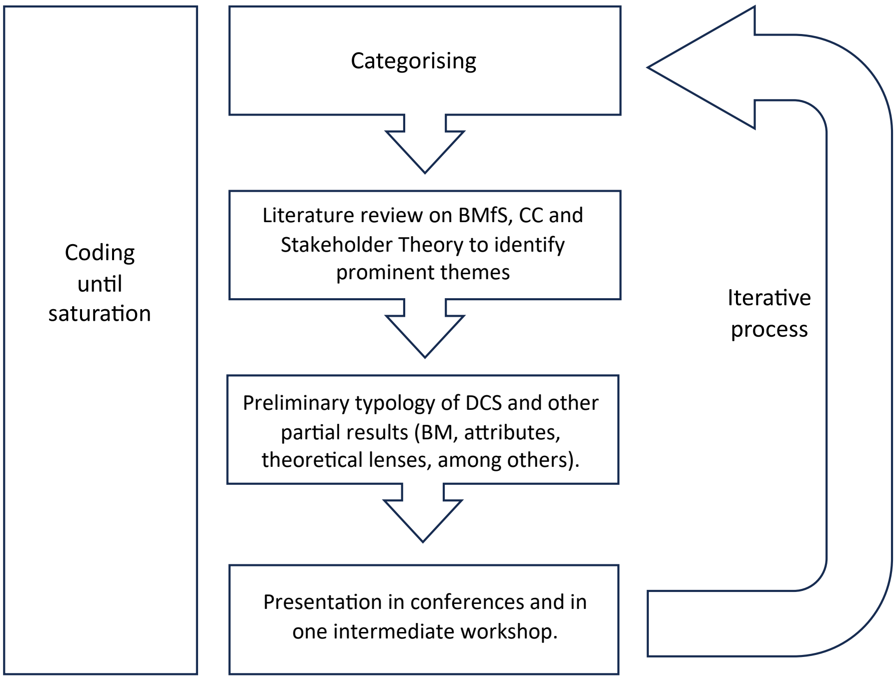
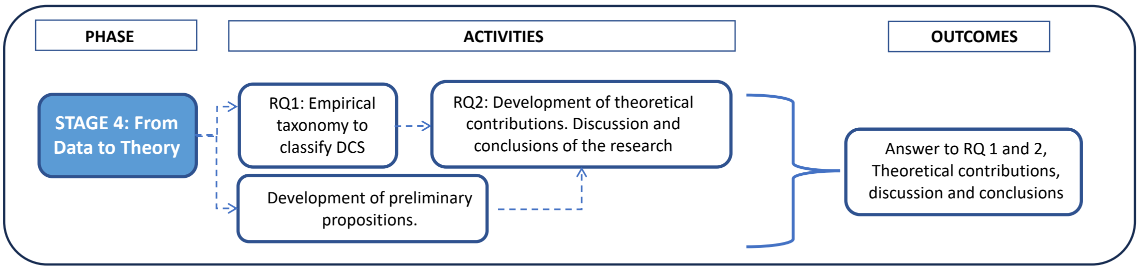


Figure 5-3: Iterative process for data processing and analysis (adapted from Bocken, 2014, p.45)

In particular, after the conclusion of the first half of interviews, a workshop was planned with representatives from EIT Climate-KIC (Knowledge and Innovation Community - KIC), a leading organisation in Europe based in The Netherlands, working to accelerate the transition to a zero-carbon, climate-resilient society[7]. The objective was to receive early feedback after half of the interviews were carried out and preliminary data analysis had commenced. The expected feedback was mainly in relation to RQ1: How do we unpack the value proposition of digital start-ups tackling climate change? (the taxonomy aspect).

[7] EIT Climate-KIC is supported by the European Institute of Innovation and Technology, with the aim to identify and support innovation that helps society mitigate and adapt to climate change. In particular they have an Entrepreneurship Programme aimed at measuring and improving the positive climate impact of start-ups.

5.4. Stage 4 – From Data to Theory



The continuous validation process shown in **Figure 5-3** not only allowed for a more robust codifying and categorising process, and the development of improved propositions of typologies of DCS (RQ1), it also allowed for the identification of the most suitable theoretical lenses to be used in the second part of this research (RQ2), thus defining what would be the contribution to theory of this research. As expressed by Corley & Gioia (2011, p. 12) and ratified by Gehman *et al.* (2018), "theory is a statement of concepts and their interrelationships that shows how and/or why a phenomenon occurs".

As previously described in the Literature Review Chapter (Sections 3.2 to 3.6), the Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) formulated by Freudenreich *et al.* (2020), was the chosen theoretical lens to address RQ2, as it met the set of criteria that were proposed. As a reminder, these criteria included aspects such as: the Stakeholder Theory is the most used theory in sustainability management research, it is also the most used theory for the study of BMfS, it is one of the two most used theory for looking at climate change in the context of management research, it explicitly links sustainability to firms, recognises the natural environment as a key stakeholder, looks into the value proposition of firms, among others.

The generic SVC Framework was designed to enrich business model research by incorporating stakeholder theory into the analysis of stakeholder relationships within a business model, particularly emphasizing value creation (aspects that belong to the field of strategic management). Thus, the two distinctive elements of BM based on stakeholder theory versus BM built exclusively around customer value propositions, are the analysis of relationships among stakeholders and the existence of a joint purpose.

The authors shifted the focus to the interconnections between various stakeholders (beyond just clients), underscoring the vital role each stakeholder plays in the process of creating value. They highlighted the importance of applying stakeholder theory, moving away from just developing customer-centric value propositions to generating a range of outcomes or a value portfolio that holds significance for different stakeholders. Moreover, they suggested that any examination of a Business Model for Sustainability (BMfS) should begin with an in-depth analysis of its stakeholder network, using the framework they devised. Under this Framework, the "stakeholders are both recipients and co-creators of value in joint value creation process" (Freudenreich *et al.*, 2020, p. 3).

Figure 3-5 shows a simplification of the framework (a full version can be seen in Freudenreich *et al*., 2020, p.9), where the arrows indicate that value is being created in both directions (from the focal firm to stakeholders and vice versa) in a permanent exchange process, where the value created for the focal company is at the centre (and at the same this represents a joint purpose with all stakeholders). As explained by the authors, the circular shape of the framework is a reference to the underlying idea of multiple reciprocal value flows, as opposed to the more traditional conceptualisations of unidirectional and customer-centric value flows. In fact, under the SVC Framework, each stakeholder is not only a recipient of a value, but also an active contributor to the development of the value portfolio. This focus on all types of value, and not just financial value, provides a better ground for the development of sound BMfS.

Freudenreich *et al.'s* framework is a generic one. As they described it, it does not specify what constitute value nor does it define which stakeholders should be part of the value creation process, although they did discuss the case of BMfS and how the framework can support the analysis of value creation with and for stakeholders in this context. With this purpose, they developed four theoretical propositions accompanied by eight questions (**Table 5-5**).

Table 5-5: Propositions and questions regarding the creation of stakeholder value through BMfS (from Freudenreich at al., 2020)

Propositions	Questions
Proposition I: All relevant stakeholders are engaged in identifying and solving sustainability issues as part of a business model for sustainability's value creation processes.	**Question 1** Who are the stakeholders in and beyond the five stakeholder groups identified in the framework? **Question 2** To what extent are each of these stakeholders engaged in identifying and solving sustainability issues?
Proposition II: The joint purpose of a business model for sustainability is directed toward sustainable development and explicitly refers to stakeholder contributions to achieve this purpose.	**Question 3** What is the joint sustainability-related purpose of the business model, and how does it provide a basis for stakeholders to engage in value creation with the focal business? **Question 4** How do stakeholders contribute to achieving the joint sustainability-related purpose?
Proposition III: A business model for sustainability aligns stakeholder interests to contribute effectively to sustainable development, in particular by integrating the ecological, social, and economic value stakeholders receive.	**Question 5** What are the individual sustainability-related expectations of each of the business model's stakeholder groups? **Question 6** Where are potential conflicts or synergies among value creation activities in the business model?
Proposition IV: Business models for sustainability embody an integrated perspective of ethical and business considerations in their value creation with and for stakeholders	**Question 7** What are the value propositions offered to each stakeholder group, and do they reflect the diversity of different types of value? **Question 8** Can each stakeholder relationships be characterized as respectful and ethically sound?

Question 1 in this list of propositions is particularly relevant for this research. Although under this framework the environment was included as part of Societal Stakeholders, based on the empirical results, this research did a deeper analysis to evaluate the increasing relevance of the environment as a key stakeholder and evaluate the necessity for an extended framework (adding a sixth category). In addition, the case can be made for a BM for Climate Change (BMfCC), as a subgroup of BMfS.

The application of this framework is presented in the Results Chapter, based on the empirical data that was obtained.

5.5. Chapter Conclusions

In this chapter the four stages fieldwork methodology was presented. Stage 1 was centred in a desk-based analysis of digital climate start-ups, with the aim to understand the landscape of solutions being available, their value propositions, and business niches. The sources of information were also presented. A database was developed with some of the most relevant features of the identified firms.

Stage 2 presented the interview protocols that were developed, the pilot interviews to test the initial interview protocol, and the criteria for selecting the sample of companies to be interviewed. Finally, the Unit of Analysis was explained.

Stage 3 explained the data processing and analysis phase of this research, which considered data transcription, open and axial coding, and the continuous validation mechanisms, including the intermediate workshop.

Stage 4 reinforced the selection of the Stakeholder Theory and in particular the selection of the Stakeholder Value Creation Framework for Business Model Analysis (SVCF-BMA) developed by Freudenreich *et al.* (2020), as the theoretical lenses for this research.

Chapter 6: Results

6- Results

This Chapter presents the main results of this research. These are presented in a sequential order, i.e., according to the steps presented in the Fieldwork Methodology Chapter. Thus, the first part presents the landscape of DCS based on the desk-based analysis, covering topics such as: the type of digital technologies being used, market needs being tackled, and value proposition being developed by firms.

Secondly, the results of the semi-structure interviews are shown, in terms of listing the companies that were interviewed and providing some examples of their value proposition for illustrative purposes.

The third stage corresponds to data processing and analysis, explaining the codification process and the validation mechanisms.

Finally, the fourth stage addresses the research questions in a sequential order. RQ1 tackles the aspect of how to unpack the value proposition of DCS, for this a proposal of a taxonomy framework is presented, together with a complementary approach based on the value proposition of DCS. RQ2 refers to the development of an extended framework based on the "Stakeholder Value Creation Framework for Business Model Analysis" proposed by Freudenreich *et al.* (2020), making the case for the natural environment as a key stakeholder and the attributes that are necessary to increase the value creation potential of DCS. In this section qualitative evidence is also presented for illustrative purposes, providing examples of the phenomena as part of the discourse that leads to the expected theory contribution. As it was first introduced in Chapter 5: Fieldwork methodology, the relevant section of the methodology will be shown at the beginning of each Results Section to facilitate the reading.

6.1. Stage 1 – The Landscape of DCS

The first part of this research was aimed at obtaining a general understanding of the landscape of firms born to tackle climate change and the role digital technologies played in their value proposition. As presented in Section 5.1, three questions were used as a guidance for this stage:

a) What digital technologies were utilised and for what objectives?
b) What market needs were tackled by DCS?
c) How did firms define their value proposition?

In general terms, as a result of this preliminary desk-based analysis of over 200 companies, it was found that companies can be classified in those that focus on mitigation of climate change and those that have value propositions focused on adaptation to climate change, where the immense majority of firms focus in the former.

Mitigation value propositions included services to identify and invest in sound carbon offset projects, visualisation of the impact of mitigation projects, and long-term monitoring. Adaptation value propositions included services to identify, prevent, anticipate, and mitigate the impacts of CC on companies´ assets.

The most mentioned target sectors were transport, energy, construction and food, although very often companies declared to be agnostic to sectors (implying that their value proposition is wide reaching).

DT adopted by these firms included a broad range of solutions and their business models usually considered a combination of these technologies. Some of these companies aimed at improving the CC decision-making process for their clients (e.g. deciding on a portfolio for carbon offsetting), others dealt with CC risks (insurance, smart contracts, climate intelligence) while others attempted to directly contribute to carbon sequestration through the restoration of ecosystems or the promotion of tree planting. These aspects are developed in more detail below.

6.1.1) What DT were utilised and for what objectives?

It was found that the role of digital technologies was to act as enablers of the value proposition of digital climate start-ups. These technologies included: Internet of Things (IoT), Big Data Analytics, Artificial Intelligence (AI), Remote Sensing and Satellite Imaging, Digital Platforms and Mobile Apps, cloud computing, blockchain, Augmented and Virtual Reality (AR/VR), Digital Twin Technology, and other emerging and exponential technologies. According to Katsamakas (2022), these technologies are never stand-alone; they are most of the time used in combination to create more complex technologies leveraging various interfaces (APIs or Application Programming Interface) and architectures.

Table 6-1 below provides a brief description of some of the technologies found in this stage and their application in the space of climate change. An attempt is made to connect this range of digital technologies found in Stage 1 with the value proposition of the studied companies described in Stage 2.

Table 6-1: Examples of digital technologies and their potential contribution to tackling climate change.

Digital Technology	**Application to Climate Change within the Studied companies**
Internet of Things (IoT) Sensors: IoT sensors are used to collect real-time data on various environmental parameters like temperature, humidity, air quality, and energy consumption, among others.	Data collected is valuable for, for instance, monitoring and managing energy usage, optimising resource efficiency, and assessing climate impacts. For example, Company “L” uses IoT to monitor keystone species in the forest in Africa.
Big Data Analytics (BDA): BDA involves processing and analysing large datasets to identify patterns, trends, and correlations.	It can be applied to climate-related data to understand climate patterns, model scenarios, assess risks, and inform decision-making for adaptation and mitigation strategies. Example, the value proposition of Companies “D” and “S”

Digital Technology	Application to Climate Change within the Studied companies
	both depend on the ability of their BDA to model and predict climate change risks for their customers.
Artificial Intelligence (AI): AI technologies, including machine learning and predictive analytics, can be utilized in climate-related applications.	AI algorithms can analyse vast amounts of climate data, improve climate models, optimise energy systems, and enhance predictive capabilities for extreme weather events and climate impacts. Example Company "J" uses AI to help its clients (water utilities) manage their water network/assets remotely, decreasing water losses and their carbon footprint.
Remote Sensing and Satellite Imaging: Remote sensing technologies, such as satellite imaging and aerial photography, provide valuable data for climate monitoring, land cover analysis, deforestation detection, and ecosystem management.	This information is key for the assessment of climate change impacts and for implementing effective adaptation and mitigation strategies. For example, Company "X" does analysis of catchment dynamics through remote sensing.
Digital Platforms and Mobile Apps: Digital platforms and mobile applications can be designed to raise awareness, educate, and engage individuals and communities in climate action in different ways.	These platforms provide information on sustainable practices, carbon footprint tracking, renewable energy options, among others, and enable collaboration and knowledge sharing. As an example, Company "E" has a specific App, a debit card, that provides information on the carbon footprint associated with every purchased item.
Blockchain Technology: Blockchain technology can be utilised for traceability and transparency in supply chains related to renewable energy, carbon credits, and sustainable products.	It enables secure and decentralised transactions, ensuring the integrity and accountability of climate-related data and certifications. For example, Company "Beta" uses blockchain in their carbon marketplace (for buyers and sellers), with the aim to increase transparency in the voluntary carbon market.
Digital Twin Technology: Digital twins create virtual replicas of physical systems or environments, allowing real-time monitoring and simulations.	They can be applied to optimise energy efficiency in buildings, simulate climate adaptation strategies, and improve the performance of infrastructure systems. Digital twins can be used for Life Cycle Assessment and replacement of materials to decrease the environmental

Digital Technology	Application to Climate Change within the Studied companies
	impact of a building (Tagliabue *et al.*, 2023), no specific examples from the studied firms.
Virtual Reality (VR) and Augmented Reality (AR): VR and AR technologies can be used for immersive experiences and simulations related to climate change impacts	They can help visualize future scenarios, communicate climate risks, and enhance public understanding and engagement in climate action (no specific examples from the studied firms).

These examples represent just a fraction of the range of digital technologies and their application to climate change. Very often a combination of these technologies was observed in the companies that were studied.

6.1.2) Market needs being tackled by DCS

A recent study by the World Economic Forum and Accenture (2022) suggests a way to group digital climate technologies. They describe four clusters of digital technologies for decarbonisation, as follows:

I. Decision making technologies (e.g. digital twins, AI, ML),
II. Sensing and control technologies (e.g. IoT, drones, imaging),
III. Enabling technologies (e.g. 5G, blockchain, VR, cloud),
IV. Foundational technologies (e.g. measuring & reporting, big data analytics).

Based on this categorisation, **Table 6-2** provides a non-exhaustive list of business opportunities being tackled by DCS, making the connection between the business opportunity/value offering and their actual contribution to the fight against CC. These business opportunities were also identified during desk-based analysis.

Table 6-2: Market opportunities identified from the desk-based analysis.

Cluster	Business Opportunity/ Value Offering	Contribution to the Fights Against CC
I	Carbon Sequestration	DT can contribute with the visualisation/analysis of restoration projects of forest and agroforest landscapes, improving carbon

Cluster	Business Opportunity/ Value Offering	Contribution to the Fights Against CC
		sequestration capacity, hence increasing the quality of offset carbon footprint projects and nature-based solutions (NBS).
I	Energy Efficiency	Smart grids and smart meters help to optimise energy consumption in homes and industries, reducing wastage. Additionally, building management systems can control lighting, heating, and cooling to minimise energy use.
II	Data Collection & Monitoring	Satellite imaging, remote sensors, and IoT devices can collect data on deforestation, ocean temperatures, ice melt rates, and other climate indicators. This data is essential for understanding the current state of the environment and predicting future changes. They can also detect and monitor native and invasive species, help with the monitoring of biomass health, composition, and progress, trace commodities from extraction to the finished product, supporting manufacturers with their CC goals, low-cost monitoring systems for energy performance of buildings, automated monitoring of investments on nature-based solutions NBS for CC.
II	Renewable Energy Integration	Digital technologies can help to manage and distribute energy from renewable sources more efficiently. For instance, battery storage combined with intelligent software can store excess solar or wind energy and release it when needed.
II	Adaptation to climate change	Digital tools can support communities adapting to climate change, such as platforms that provide early warnings of extreme weather events, help with risk assessment of business locations, or apps that offer guidance on crop selection in changing climates. They can also help to define adaptation pathways.
II	Agriculture 2.0	Precision agriculture, powered by AI and IoT devices, can help farmers make efficient use of water, fertilizers, and pesticides, thereby reducing their carbon footprint.
II	Transport	Digital platforms support the growth of shared transportation and electric vehicles. Additionally, route optimization software can reduce travel times and emissions.
II	Natural Resource Management	Drones and sensors can monitor forests, freshwater reserves, and other ecosystems in real-time, allowing for rapid responses to threats like illegal logging or overfishing.

Cluster	Business Opportunity/ Value Offering	Contribution to the Fights Against CC
II	Water Management:	DT can provide smart water management platforms that enable efficient water supply and reduced water consumption; also improved agriculture water management system.
II	Finance/Insurance/Risk Management	DT can contribute to segmentation of financial products calibrated on actual and expected risks due to CC; identification and promotion of more resilient assets; independent CC risks rating system; long term low cost green capital / Green investments; transparency on climate risks at assets level for banks, insurance companies, regulators; capital flows.
III	Climate Finance	Fintech solutions can support green bonds, carbon credits, and other financial instruments that fund climate-positive projects.
III	Circular Economy	AI and analytics can support waste management, recycling, and the efficient use of resources, promoting a more circular economy where products and materials are reused and recycled extensively.
III	Collaboration Platforms	Digital platforms enable collaboration among scientists, policymakers, activists, and citizens from around the world. This collective effort is vital for addressing a global issue like climate change.
III	Carbon Tracking and Reporting	Blockchain and other digital tracking systems can verify and trace carbon emissions across supply chains, ensuring companies meet their sustainability goals and comply with regulations.
III	Education and Awareness	Online platforms, virtual reality, and other digital tools can educate the public about the impacts of climate change, fostering more sustainable habits and decisions.
IV	Climate Modelling & Simulation	High-performance computing allows scientists to create more accurate models of the Earth's climate. These models can forecast the impacts of various scenarios and help policymakers make informed decisions.

It is important to note that some of these categories are not clear cut, which means some of the solutions could be in more than one category. Additionally, it was found that, while digital technologies offer significant potential in the fight against the climate crisis, their production and use also have environmental impacts (e.g. high energy demand and water consumption in data centres). This aspect is later discussed under "unintended consequences", although the quantification of this was out of the scope of this research.

6.1.3) How do firms define their value proposition

In order to preliminary understand the business model of these firms (focussing on their value proposition), **Table 6-3** shows five selected DCS. These companies were chosen as they all have a similar climate change objective in terms of tacking CC through the protection and restoration of forest for enhanced carbon sequestration.

Table 6-3: Brief description of the value propositions of five selected companies (desk-based analysis)

Company	Customer and Environmental value proposition
Alpha	This is a B2C firm, an internet search engine, a not-for-profit business that dedicates 100% of its profits to climate action, with at least 80% financing tree-planting projects. According to them, they are one of the World's leading planters of native trees.
Beta	A B2B and B2C firm, an "efficient and transparent" carbon credits marketplace that uses blockchain technology and tokenomics to reduce barriers (e.g. opacity of pricing, transparency, high transaction costs, low liquidity). They seek to democratise access to on-chain carbon credits issued by accreditation bodies. Verified credits can be bought and sold, held or retired by companies or individuals committed to offsetting their carbon footprint. They also seek to create access to a market previously inaccessible to retail investors.
Gamma	A B2B marketplace for "high-quality" nature-based climate solutions, through a data-driven, science-backed, and well-regulated framework (projects prefiltered by AI and manually screened by a team of experts).
Delta	A B2B platform for forest analytics. Use of scalable monitoring, reporting and verification (MRV) platform to optimize forest monitoring and get an overview of deforestation, carbon storage, biodiversity, risk modelling. It allows to assess carbon projects easier and faster.
Epsilon	A B2B carbon intelligence credit ratings platform. It includes Carbon Credit Analytics and a Data Directory that enables users to review the projects companies have purchased carbon credits and retired from, including volumes, project type (REDD+, Renewables, etc.), country, and retirement year.

As can be seen, these five companies based their value proposition on the use of digital technologies, including blockchain, artificial intelligence (AI), satellite images, and machine learning, among others.

As part of this desk-based analysis phase, the BM of these companies were also investigated in order to get preliminary insights. Thus, it was found that they all have a value proposition that goes beyond customers, as their final goal as a company is to effectively contribute to the fight against CC (e.g. optimise forest monitoring, promote nature-based climate solutions, promote tree planting), as shown in **Figure 6-1**. Four of these companies are enablers of forest protection and have interlinked value propositions (companies Epsilon, Beta, Gamma, and Delta), while company Alpha acts independently of the mainstream carbon market.

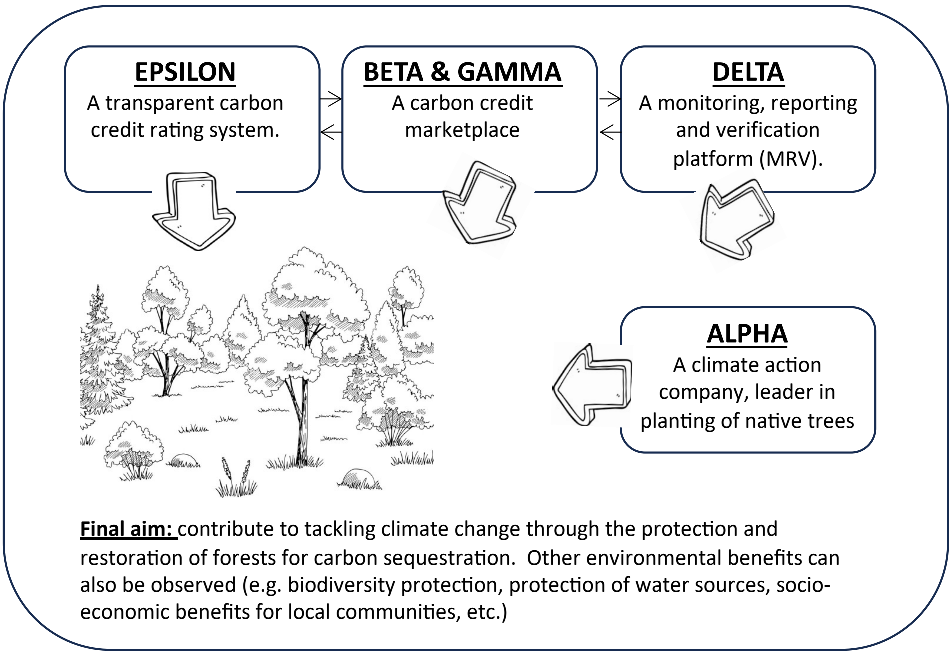


Figure 6-1: Representation of value proposition of five selected companies.

When trying to further understand the value proposition for the environment (based on publicly available information), only one of these five companies (Company Alpha) presented some degree of detail (for example, a quantification of potential climate impact). **Table 6-4** shows some of the main characteristics of Alpha´s value proposition (a search engine created with the aim of contributing to climate change mitigation), including the use of ecosystem services as part of their offering. An indication of the actual impact they have achieved over time is highlighted by the company.

Table 6-4: General description of value proposition of the company Alpha.

Company Description	
Alpha is a social business founded in 2009. It is a not-for-profit business, that dedicates 100% of its profits to climate action, with at least 80% financing tree-planting projects. It is the World's leading planter of native trees (information provided in Alpha´s website).	
Value Proposition for the Customer	**Value for the Planet**
▪ Internet search engine. ▪ Search ads generate income for Alpha (revenue model based on ads). ▪ Alpha uses this income to plant trees. ▪ They don´t sell the data to advertisers and has no third-party trackers. ▪ They also have an on-line store to sell trees (to be planted by them). ▪ The company plants trees across all six inhabited continents, mostly in biodiversity hotspots. They carefully select their planting partners, ensuring that all work is done with local communities. ▪ They use the latest technology to ensure the trees are robust enough to survive long-term. They track using satellites, geo-tagged photo evidence, and field visits. If a tree dies, the company will replace it at no additional charge. ▪ Alpha is powered by 200% renewable energy. Their solar panels produce twice the amount of energy needed to power all searches with renewables. ▪ They are transparent about everything they do, publishing detailed monthly financial reports and frequent updates from their tree planting projects. ▪ They publish monthly financial reports and tree planting receipts. This way they can be held accountable in their "journey to a reforested world". ▪ Promote a new legal form of business: the Steward Ownership Organisation ▪ Planting, monitoring and protecting one Alpha tree costs €1.	▪ They plant native species where they are needed most; the company monitors the trees for at least 3 years; shares quarterly performance reports. ▪ 136 millions of trees planted. ▪ 30 countries around the world. ▪ 13 millions Euros invested. ▪ 50 million trees means 2.5 million tonnes of CO_2 removed from the atmosphere. Other Benefits: ▪ Increase food security. ▪ Protect water sources. ▪ Prevent erosion. ▪ Create wildlife habitats. ▪ Fight desertification.

This was an initial classification of the business opportunities emerging from the overlapping between digitalisation and sustainability (climate change), and the main objective was to refine the search criteria in preparation for the selection of companies to be interviewed in Stage 2.

6.2. Stage 2 - Semi Structured Interviews

Stage 1 of this research was essential to have a preliminary understanding of the landscape of DCS (i.e., digital technologies being used, market niches being targeted, and an incipient understanding of their value propositions), and thus improve the design of the following activities. This was particularly relevant to develop the interview protocol and the selection criteria of companies.

As explained in the Fieldwork Methodology Chapter (Chapter 5), a preliminary interview protocol and selection criteria were tested with four companies. Based on this experience a final interview protocol and final selection criteria were developed (please refer to Section 5.2 for details).

As a result, 27 firms were interviewed (in a first and second round of interviews). This allowed the collection of near 300 pages of data in the form of text and near 20 hours of recordings, information that was analysed in Stage 3. **Figure 6-2** shows the pipeline of companies that were part of the research in the different steps, from early stages until the final 27 interviewed companies. As previously explained, all interviews were carried out in English language and no translation was needed.

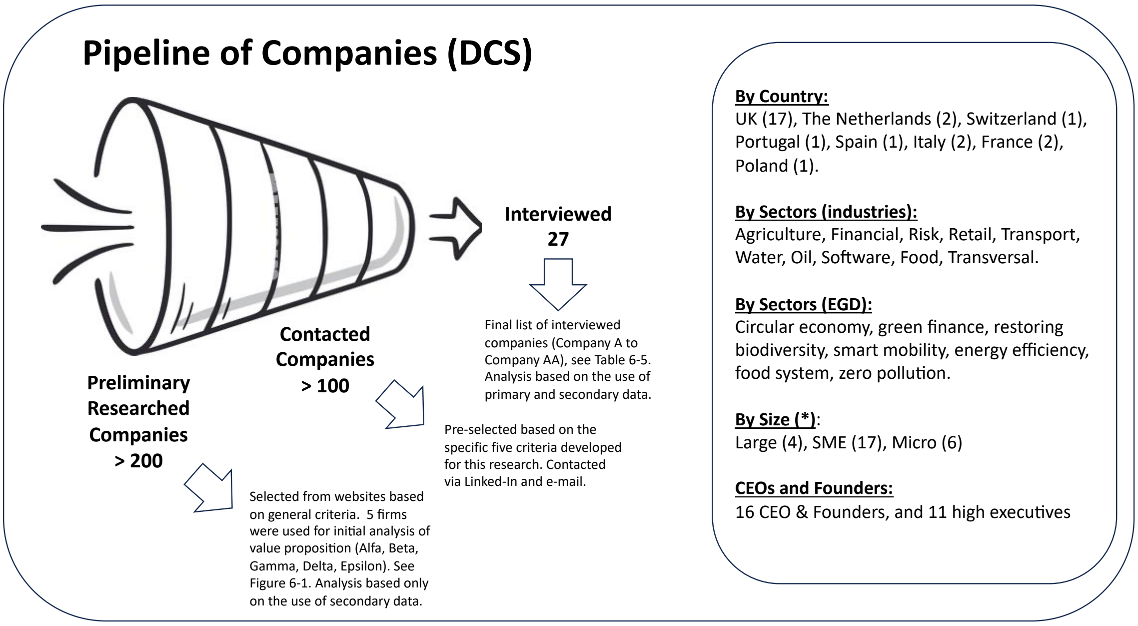


Figure 6-2: Pipeline of studied companies, from early identification until the final 27 interviewed.

NB: where Large (>250 employees), SME (10-250) or micro (<10).

Thus, from **Figure 6-2** it can be seen that the 27 interviewed companies were from eight different countries, ten different industrial sectors (or seven sectors according to EGD classification), and that the majority of interviewees were CEO and Founders of the start-ups, while the remaining interviewees were all high level executives. As explained before, having high-level representatives was essential to the success of this research (knowledgeable actors), given the strategic nature of the questions contained in the interview protocol. Similarly, having a great diversity of companies (based on size, sector, technology, and country), as opposed to, e.g. concentrating in only one sector or technology, was considered a strength in order to effectively answer the RQs, particularly RQ1 (understanding the landscape of DCS and their value propositions).

Table 6-5 provides a list of the 27 companies that were considered for the analysis. Only one person per company was interviewed and their names have been anonymised.

Table 6-5: List of 27 digital climate start-ups interviewed.

Company	Country	Founded	European Green Deal Sector	B2B vs B2C	Output	Size (NºStaff)	Stage
A	UK	2015	Other	B2B	Organisation providing data science and software engineering services to industry.	25	7
B	UK	2013	Other	B2B	Data science platform enabling data experts to build AI into their operations.	>1,000	8
C	UK	2018	Restoring BD	B2B	Carbon offset	20	3
D	UK	2016	Green Finance	B2B	Risk management (Climate Intelligence)	50	7
E	UK	2021	Green Finance	B2C	Cabon Footprint Information	13	4
F	Switzerland	2015	Restoring BD	B2B	Carbon footprint calculations, Carbon Offsetting	1,100	7
G	Portugal	2013	Smart Mobility	B2B	Drivers behaviour, reduction of emissions	<10	3
H	The Netherlands	2016	Circular Economy	B2B	Carbon Footprint Information of the supply chain	30+	7
I	UK	2015	Circular Economy	B2B	Reduction of Energy consumption in equipments	7	7
J	Spain	2013	Circular Economy	B2B	Water losses reduction in water utility companies	25	7
K	Italy	2017	Green Finance	B2C	Carbon Footprint Information	10,500	8
L	UK	2021	Restoring BD	B2B, B2C	Carbon Credits (bidiversity), Offsetting	3	4
M	Poland	2021	Circular Economy	B2B	Carbon Footprint Information	15	4
N	UK	2021	Energy Eff. Building	B2B, B2C	Sustainable Housing development	10	2
O	UK	2020	Restoring BD	B2B	Monitoring of insects	8	4
P	UK	2021	Food System	B2B	Algae production	10	4
Q	The Netherlands	2018	Zero Pollution	B2B	Cognitive cleaning, energy use reduction in oil industry	30	4
R	UK	2015	Food System	B2C2C	Rescue and redistribute food	100	7
S	France	2019	Green Finance	B2B	Risk management	11	3
T	UK	2017	Food System	B2B	Sustainable farming robots	55	4
U	UK	2020	Zero Pollution	B2B	Carbon management	20 (now 11.000)	4
V	France	2021	Zero Pollution	B2B	Carbon credits	2	4
W	UK	2022	Zero Pollution	B2B	Carbon removal	55	4
X	UK	2018	Circular Economy	B2B	Global water security	7	4
Y	Italy	2019	Restoring BD	B2B	Carbon Offsetting	25	7
Z	UK	2021	Circular Economy	B2B	Carbon Footprint Information, offsetting	13	4
AA	UK	2021	Circular Economy	B2B	Carbon Footprint Information for software dvelopers	<10	3

NB:

(a) Four companies have large number of staff (above 250), as opposed to a traditional start-up. The reason behind is that either the start-up was acquired by a larger firm (Company U) or that the start-up is an initiative within a larger organisation (Companies B, F and K).

(b) Regarding stages: 1-Idea generation; 2-Market research and validation; 3-Product development; 4-Launch and entering the market; 5- Seed stage; 6-Growth stage; 7-Scaling; 8-Expansion and maturity; 9-Late stage and exit.

In order for the reader to better understand the type of firms that were interviewed, ***Table 6-6*** presents the value proposition of five of them. **Appendix 7** provides a full list of the value proposition of the 27 interviewed companies.

Table 6-6: Examples of digital climate start-ups that were interviewed as part of the study.

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
D	A B2B open climate risk platform ("climate intelligence"), able to combine and decipher complex scientific information to evaluate risks at asset level; "doing very complicated synthesis of data, data engineering and machine learning". The company uses artificial intelligence (AI) and ML, among others.
E	A climate B2C debit card. "One of the challenges for people to manage and reduce their carbon impact is the lack of information about what makes their carbon impacts; the information that they require to reduce it and the easy access and ability to offset it". This is what the company is trying to provide: "make people's money work for them and also for the planet". The debit card is only a means to a superior climate change objective. They manage large databases and use machine learning (ML).
L	A B2B company that offers carbon offsetting through the protection of biodiversity. It is a solution that addresses climate change, the loss of biodiversity, and investing in local communities, "all into one package", by putting an economic value to ecosystem services. "The main thing about what we do is mixing digital technologies and nature technologies". They use technologies such as blockchain to ensure transparency, plus AI, and internet of things (IoT).
O	A B2B firm that provides local sensors to monitor pollinators in the environment, aimed at farmers suffering with suboptimal pollination. The aim being to get pollinators in the right place at the right time to increase yields.
U	A B2B carbon accounting software. The company helps small businesses measure their carbon footprint in an automated way, "for a small monthly fee". Use of mobile App and a whole set of back-end API's.

NB: please note this is a static picture of the value proposition of these firms. Given the very nature of these companies, their value proposition is constantly and rapidly evolving, with new products, features and capabilities being developed.

6.3 Stage 3 – Data Processing and Analysis

The objective of this Stage was to prepare the data for the coming Stage and thus address the two research questions. To that aim, the data collected from the interviews was transcribed and codified as explain in Section 5.3.2: Codifying and categorising. The following three results are described: codifying and categorising, presentation of preliminary results in conferences and intermediate validation workshop. Please notice that the last two activities (presentation of preliminary results in conferences and intermediate validation workshop) were part of the validation mechanisms (please refer to Section 5.3.3).

6.3.1) Coding and Categorising

As a result of this open coding stage (or First Cycle process as described by Saldaña, 2013) a constellation of first order codes were derived (67 in total), as shown in **Figure 6-3**.

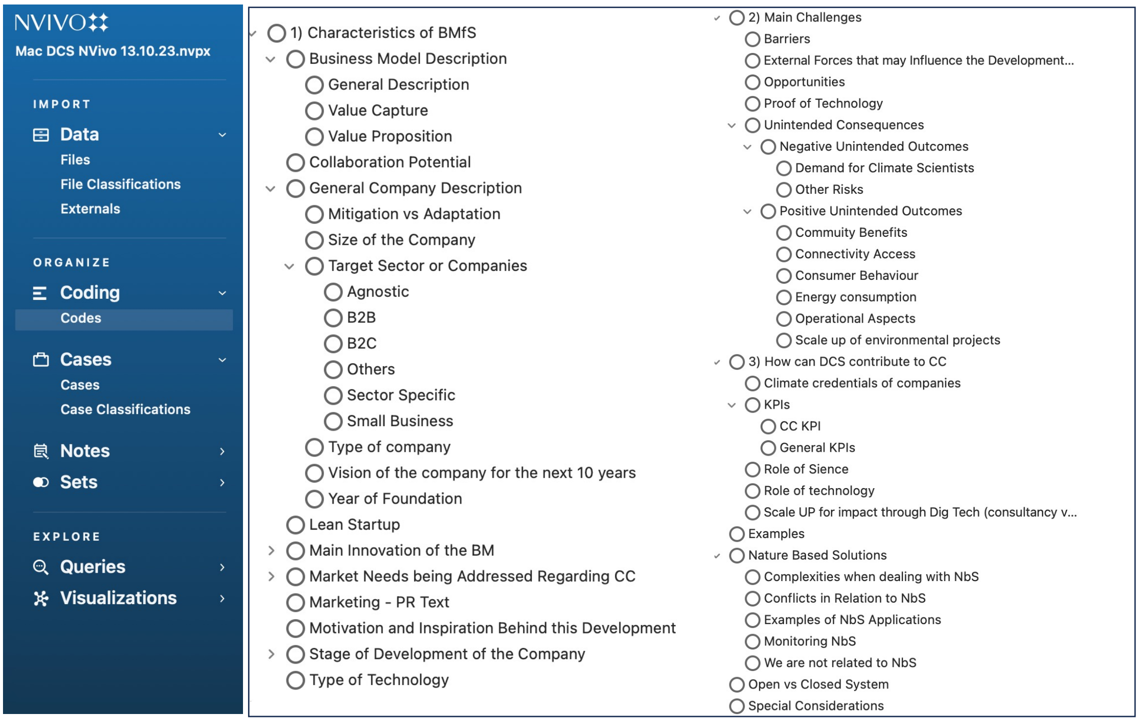


Figure 6-3: First cycle of coding (open coding), as seen in NVivo software.

As previously explained, this process of adding new codes was designed to conclude once saturation was achieved. **Figure 6-4** shows that saturation was achieved after 16 interviews had been processed, although a decision was made to finalise processing the 27 interviews that were already available (i.e. 11 interviews above the saturation level).

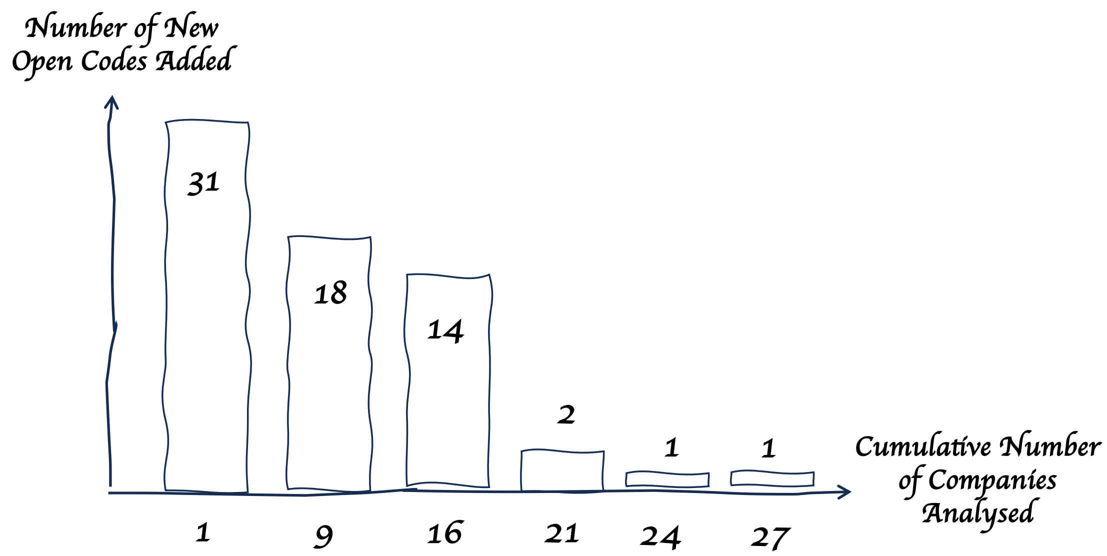


Figure 6-4: Open coding process until saturation.

Table 6-7 shows some examples of the analysis of the data, where the researcher tried to capture the essence of these qualitative codes. Selected paragraphs attempt to illustrate how the researcher went from the "rich text data" to the first order codes (full data is at the repository of the University of York):

Table 6-7: Examples of data analysis in the open coding stage.

Text Data (extracts from the interviews)	First Order Codes Derived
"Well, yes, basically it's about mitigation, but it also has a small component in adaptation, because these carbon credits from the regulated carbon market are being used to head against the climate transition risk, so I would say, is 95% into mitigation and 5% into adaptation". Company V.	▪ Mitigation ▪ Adaptation
"Well value proposition for the customer is easy, I mean easier, because we try to be as scientific as possible, as current as possible, as credible as possible, as transparent as possible. So our 4 Pillars are scientific, transparency, credibility, also generating social impact and environmental". Company Y.	▪ Value proposition ▪ Need for information (transparency) ▪ Science (role of Science)

Text Data (extracts from the interviews)	First Order Codes Derived
"So there are two parts. Transition and physical risks at TCFD. And we focus on the physical climate risk… because there is literally no offer in the space. So for companies there is nothing they can use to. So basically the regulation says all companies in Europe and the UK need to evaluate the physical climate risk, but the regulators simply forgot how to explain the companies how they should use it, how they should do it". Company S.	▪ Regulations ▪ Need for climate risk information.
"So BY 2,025 we want to remove a 1 million tons of CO_2 from the atmosphere, and early 2030, maybe even 2,030, we'd like to be removing 1 billion tons of CO2 from the atmosphere, a Gigaton, kick it at scale impact. You see, is what we want to achieve". Company W.	▪ Climate change KPIs ▪ Impact at scale
"In big terms I would say the performance will be measured in the amounts of ton of CO_2 surrender, compared to the amount of ton of CO_2 equivalent that we're tokenizing, I think that would be one of the main KPIs, and we expect this to be at least over 5% probably to 10%". Company V.	▪ Climate change KPIs ▪ GHG emissions
"So one of our objectives is to get to the point where we are removing from the process 1.5 tons of carbon CO_2e per Ha per farmer". Company T.	▪ Climate change KPIs
"Those are the two big components of why we're different, right, one is on the business model side which is open intelligence, and one is some scientific IP that we have". Company D.	▪ Business model ▪ Science (role of Science)
"So we are on the mission to make every single product and service climate positive by default, and we offer software solutions to make it really easy for companies to integrate climate impact into their existing products and services so it becomes a part of their customer experience". Company Z.	▪ Value proposition
"Our product is a digital product, it's a software that focuses on the reduction of non-revenue waters, so the reduction of the physical losses, through the location and identification of the leaks, saving a lot of time, money and water and also the reduction of the commercial losses, which are sometimes hidden and not counted". Company J.	▪ Value proposition ▪ Water savings (losses)

Appendix 8 shows a more detailed example of the type of information obtained from 15 companies after data processing with NVivo 20 (a particular example related to the code "climate change KPI" is provided), while **Appendix 9** shows a full example of one of the transcribed interviews (Company M).

In further analysis of the first-order codes and transcripts, axial coding (or secondary coding) was conducted with the objective of forming categories and so uncovering relationships between codes and the formed categories and subcategories (thus generating themes in this research). As explained in Chapter 5: Fieldwork methodology (Section 5.3.2), this part of the data analysis was an abductive process, as more theoretically informed second-order themes and sub-themes were derived. This step resulted in the identification of various theoretically informed themes (second order themes and aggregate dimensions). The main aim of this abductive process was to give meaning to the data and identify their connections. **Figure 6-5** shows the result of this process.

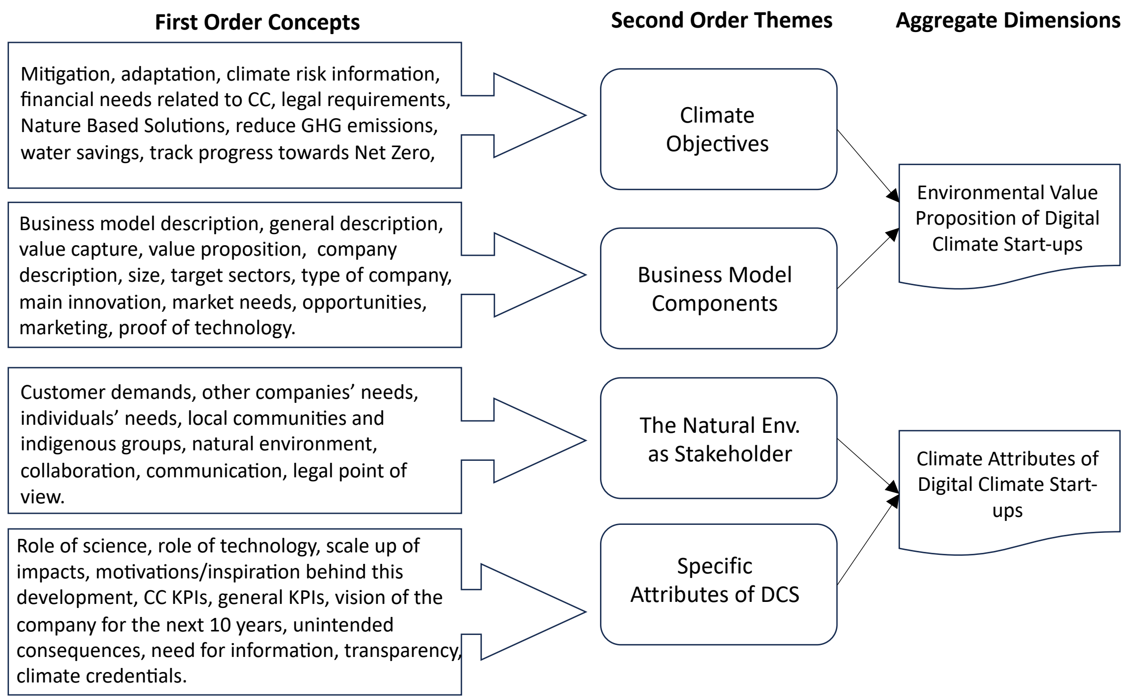


Figure 6-5: Data structure (adapted from Corley and Gioia, 2004).

For example, if we look at the second order theme "the natural environment as stakeholder", **Table 6-8** provides an example of how the first order concept "individual's needs" relates to it.

Table 6-8: Example of a relationship between a first order concept and a second order theme

Company	First order concept: "Individual's needs" – Answers given by the interviewees and its connection with the second order theme – "The Environment as Stakeholder"
E	"Make people's money work for them and also for the planet; one of the challenges for people to manage and reduce their carbon impact is the lack of information regarding about what makes their carbon impacts… and that is what we are trying to do with our market offering… allowing people to see the carbon impact that their spending has". Tech Lead.
G	"When we speak about sustainable road mobility and sustainable urban mobility, we are not just speaking about environment, not just speaking about climate change, we are speaking also about digital transitions…". Major Shareholder, CEO, Manager.
L	"The same thing with the users and the consumers, the households, they want to have an impact on nature, a positive one not a negative one, but they're very afraid of what the corporates are doing, which is greenwashing… it's about how can we give, how we can help you measure the impact you are having in nature, and you can share that story in a positive way". CEO & Founder.
N	"Building houses, providing, sustainable and affordable homes on a scale". CEO & Founder.
R	"So we are in business to put an end to waste in the home and in the local community. Specifically, we are tackling food waste. A third of all the world's food that's grown is never eaten and this accounts for 10% of global carbon emissions". COO and Cofounder.

Thus, **Table 6-8** shows that under the code "individual's needs" the interviewees were referring to the relevance given by their clients to the environment (i.e. the natural environment as a stakeholder). It must be remembered that these connections were established through a reflexive reading, as appose to a more literal analysis (i.e. the connections were not always explicit or obvious, there was an act of interpretation by the researcher). **Appendix 10** contains three other examples as raw data, showing answers provided by nine interviewed companies, presenting as first order concepts Mitigation vs Adaptation, New Legal Requirements, and Customers Demands, and relating these to second order themes (The Climate Objectives, and The Natural Environment as Stakeholder).

As a result of this processing and analysis, four main themes and two aggregate dimensions emerged. These themes are:

- Business models components: based on the literature on BM, several open codes were identified that relate to BM components. Open codes grouped under this theme include value capture, value proposition, market needs, etc.
- Climate objectives: based on the literature on climate change, several open codes were identified as pertaining to this Theme, including mitigation, adaptation, Nature Based Solutions, reduce GHG emissions, Net Zero, among others.
- The Natural Environment as Stakeholder: based on the literature on stakeholders, several open codes were considered related to this theme, such as individuals' needs, local communities and indigenous groups, natural environment, communication, etc.
- Specific attributes from DCS: It became apparent that firms tended to mention elements that in their view were relevant for the success of their value proposition and their impact, such as transparency, collaboration, need for scientific support, scale, clear KPIs, etc.

In addition, two third-order Aggregate Dimensions were identified:

- Environmental Value Proposition of Digital Climate Start-ups: this third-order aggregate dimension was key to answer RQ1, as it provided the basis for a taxonomy of DCS.
- Climate Attributes of Digital Climate Start-ups: this third-order aggregate dimension was key to answer RQ2, as it allowed the identification of climate attributes that were essential for DCS, while also making the case for including the natural environment as a key stakeholder.

6.3.2) Continuous Validation Mechanisms

After the conclusion of the first twelve interviews (second round of interviews), in July 2022 a one-hour on-line workshop was carried out with three staff members from EIT

Climate-KIC[8]. The results contributed to improve the initial proposal for a taxonomy of companies. **Appendix 11** contains the detailed feedback that was received during the workshop. Some of the main comments and recommendations received included:

- How to start a company that is truly addressing CC? can this research answer this type of question?
- What other sectors need to be included in the sample? e.g. food production, agriculture.
- What are the blocks that form the basis for a company that is truly addressing CC in a positive way? (i.e. a taxonomy aspect and necessary attributes).
- Think on enablers: creators and facilitators, the former create while the later make something more efficient; the former are more independent, while the later depends on others.
- In terms of how to classify BM: Look at product/service and the way they integrate into the ecosystem, how are these companies connected, and how do they collaborate? Also, where is the regenerative component, beyond compensating, mitigating, reducing.
- Another way to differentiate the interventions of the companies, is to look at if they focus on energy intensity or carbon intensity.
- Classify: if the solution is enabling others to do something or expected to have a direct mitigation benefit. If it is enabling, distinguish between energy or carbon intensity at a user level.

Complementary, presenting the research progress in technical conferences was considered a key element of this research (and this iterative process of data analysis and validation). To this aim, the researcher was accepted to present in nine conferences since early stages of this investigation (from 2021 until 2023). **Appendix 12** provides a list of these events.

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[8] The participants of the meeting were: Christine Roehrer (Entrepreneurship Programme Designer and Manager - Focused on Climate Impact); Emily Amann (Project manager, entrepreneurship), and Lia Montserrat Alvarez (Project manager, climate impact).

The feedback received both from reviewers during the application process as well as from the attendees during the conferences, was assessed and in many cases incorporated in the iterative process of data analysis. **Appendix 13** shows some examples of the feedback received.

As a result of attending these conferences several research outcomes were produced. A full list is presented at the beginning of this Thesis (Disclaimer section). In addition, a paper was presented and selected to be part of the book "Regenerative Futures and Artificial Intelligence" (by Springer), Volume 3: Profit - Challenges and Solutions of Economic Sustainability Goals (Edited by K. Gondlach, B. Brinkmann, J. Plath, M. Brinkmann). The article was entitled: "The Competitive Business for Saving the Planet: The Case of Digital Climate Start-ups and their Value Proposition" and is expected to be published in Q3/2024. An abstract of the article is included in **Appendix 14**.

As it was previously explained in section 5.3.3 of the Fieldwork Methodology Chapter, this iterative process of validation and analysis was essential to obtain solid grouping and categorisation of the information gathered. **Figure 5-3,** introduced in the Methodology Chapter, illustrates this continuous process of data analysis, codifying, further literature review, presentations for discussion, and back to codifying and categorising.

This iterative process was key to achieve a coherent, robust and traceable analysis of the data. In fact, the final grouping shown in **Figure 6-5** is substantially different from preliminary results.

6.4. Stage 4: From Data to Theory

This Section attempts to provide an answer to the research questions of this investigation, defined as:

- RQ1 - How do we unpack the value proposition of digital start-ups tackling climate change?
- RQ2 - How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?

As shown in **Figure 6-6**, the answer to RQ1 (Result 1) has two parts, while the answer to RQ2 (Result 2) has three parts (i.e., for each RQ there are several outcomes). These aspects are further explored below.

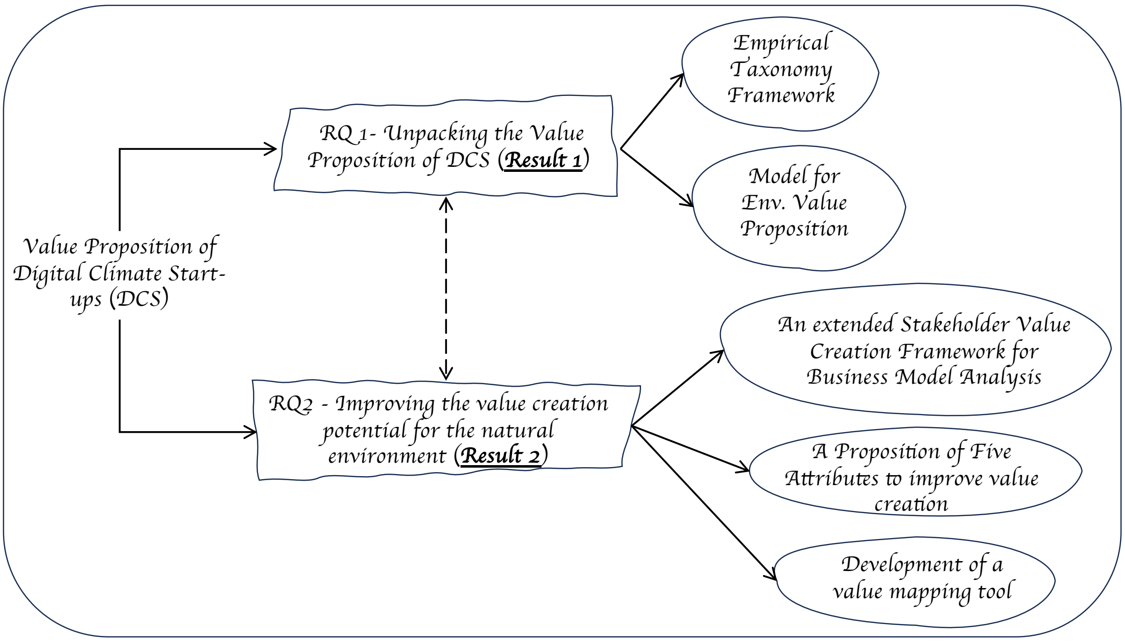


Figure 6-6: Summary of the main results of this investigation

6.4.1) Result 1 - Unpacking the Value Proposition of DCS (RQ1)

This RQ was concerned with further understanding the landscape of digital climate solutions being developed, the value for the environment being created and proposing a taxonomy of BM based on their value proposition (i.e. a typology of business models or Taxonomy Framework).

i- Empirical Taxonomy Framework

The primary answer to RQ1 is a proposal of an empirical taxonomy to classify DCS (the Taxonomy Framework). As explained in the Methodology Chapter, this taxonomy was developed by a combination of inductive and abductive approaches. The main objectives for developing a taxonomy of BM of DCS are to:

a) Provide a means of categorising and explaining business models tackling CC in the context of DCS,
b) Provide examples of DCS which explain and communicate these business models,
c) Contribute to the improvement of their BMfS, and
d) Help defining a research agenda for business models for sustainability of DCS.

In addition, understanding the profile of DCS can be of strategic importance for several stakeholders that are part of the stakeholders network of a given DCS since they can make decisions to improve the value portfolio based on these profiles, as will be discussed later on.

Thus, the proposed taxonomy (typology of business models) was primarily based on the objectives of the DCS regarding CC, i.e. what they want to achieve through their value proposition, whether it is climate change mitigation or adaptation. These are defined as:

- Climate change mitigation: Climate change mitigation is achieved by limiting or preventing greenhouse gas emissions and by enhancing activities that remove these gases from the atmosphere.
- Climate change adaptation: are the processes and actions that enable people to cope better with increasingly challenging weather and climatic conditions.

Examples of DCS focussing on mitigation include:

- Impact investment platforms for the restoration of forest and agroforest landscapes.
- Eco-cars delivered as a service (mobility as a service, with up-stream suppliers integrated and distributed manufacturing model).

- Satellite imaging system for biomass monitoring and natural disaster response, among others.

Examples of DCS focussing on adaptation include:

- Climate risk platforms (solutions to de-risk decisions and build more resilient companies using big data analytics tools, geospatial machine learning (ML), climate science, and catastrophe simulations).
- Smart water management platforms that enable efficient water supply and reduced water consumption (aimed at water distribution companies).
- Agriculture water management system (that utilises smart agriculture sensors, AI, and advanced agronomic models).

On a second level (the first level being the objective of the DCS regarding CC), the proposed taxonomy considered the strategy DCS followed to contribute to the fight against CC, i.e. how they plan to contribute to the fight against CC, acting as impact enablers vs impact creators. Definitions of these two additional categories are:

- Impact enablers: Economic activities that, by provision of their products or services, enable a substantial contribution to be made in other activities. For example, an economic activity that manufactures a component that improves the environmental performance of another activity.
- Impact creators: Economic activities that make a substantial contribution based on their own performance. For example, an economic activity being performed in a way that is environmentally sustainable.

These categories initially emerged from the analysis of the open and axial coding stages. In effect, several of the questions of the interview protocol were used to collect empirically grounded information that led to this Taxonomy Framework. In particular, questions related to why the company is in business, market needs being addressed, description of their value proposition, description of their KPIs, and general company description, among others, shed light on preliminary ideas (the inductive approach).

This was later further enhanced with literature on climate change (the abductive approach) through the identification of various theoretically informed types of CC strategies, including the work done by the Impact-Forecast methodology[9], strategies identified in the IPCC Report (2022), USEPA (2017), TCFD (2017), and the results of the validation workshop (see Section 6.3.2). Examples of this relationship between open codes and the objectives and strategy are provided in **Table 6-9**.

Table 6-9: Examples of relationship between open codes and the objectives and strategy.

Question related	Examples of codes	Objective & Strategy
Market needs being addressed	Need for information (e.g. climate risk information, financial information, understanding the impact of making a software)	Impact Enablers
	New legal requirements	Impact Enablers
	Offsetting emissions	Impact Creators
	Reduce GHG emissions	Impact Creators
	Track progress to Net Zero	Impact Enablers
	Water savings	Impact Creators
	Local communities and indigenous groups	Impact Enablers
	Protect the Natural environment	Impact Creators
Value proposition	Main innovation	Enablers or Impact Creators
	Motivation	Mitigation/adaptation
	Mitigation	Mitigation
	Adaptation	Adaptation
KPIs	CC KPIs, other general KPIs	Enablers or Impact Creators

Thus, the taxonomy method here presented is less concerned with the type of technology, focussing instead on the purpose and expected impact of the start-ups. In fact, as previously mentioned, most of the time the start-ups will have a combination of

[9] Impact Forecast is a methodology developed by the company "Impact Forecast" with the aim to improve and validate climate impacts of products. It is divided in projects that are enablers, or focus on mitigation or adaptation. More information at https://impact-forecast.com/

digital technologies as part of their value offering, and this combination may be extremely dynamic.

In order to understand how the case study companies fit into the four categories previously mentioned (climate change mitigation, climate change adaptation, impact enablers and impact creators), a cross-comparison of the 27 interviewed firms was performed, shown in **Table 6-10**.

Table 6-10: Cross comparison of 27 firms against the four categories emerged from the coding stage.

	Companies																										
Aspects for Cross-comparison	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
Climate change mitigation	■	■	■		■	■	■	■	■	■	■	■	■			■	■	■			■	■	■			■	■
Climate change adaptation				■										■	■			■	■	■				■	■		
Impact enablers	■	■	■	■	■	■	■	■	■	■	■		■		■				■		■	■				■	■
Impact creators												■		■		■	■	■		■			■	■	■		

As it can be observed, the majority of companies aim to contribute to climate change mitigation, with only one declaring contribution to both, mitigation and adaptation (Company R). The reason for this is that Company R was founded with the objective of "unlocking the value of the food that is wasted", so by doing this the company can potentially contribute to both CC strategies. Company R is a marketplace that connects people in real time with other people nearby to "*facilitate the safe, easy and fast exchange of goods that would otherwise go to waste, and everything is given away for free*". Their ambition is to "*put an end to waste at home and in the local community*" (COO and Cofounder, Company R). Similarly, most of the interviewed companies seek to act as enablers or facilitators of impact, as opposed to impact creators. This cross - analysis is based in the knowledge the researcher has on the value offering of these firms (based on the interviews), as well as on the definitions provided for each of these categories, as presented above.

Thereby, this research suggests the categorisation of four business models. These categories are divided into subcategories, based on their strategic approach. **Figure 6-7** presents a definition of these four categories and provides examples based on the interviewed companies (adapted from Bocken, 2014).

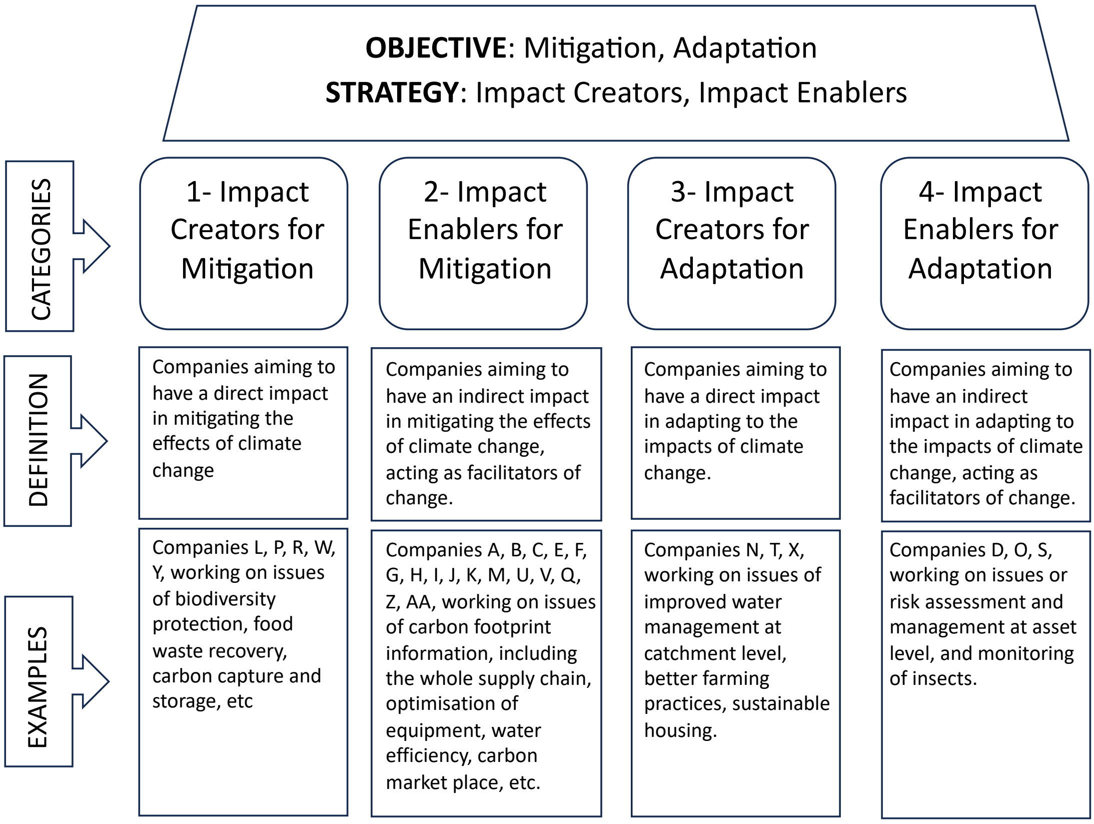


Figure 6-7: Taxonomy Framework for Digital Climate Start-Ups (based on Bocken, 2014).

For those DCS addressing mitigation (as already shown, the majority of the studied companies fell under this category), several other sub-categories could be identified. This is concerned with the specific value offering, for example whether it is energy or carbon intensity, carbon avoidance, carbon removal, energy management, or carbon management. In some cases, even a fourth level can be distinguished. For example, when it comes to carbon management, a separation can be made between awareness raising as a value offering or selling carbon offset projects. **Figure 6-8** shows a complementary classification framework with the four categories above defined and additional subcategories (this time separated by their CC objective, mitigation or adaptation). This classification is considered to be clear and intuitive, mutually exclusive and explanatory.

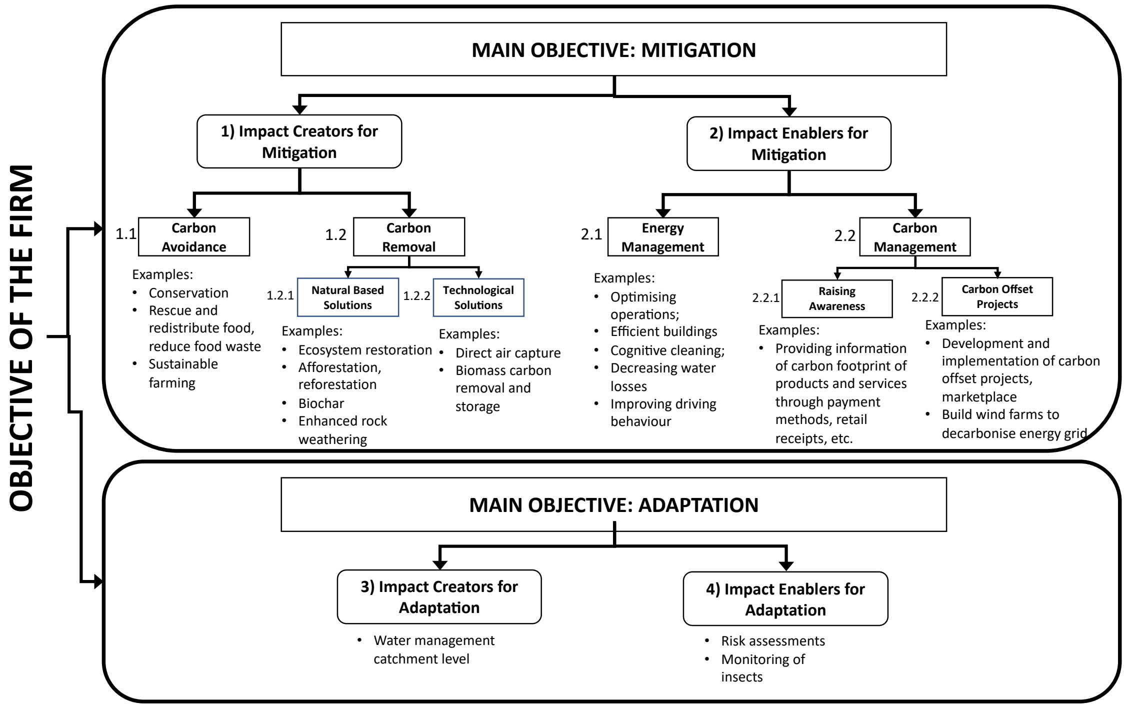


Figure 6-8: Complementary Empirical Taxonomy Framework for Digital Climate Start-Ups.

For example, a DCS aimed at raising awareness of climate change among its clients using a debit card (Company E), is a 2.2.1 according to the proposed classification method. A digital company dedicated to planting trees is a solution born to contribute to mitigation strategies (Company Y), and at the same time they are creating direct impact by removing carbon through a Nature Based Solution or NBS (i.e. in our classification scheme a 1.2.1). However, it is important to note that many digital solutions may fall into multiple categories or have overlapping functionalities. The classification provided here serves as a general framework to understand the diverse range of digital solutions addressing climate change challenges.

This clustering contributes to address two of the four objectives that were set for developing a taxonomy of DCS, this is it provides a means of categorising and explaining business models tackling CC in the context of DCS, and it provides examples of DCS which explain and communicate these business models, i.e. objectives a) and b).

In order to address the other two objectives (objectives c) and d)), however, some additional analysis was required. Thus, in the next section a complementary approach for "unpacking the value proposition of DCS" is presented, which can complement and enhance the above taxonomy framework.

ii- The Value Proposition Approach

A secondary part of the answer to RQ1 was about better understanding the value proposition for the natural environment of DCS and its relationship with the value proposition for the clients.

Indeed, after having classified the typology of BMfS of a given DCS, in order to fully unpack their value proposition, there is a need to provide a description of three elements: the customer value proposition, the environmental value proposition, and a description of the way in which the firm is going to impact (i.e. positively contribute) in the fight against climate change. Using as inspiration the diagram of a generic logic of business model for sustainability proposed by Abdelkafi and Täuscher (2016)[10] and applied by Cosenz *et al*. 2020, ***Figure 6-9*** provides a simplified view of the relationship between the customer value proposition and the environmental value proposition. Although the study by Abdelkafi and Täuscher (2016) was different in nature and scope, as it looked into business models as complex and dynamic systems, presenting stock and flow diagrams, their approach was considered relevant for this research in terms of looking into the positive loops that are generated between the customer value proposition and the environmental value proposition.

As in the study by Abdelkafi and Täuscher (2016), in this research the customer value proposition is defined from the firm´s point of view and not from the value perceived by the customers. The same logic was applied to the environmental value proposition (i.e.

[10] Please notice that this research is mainly concerned with the value proposition aspect, with emphasis in the environmental value proposition. Instead, the research by Abdelkafi and Täuscher (2016) looks into business models as complex and dynamic systems, presenting stock and flow diagrams and looking into the relationship among all the BM dimensions (value proposition, value capture and value creation) and how they can reinforce each other.

the intended impact on the environment from the firm's perspective, mainly CC mitigation or adaptation). However, an additionality of this research is a deeper exploration of the impact regarding CC by for example looking into their climate hypothesis, climate objectives, KPIs, vision, etc, as explained later in this chapter.

Figure 6-9 illustrates that, in the case of DCS, it is expected a strong positive feedback loop between the customer value proposition and the environmental value proposition.

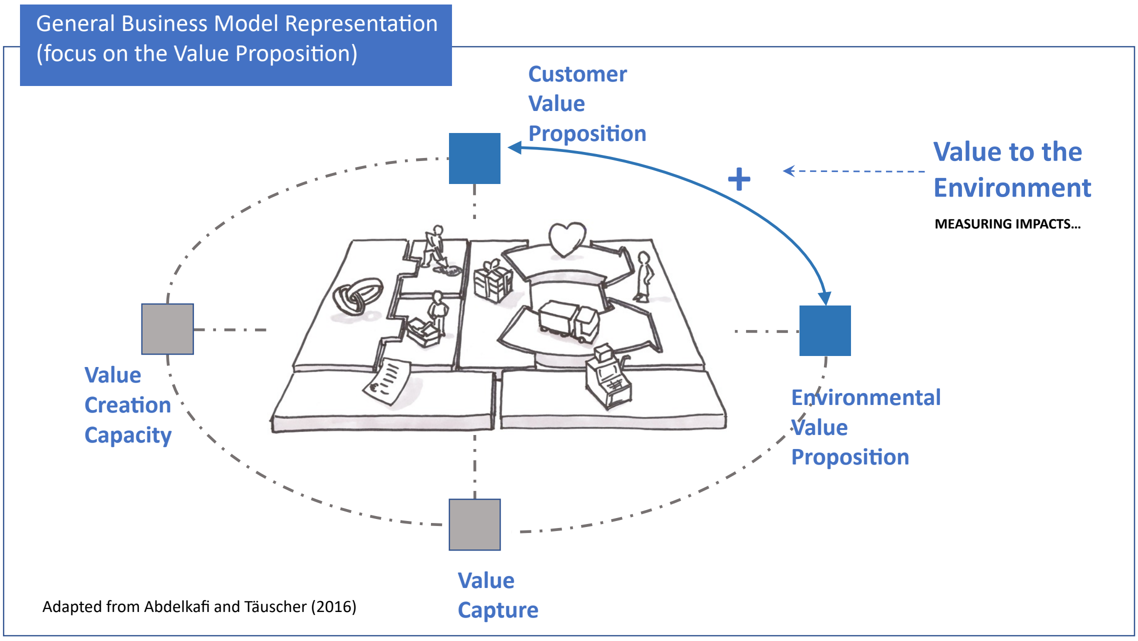


Figure 6-9: Generic Logic of Business Models for Climate Change (adapted from Abdelkafi & Täuscher, 2016, p.81).

To better explain this, let us analyse the value proposition of five of the interviewed firms, selecting one for each of the categories (in the case of Category 2, Impact enablers for mitigation, two companies were selected, one with a B2B model while the other has a B2C model). **Table 6-11** provides a summary of the selected examples.

Table 6-11: Examples of value proposition by archetype

Archetype	BM	Company	Example of CVP	Example of EVP
Category 1: Impact creators for mitigation	B2B	L	Carbon offsetting for corporations.	Protection of keystone species and ecosystems.
Category 2: Impact enablers for mitigation	B2B	Z	Make every product and service climate positive (retailers as a target sector).	Offsetting client's carbon footprint.

Archetype	BM	Company	Example of CVP	Example of EVP
	B2C	E	Virtual debit card working to tackle CC.	Supporting carbon sequestration projects.
Category 3: Impact creators for adaptation	B2B	X	Water management platform at catchment level.	Contribute to more resilient basins.
Category 4: Impact enablers for adaptation	B2B	S	Evaluating physical climate risks to assets due to CC.	Indirect benefit through for example water and energy efficiency in the assets.

NB: CVP: Customer value proposition; EVP: Environmental value proposition.

These examples are further developed below.

Category 1: Impact creators for mitigation

This first example is provided by Company L, a B2B company that offers carbon offsetting for corporations through the protection of biodiversity. It is a solution that addresses climate change, the loss of biodiversity, and investing in local communities, “all in one package”, by putting an economic value to ecosystem services. The main innovation is bringing digital technologies to help measure and understand the inputs and the outputs of biodiversity to the challenge of climate change. The company uses technologies such as blockchain to ensure transparency, plus AI, and IoT. Using the Taxonomy Framework, this is a 1.2.1 firm, i.e. working towards mitigation, an impact creator, using carbon removal, and using NBS. Thus, the value to customers is the offering of carbon credits (Ecosystem Service Credits), while the environmental value proposition is contributing to the protection of keystone species and their ecosystem (**Figure 6-10**).

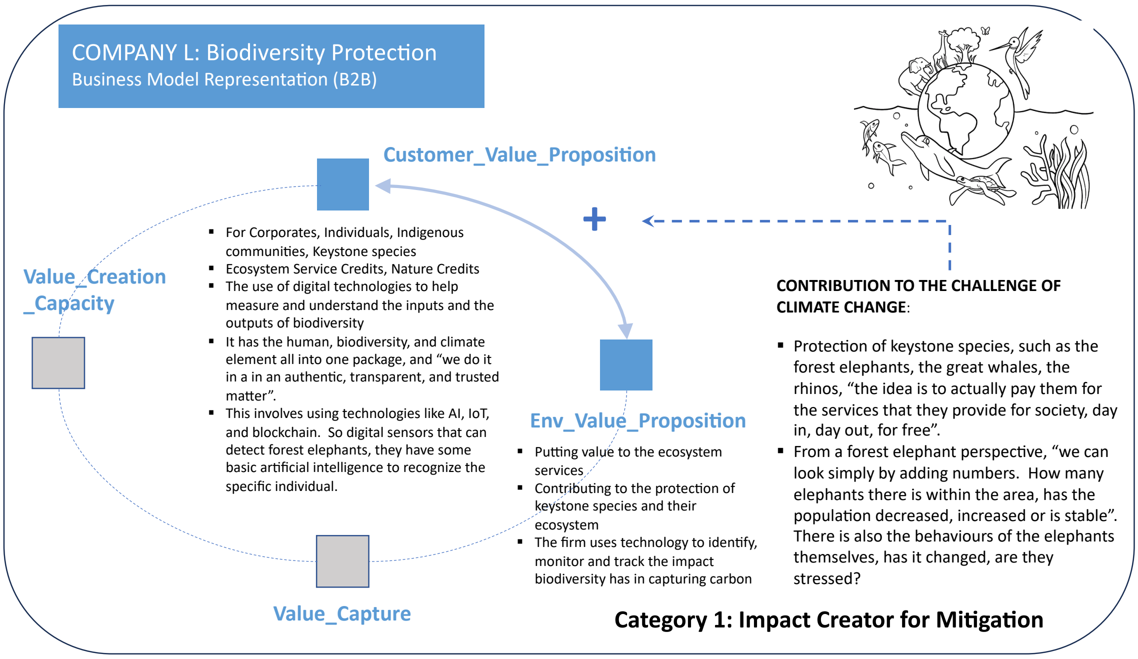


Figure 6-10: Customer and environmental value proposition of Company L.

The positive loop observed between the customer value proposition and the environmental value proposition in the case of DCS is expected to draw the attention of managers and entrepreneurs to the natural environment and to the stakeholders who care about it, putting the relationship between stakeholders, the natural environment, and the company at the centre of the conversation (Abdelkafi and Täuscher, 2016). Although not study in this research, it is expected this positive loop will also feed back into the value capture dimension of the BM of the firm, in a way that the better is the environmental value proposition the more value the company will capture.

Category 2: Impact enablers for mitigation

Company Z (**Figure 6-11**) is a start-up at the "entering the market" phase and has developed a software to make it easy for its clients (the main target sector is the retail industry, on a B2B model) to integrate climate impact information into the products they sell, becoming part of their customer experience. Based on the Taxonomy Framework, this is a 2.2.1 firm, i.e. a company addressing mitigation as its objective, acting as enabler or facilitator of a solution through a carbon management strategy based on awareness raising.

The value proposition for its customers is that the retailers are able to embed a climate impact approach into their products (by providing information about their carbon footprint and also about offsetting strategies), in turn making it easy for the clients of the retailers (i.e. the shoppers) to know the climate impact associated with the products they are buying. The software also allows the shoppers to decide how they want to offset the carbon footprint of their purchases, by choosing from alternative offsetting projects (the environmental value proposition). For this purpose, Company Z has partnered with several providers of carbon offset projects. In addition, clear and transparent climate change KPIs need to be explicit, and a monitoring and reporting system put in place (information that needs to feed back into the virtuous relationship between customer and environmental value proposition).

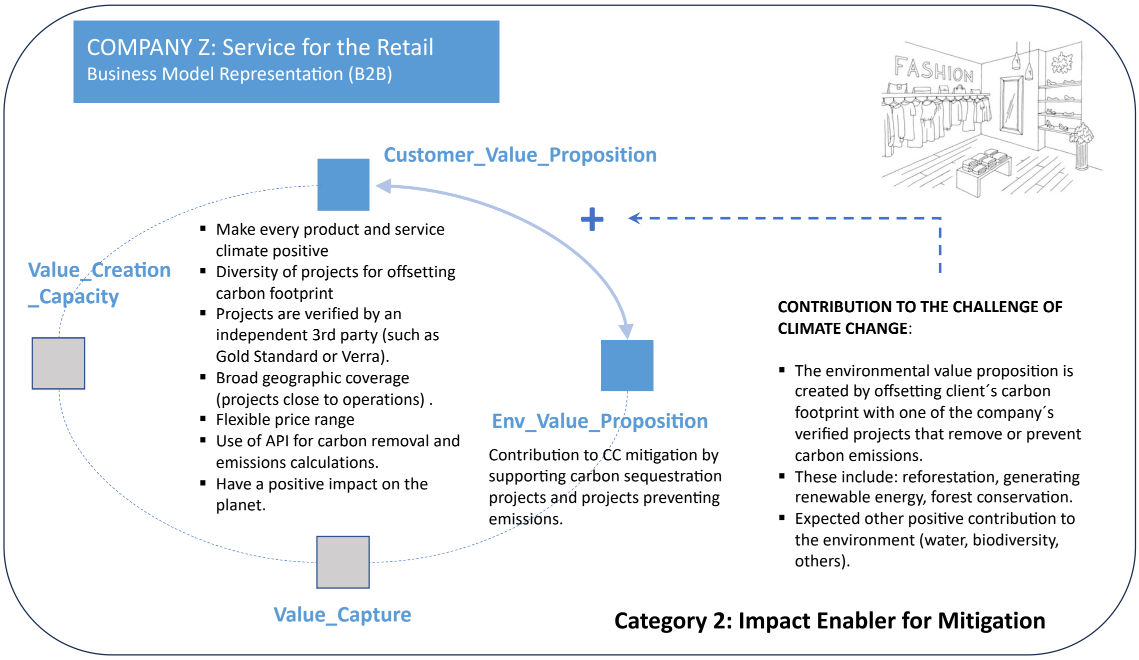


Figure 6-11: Customer and environmental value proposition of Company Z

Another example under archetype 2 is provided by a Fintech product (Company E), a debit card that has the additional aim to create awareness about CC using a B2C model (**Figure 6-12**). Based on the Taxonomy Framework, this is also a 2.2.1 firm.

In this case customers receive every month a bank statement with transaction details, with the added value of also receiving the carbon emissions associated to these purchases (calculations are made based on general information available regarding the carbon footprint of products involved). On top of this, clients are given several options to offset their emissions (the customer value proposition). In this case, the value for the environment is meant to be realised in at least three ways. First, by the clients of Company E deciding to compensate their carbon emissions through them. Second, clients can also switch to more environmentally friendly alternatives on recommendations from Company E App. Finally, it is expected that in the long run clients will also change their patterns of consumption towards a less impactful behaviour. As in the previous example, in order to provide a full picture of the expected positive impact (its contribution to the fight against climate change), Company E needs to develop a Climate Hypothesis, specific and relevant climate change KPIs, and a monitoring and reporting system in place, and this information needs to feed back into the BMfS.

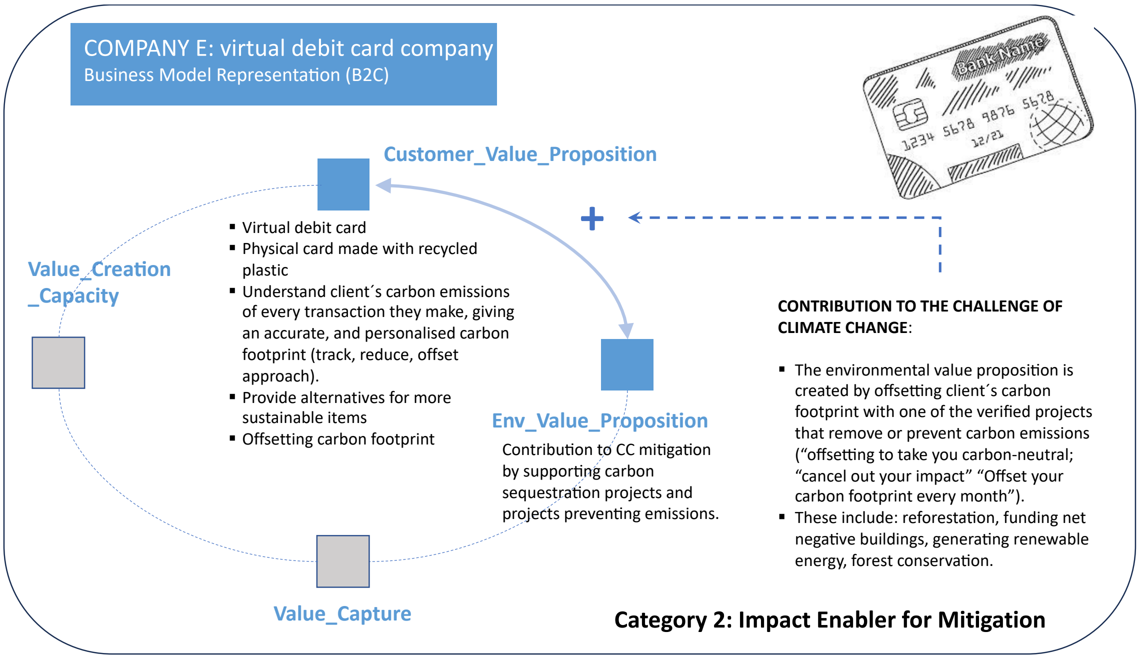


Figure 6-12: Customer and environmental value proposition of Company E

These examples represent the intended contribution to the climate crisis from these two firms (Companies E and Z) and from their clients and show the reinforcing feedback loop between the customer value proposition and the environmental value proposition. This is because it is expected that the clients (whether B2B or B2C) will value the information given in relation to the carbon footprint of their purchases, which in turn will encourage them to take actions by, for example, offsetting their footprint. This will benefit the environment through more projects being funded which in turn may attract new clients to the firms (as the firms may be seen as being active and successful in targeting climate impact), improving the financial sustainability of the firm.

Category 3: Impact creators for adaptation

The fourth example is provided by Company X (**Figure 6-13**), a water management platform developed to contribute to the understanding and measuring of water risks at a catchment level. According to its CEO and Founder, this is a very challenging risk to understand, as it manifests itself locally rather than globally, and providing decision-ready information at global scale on water risks has proven very difficult. One of the challenges for efficient water management at catchment level is information asymmetry, which is one of the main focuses of this start-up (i.e. it has a public goods mission, to reduce information asymmetries, and that means providing information to stakeholders such as communities, regulators, farmers, municipalities, and so forth). The company uses ML, with computer vision, and the integration of climate and weather data, in order to understand the hydrology, hydrogeology, and catchment dynamics.

As this company is on the adaptation side of the CC arena, the environmental benefits of its value proposition are indirect, but they may include improved water quality, and enhanced water availability for ecological purposes (e.g. maintaining a healthy ecosystem).

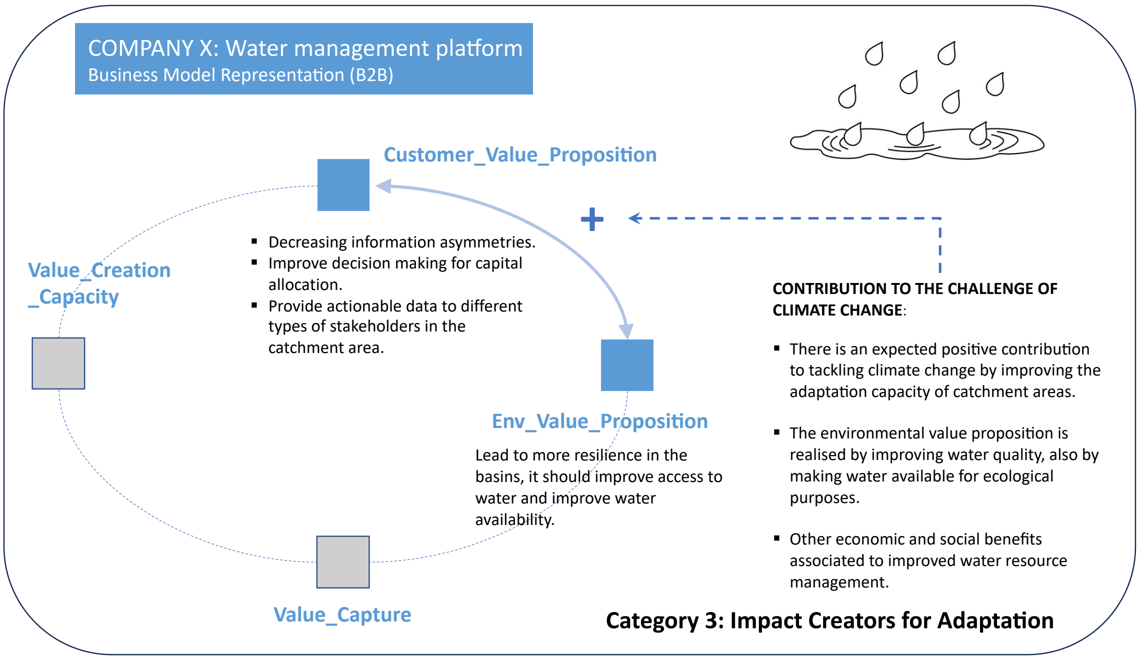


Figure 6-13: Customer and environmental value proposition of Company X

Category 4: Impact enablers for adaptation

The last example provided is from Company S (**Figure 6-14**), this is a firm that was born to solve the problem of evaluating the physical risks of companies to the effects of CC. New regulations already in place in Europe demand that companies conduct these types of assessments, but according to its CEO and Founder the information needed to do that is not readily available in the market, particularly for forward-looking risks. For this the firm uses deep learning (for the statistical or dynamic models to detect floods), neural networks, and also non-supervised learning.

As with the case of Company X, also in the area of CC adaptation, the environmental benefits of this firm's value proposition are indirect and may be related to the measures included in the adaptation plans companies need to develop.

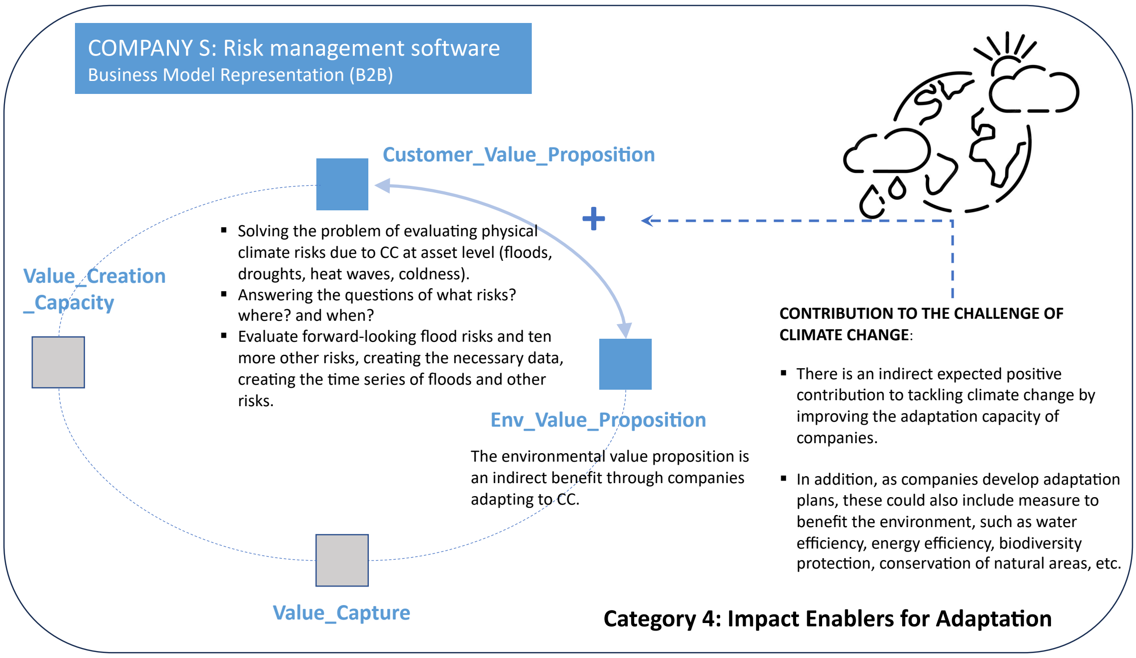


Figure 6-14: Customer and environmental value proposition of Company S

Having a clear proposition for unpacking the value offering of DCS, based both on the Taxonomy Framework and on the description of three key components (the customer value proposition, the environmental value proposition, and a description of the way in which the firm is going to contribute to the climate change challenge), the next step is addressing RQ2, which is about how can firms improve their environmental value proposition.

6.4.2) Result 2 - Improving the value proposition for the natural environment (RQ2)

The proposed answer to RQ2 has three parts. The first part is about recognising the natural environment as a key stakeholder for DCS as a necessary condition to increase their value proposition (the primary attribute), the second part suggests a set of additional attributes that need to be considered, while the third part proposes a practical tool that could contribute to improving the value proposition of DCS . This follows the outcomes of Stage 3: Data Processing and Analysis, where two second order themes relevant to address this research question were derived, indicated in the dotted line in **Figure 6-15**.

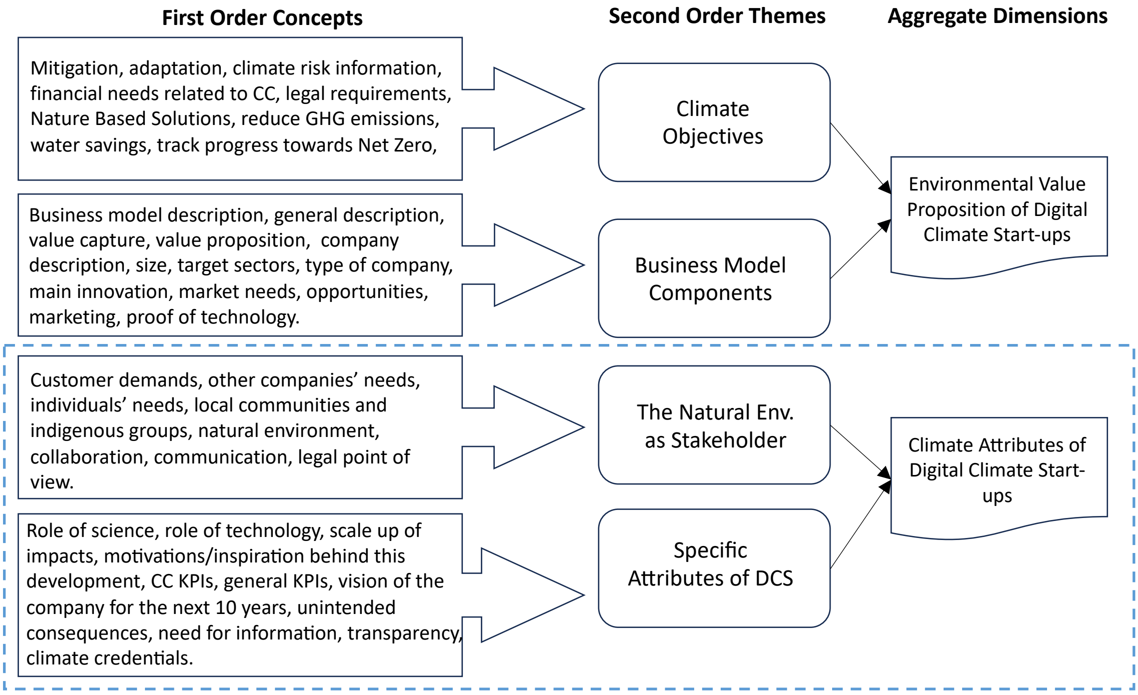


Figure 6-15: Data structure (adapted from Corley and Gioia, 2004).

As it can be observed, the first and second order codes support the identification of a set of attributes that are essential to increase the value proposition of DCS. Based on these results, **Table 6-12** shows a cross-comparison of the 27 interviewed companies, highlighting the presence/absence of grouped attributes that emerged from the analysis. One additional attribute ("the need to have an explicit joint purpose") has been suggested based on literature (the SVC Framework developed by Freudenreich *et al.*, 2020).

Table 6-12: Cross comparison of 27 firms against attributes emerged from the coding stage.

	Companies																										
Aspects for Cross-comparison - Attributes for Value Creation	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
Having the Environment as a key Stakeholder	■				■	■	■	■		■		■	■		■			■	■	■	■	■	■	■	■	■	
Having an explicit joint purpose																											
Identifyng and managing unintended consequences												■	■		■	■		■		■		■	■	■	■		
Having science as enabler	■	■		■	■	■						■	■		■				■		■		■	■	■		■
Measuring climate impacts						■	■					■	■							■		■	■				
The need for information transparency				■	■	■															■				■	■	■

Note: please notice that at this stage of the data analysis the aspect "having explicit join purpose" was not identified. This was, however, unveiled at a later stage.

The cross-case comparison showed that for the majority of companies the environment is a key stakeholder, as their value offering is built around objectives of climate change (e.g., biodiversity protection, restauration of ecosystems, CO_2 sequestration, efficient use of energy, improved water management, among others). In reference to the attributes of: identifying potential unintended consequences, having science as enabler of their value proposition and having clear methods to measure the expected climate impacts, the results are to some extend similar, as near half of the companies addressed these three aspects. The later attribute, measuring climate impact, was however lower than could be expected, as many of the firms were just starting to think about forms to measure this. Finally, the last attribute, information transparency, grouped first order codes such as: information transparency, climate credentials, and need for information. Seven companies made explicit reference to this attribute.

The following two sections expand on these attributes providing evidence that justifies their inclusion as essential attributes (both primary and secondary). Given that a significant amount of data is presented (Tables 6-14 to 6-24 providing more than 50 pieces of evidence extracted from the interviews), the following conceptual map is used to guide the reader throughout these sections (**Figure 6-16**), therefore enabling the reader to follow this process without feeling overloaded with information (able to "see the wood from the trees").

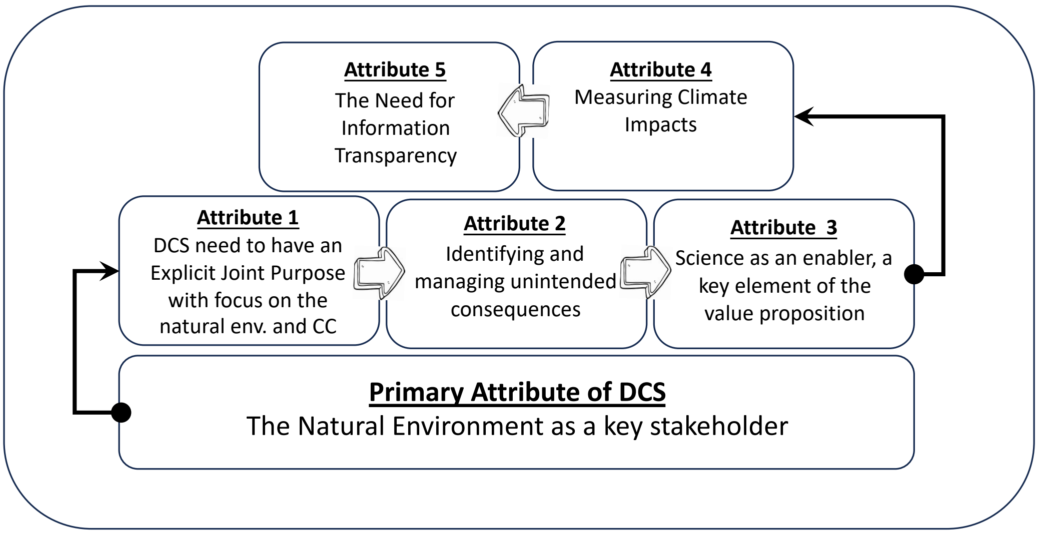
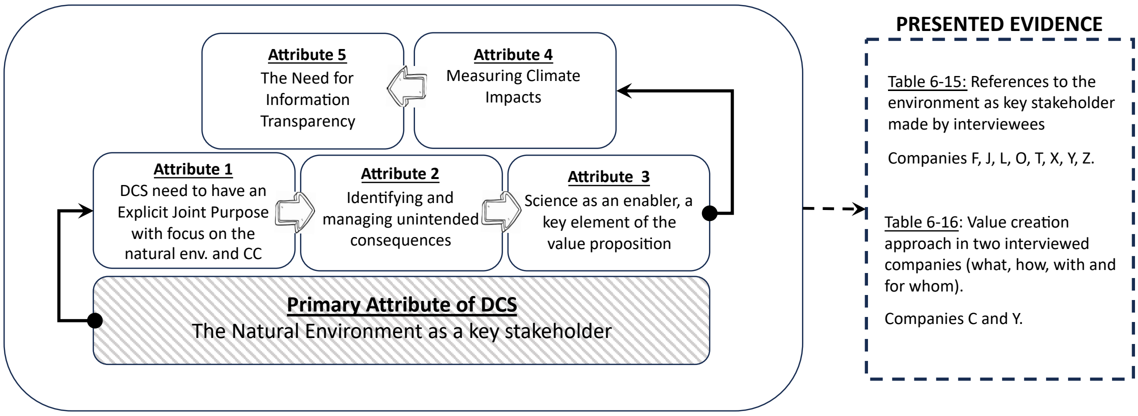


Figure 6-16: Conceptual Map to navigate the development of DCS attributes and verification data

At the beginning of each section this map will be re-introduced highlighting the attribute to be covered and making reference to the supporting evidence.

i- The Natural Environment as a Key Stakeholder



The empirical analysis of the data showed that the natural environment was a key stakeholder for DCS. The reasons behind these findings are to some extend straightforward, and can be summarised in these three elements:

- The value proposition of these companies is built around tackling climate change and improving nature (for example see **Table 6-12, Figure 6-10, Figure 6-11, Figure 6-12, Figure 6-13, Figure 6-14**),
- The criteria for success very often revolved around environmental and climate change KPIs and,
- The long-term vision of the firms was frequently built around improving the natural environment (through tackling climate change), and not just having economic success.

In addition, the relevance of the natural environment as an essential part of the value offering (i.e. the natural environment as a key stakeholder) was permanently referred to by the interviewees, as shown in the examples of **Table 6-13**.

Table 6-13: References to the environment as key stakeholder made by interviewees

Company	Comments
Company F	"The capacity of nature to contribute to tackling climate change is embedded into the business model of the company". Director of Digital Climate Solutions.
Company J	"With our product we aim to reduce a huge part of the water that is wasted nowadays. Depending on the country, the water that is lost either within the pipelines, or because it's not properly measured, is about 40-50%, depending on the region, it can go from 10 to 50%". Key Account Manager, Middle East, Oceania, Eastern Europe.
Company L	"The third market, which is also related to consumers, but it's from a different perspective, are local communities and indigenous tribes… That is fundamentally one of a care or guarding nature, and that is by giving them, you know, the necessary resources that they rightly deserve". CEO & Founder.
Company L	"So at a global level, we're here to address the need that nature is treated as an externality instead of an internality… So that if you wanted to set the scene, we're here to address the problem that we give no value to nature except when is dead, and then we have to give it value in economic terms when it's alive". CEO & Founder.
Company O	"we absolutely think that ecosystem services is all at the heart of what we're doing. So having, you know, pollinators play a valuable role in food production for humans obviously, but also they pollinate crops to that are important for bird life or for animals… So we want to create the world's largest database on insect biodiversity". Founder & Chief Executive.
Company T	"We are set to encourage diversity of plants in the field, to give cover, to allow for pests predators like beetles for that to be able to exist in the field and to build soil health, particularly around microorganisms, fungi, and bacterial health, so that you have a really strong sort of biome, which also encourages healthy crops, it's makes perfect sense". CEO.
Company X	"we use wetlands and things like that rather than hard engineering" (when referring to the use of Nature Based Solutions). CEO & Founder.
Company Y	"we are interested in companies who need to integrate in their business reforestation, CO_2 offsetting, and so on". CEO & Founder.
Company Z	"consumers everywhere want climate-friendly products and services and businesses have started waking up to that… So, we are shifting the mentality from climate as cost centre to climate as a growth driver, and we're making it really easy with our software solution to do that". Co-founder & CEO.

From the testimonies it can be derived that the natural environment is a key stakeholder for these companies; this is sometimes very explicit (e.g. Company F and Company O), while in other occasions it may be implicit (e.g. Company Z). Thus, given the prominence achieved by the natural environment as stakeholder within the value proposition of DCS, an extended SVC Framework is proposed and shown in **Figure 6-17**, where the "Societal" category of stakeholders is replaced by "Social Stakeholders" (i.e. more related to communities) and the "Natural Environment" is added as a new explicit category.

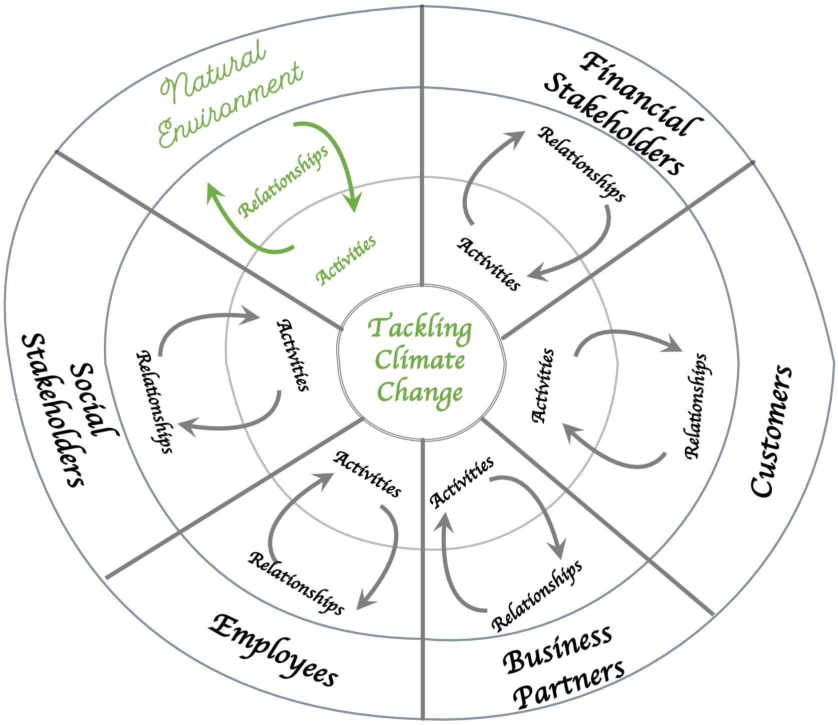


Figure 6-17: Extended version of the Stakeholder Value Creation Framework for Business Model Analysis (based on Freudenreich et al., 2020)

As it has been shown by the data, value creation is bidirectional also in regard to the environment as stakeholder. Here the environment is an essential part of the value network and, as it happens with the other five categories of stakeholders, is both a recipient and a co-creator of value, calling for expanding the SVC Framework. In this case the joint purpose can be defined as “tackling climate change”, although the rest of the value portfolio will vary according to each specific stakeholder. For example, for a client looking to offset carbon emissions, its specific value will be around complying with legislation, access to markets, answering customer’s expectations, etc, while for the employees of the focus company value can be related to have a purpose-driven job. In both cases the value for the environment can be linked to the increase of biodiversity protection and ecosystems.

Going back to Freudenreich’s *et al.* (2020) propositions, from the business model perspective value creation is about what is being created and how, while from the stakeholder’s perspective, value creation prioritises the “with and for whom” questions, as seen in **Figure 3-6**.

Taking this view to the modified framework perspective for DCS, and solely concentrating in the value for the environment, **Table 6-14** looks at two DCS that are in the carbon market business, one of them acting as enabler by developing a market place (Company C), while the other is directly involved on ecosystem restoration (Company Y).

Table 6-14: Value creation approach in two interviewed companies (what, how, with and for whom)

BM	Company C - Co-founder & CEO	Company Y - CEO & Founder
What is being created?	"The company developed a marketplace of high-quality nature based solutions (NBS)".	The company does reforestation projects and uses a technology that enables everybody to track and monitor every single tree. "We are interested in companies who need to integrate in their business reforestation, CO_2 offsetting, and so on, in a way to generate concrete effects in the everyday life of communities".
How is it being created?	Automating the pipeline of new projects, and visualisation tools for clients to see the outcomes (3D visualisations of their investments into nature). Role of tech: around verification, measurements, enabling people to access the projects, help people understand the impact that they're having with these projects.	"We have been able to build one of the most innovative tools to track the growth for every single tree, and to monitor where they are and how they are growing (traceability and transparency)". "Our 4 pillars are scientific, transparency, credibility, also generating social and environmental impact".
With whom is it being created?	With a team of eight different scientists working on the methodologies; with a big Storytelling Agency; with large project developers and local landowners; with carbon hardware sensors providers; with clients (need to align with their needs).	With a partner in Guatemala; with rural communities; a team in Italy; with two big clients; and with several universities around the world.
And for whom is it being crated?	"We're very motivated to tackle carbon and biodiversity. And so we're very focused on the climate and biodiversity crisis, rather than just climate". "NBS have the power to mitigate a third of greenhouse gas emissions between now and 2030 and they	"Our value proposition is to enable everybody to have a better life using the environment as an accelerator of the human condition". "We're not just reforesting. We are also generating social impact through the plantation in farming communities all around the world. We focus also on raising

BM	Company C - Co-founder & CEO	Company Y - CEO & Founder
	receive 3% of funding. We think a lot about how we can bridge that gap". "Looking at the global opportunity with regards to NBS. The carbon avoidance, carbon removal, but also just ecosystem restoration".	awareness about the climate crisis and sustainable development".

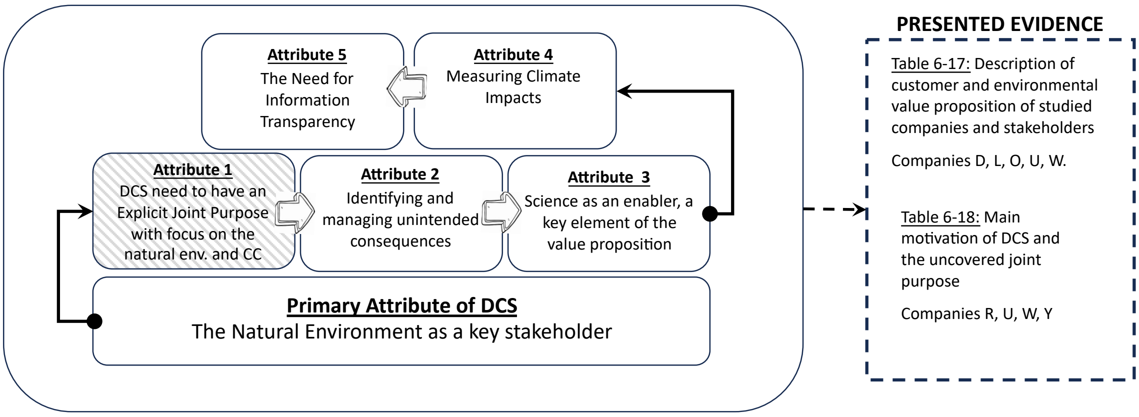
From this analysis it can be seen that the stakeholder network is relevant in the design of the value proposition of these two DCS, as proposed by Freudenreich *et al.* (2020). Similarly, the value portfolio generated is of relevance to various stakeholders ("stakeholders are both recipients and co-creators of value in a joint value creation process", Freudenreich *et al.*, 2020, p. 3). In fact, all the stakeholders that are part of the development of the value proposition (the "with whom" question) are also active recipients of the value being created. When it comes to the natural environment, from the information presented in **Table 6-14** is also clear that this stakeholder is central to their value proposition, i.e., the natural environment is a key stakeholder (the "for whom" is being created question). This is reinforced with the cross comparison of the 27 DCS that were interviewed, as shown in **Table 6-12**, where most of the interviewees identified the environment as a central stakeholder.

Thus, having made the case for the natural environment as a key stakeholder for DCS, and having proposed an extended version of the Stakeholder Value Creation Framework for Business Model Analysis, the second part of the answer to RQ2 is what (additional) attributes are necessary for DCS for them to increase/ensure the value of their value proposition. As already introduced at the beginning of this section, based on the analysis of the first order concepts and the grouping of these in second order themes (**Figure 6-15**), five additional attributes are proposed. The following section is a deep dive into each of them providing the necessary evidence to track the synthesis from data to the aggregate dimensions.

ii- Attributes Necessary to Increase Value Creation Potential

The second part of the answer to RQ2 sought to complement the extended framework (see **Figure 6-17** and Error! Reference source not found.) by proposing additional specific attributes that may contribute to improve the value proposition of DCS. In fact, the empirical analysis of the value proposition of DCS allowed the identification of these elements, based on the analysis of the themes and sub-themes obtained. Furthermore, the empirical data pointed towards elements that are considered relevant for the enhancement of the value creation potential of digital climate start-ups. These elements have been grouped into attributes and are presented below. Selected evidence is presented for illustrative purposes in the form of tables.

Attribute 1 – DCS need to have an Explicit Joint Purpose with focus on the natural environment and climate change.



Freudenreich *et al.* (2020) described as a central element of their framework the concept of "joint purpose" (together with a value portfolio generated for multiple stakeholders). If value creation is not mutually beneficial for all related parties (the stakeholders), a business risks to lose its business partners and resources as well as its legitimacy. This implies that value proposition needs to be created with the different stakeholders and for the different stakeholders (Elkington, 2004, Freudenreich *et al.*, 2016). In other words, the different stakeholders that are part of the BMfS value proposition are linked to a joint purpose regarding sustainable development (Bocken *et al.*, 2014, Freudenreich *et al.*, 2020). In the case of DCS this joint purpose is the fight against CC in some of its multiple forms (hence, a proposition is made in this research to refer to these BM as BM for Climate Change (BMfCC), as a subgroup of BMfS). For this reason, when characterising these firms, special attention should be given to understanding this component. ***Table 6-15*** presents some examples of (simplified) value propositions developed by the studied cases.

Table 6-15: Description of customer and environmental value proposition of studied companies and stakeholders

Firm	Company Description	Value Portfolio for Stakeholders
D	A B2B open climate risk platform ("climate intelligence"), able to combine and decipher complex scientific information to evaluate risks at asset level; "doing very complicated synthesis of data, data engineering and machine learning". The company uses AI and ML among others. Founder & CEO.	CVP: evaluate risks worldwide at asset level of any type of organisation. EVP: potential indirect environmental benefits through the protection of ecosystems developed as part of adaptation plans. Value for other stakeholders: provide transparency for investors and insurance sector, business partners, etc.
L	A B2B company that offers carbon offsetting through the protection of biodiversity. It is a solution that addresses climate change, the loss of biodiversity, and investing in local communities, "all into one package", by putting an economic value to ecosystem services. "The main thing about what we do is mixing digital technologies and nature technologies". The company uses technologies such as blockchain to ensure transparency, plus AI, and IoT. CEO & Founder	CVP: Offer of carbon credits (biodiversity credits) to corporations. EVP: Protection of keystone species and their ecosystems. Value for other stakeholders: improved living conditions of local communities.
O	A B2B firm that provides local sensors to monitor pollinators in the environment, aimed at farmers suffering with suboptimal pollination. The aim being to "get pollinators in the right place at the right time to increase yields". Founder & Chief Executive.	CVP: help clients to decrease losses associated with suboptimal pollination (large food retailers, farmers, and landowners) by improving the presence of pollinators. EVP: give recommendations that support native pollinators and native biodiversity.

Firm	Company Description	Value Portfolio for Stakeholders
		Value for other stakeholders: This may be relevant to real estate companies, infrastructure and utilities interested in biodiversity monitoring.
U	A B2B carbon accounting software. The company helps small businesses measure their carbon footprint in an automated way, for a “small monthly fee”. Use of mobile App and a whole set of back-end API’s (Application Programming Interface). Head of Marketing.	CVP: an easily accessible and affordable software to calculate carbon footprint of SMEs. EVP: it is expected that carbon emissions from companies will decrease, thus benefiting the natural environment. Value for other stakeholders: employees wanting to be part of the organisation, financial agents and business partners demanding CC plans and information.
W	A B2B firm that does carbon removal at scale (enhanced rock weathering), “and we do it with research that makes sure our technology is safe; we collect data and measure the carbon we remove. So CO_2 can be locked away permanently, quickly and at scale, removing one billion tonnes this decade alone”. CEO & Founder.	CVP: mining companies give their waste material, and “W” generates carbon credits for them. Typically, technology companies buy these credits. EVP: “keeping a liveable planet”; permanent removal of carbon. Value for other SH: farmers can replace some of their fertilizer needs and receive the material for free.

Where: EVP: environmental value proposition; CVP: customer value proposition; SH: stakeholders

As it can be seen, these firms have an environmental value proposition as part of their BM (although it may not always be explicit). In addition, as explained in the previous sections, in some cases they may have a direct contribution while in others they may act as enablers of impact. In any case, it is expected that companies should make explicit this value for the environment and have a method to quantify their potential contribution making it transparent to the public (see Attribute 4 – Measuring Climate Impacts).

An additionality of this research is that in the case of DCS, the natural environment should be considered a key and then explicit stakeholder (as presented in the extended version of the Stakeholder Value Creation Framework), therefore the value proposition should be built around a joint purpose related to the fight against climate change. A question was put forward to the 27 interviewees in terms of what their main motivation for the development of the business and their value proposition was, with the aim of discovering the existence of a joint purpose that went beyond the more obvious value generated for the customers and for the firm. **Table 6-16** presents some of the answers provided:

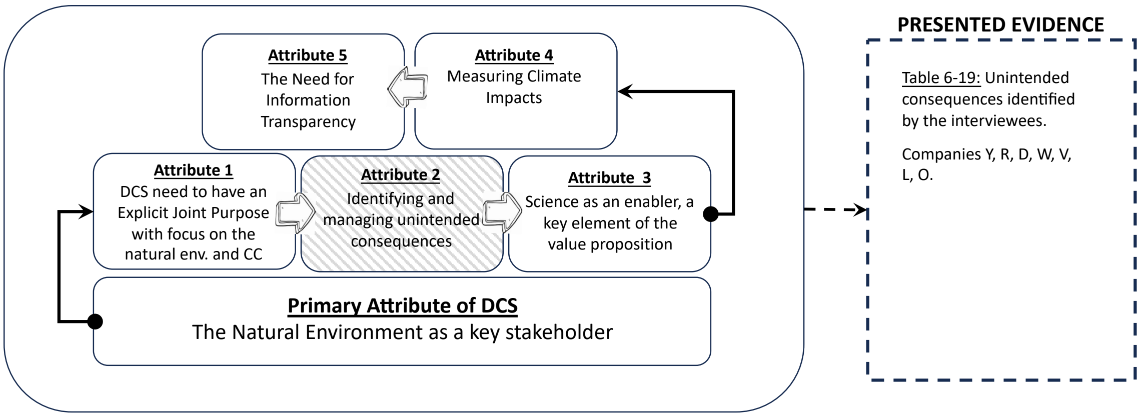
Table 6-16: Main motivation of DCS and the uncovered joint purpose

Interviewee	Main Motivation	Unveiling a Joint Purpose
Company R, COO and Cofounder A company that is specifically tackling food waste.	"The reason we exist is to solve a problem that's contributing to the climate crisis. Essentially, we are a marketplace that connects people in real time with other people nearby to facilitate the safe and easy and fast exchange of goods that would otherwise go to waste. But what differentiates us is that our mission, our environmental and social mission, is at the heart of everything we do, and we also operate sort of a 0-tolerance policy, with regard to the guidelines within which our community must operate. So we are in business to put an end to waste in the home and in the local community".	The joint purpose in this case is reducing food waste, which in turn will have positive benefits in the fight against CC and the protection of the environment. The stakeholders include the natural environment, and the whole value chain of waste providers and end users.
Company U, Head of Marketing A company that helps small businesses measure their carbon footprint in an automated way.	"So that's really what the value is, it's about opening people's eyes to the supply chain emissions, because, like I say, people know what they're doing themselves but they don't know so well what's happening within the supply chain of what they're doing…. People can see what's immediately in front of them, they can see their office emissions, they can see the fuel of vehicles which they drive, and the impact of that. What people really find hard to visualise and make tangible is the supply chain emissions, because essentially,	In this case the natural environment is a key stakeholder, this company is an Impact Enabler (which means they help other businesses to reduce their negative impact on the environment). The SH network includes the clients, business partners, and the environment.

Interviewee	Main Motivation	Unveiling a Joint Purpose
	you're outsourcing the problem with someone else…"	
Company W, CEO & Founder A company that works on enhanced rock weathering.	"So the inspiration to develop the technology was that we didn't have a solution for climate to remove CO_2. I was doing a lot of reading about what might be possible, and I felt that this was the best potential solution. So that was the inspiration".	The environment (the planet) is the key stakeholder for company W, as the developed technology aims to decrease CO_2 concentrations in the atmosphere (Impact Creator). Stakeholders that share this VP include clients, society as a whole, business partners, etc.
Company Y, CEO & Founder A company that works on preserving and restoring ecosystems and biodiversity.	"In terms of environment and in terms of the planet, our value proposition is to enable everybody to have a better life using the environment as an accelerator of the human condition. So we use reforestation in a way to generate, create concrete effects in the everyday life of communities".	The key stakeholder for "Y" is the environment, but there is also a joint value that covers a range of stakeholders (e.g., customers, community, employees, etc.). Community, for example, is a co-creator of env. value by being active in the protection and restoration of ecosystems. This company is an Impact Creator.

Although the above answers cover a broad spectrum of digital technologies and value propositions (each of these companies is targeting a different market need), it is clear they all focus on tackling CC (whether directly or indirectly), which becomes their joint purpose. In their answers it is also clear that their value proposition is of interest to several stakeholders, including the natural environment.

Attribute 2 - Identifying and managing unintended consequences



While digital climate solutions have the potential to accelerate sustainability through increased connectivity, knowledge sharing, and co-creation, they may also have a negative side. These could lead to unforeseen tensions and paradoxical effects that may risk the whole value proposition for the different stakeholders (Hellemans *et al.*, 2021). In the SVC Framework these are referred as potential conflicts and trade-offs.

Thus, potential unintended consequences are a general concern emerged when talking about the development of digital technologies, although this concern probably goes beyond climate solutions and relates to the use of digital technologies in all aspects of human lives, as it happened with the rising concern about the use of AI (Kalimeri and Tjostheim, 2020). According to Bohnsack *et al.* (2022), digital technologies for sustainable development can have positive first order consequences, as well as second order consequences (either positive or negative) which were not initially part of the indented outcome.

During the data gathering process, interviewees were asked about potential unintended consequences (both positive and negative) that could emerge from their value propositions. **Table 6-17** shows some examples of these potential consequences as mentioned in the interviews:

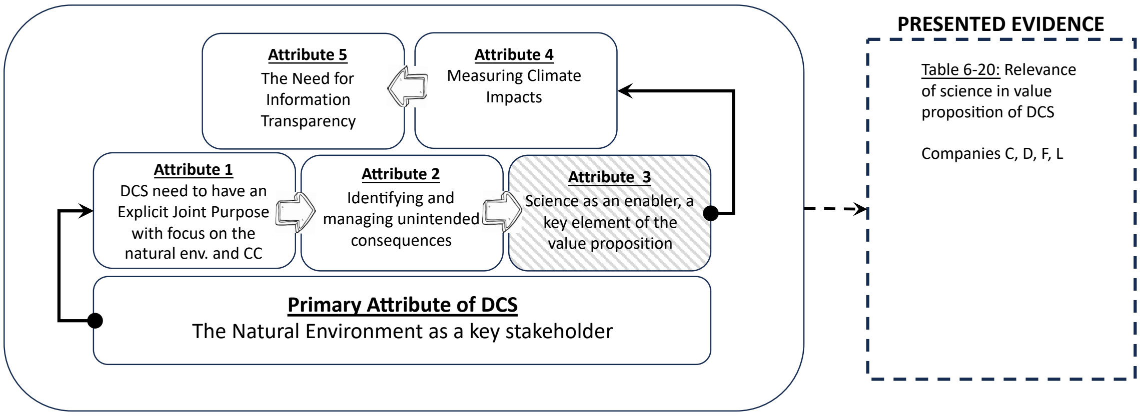
Table 6-17: Unintended consequences identified by the interviewees.

Potential Negative Consequences	Quotations by the interviewees:
Social	• "We are empowering the farming communities, and this country has a lot of narcotraffic issues, so they don't want the farming community to be empowered by us..." (CEO & Founder of Company Y, a company doing reforestation, when talking about restoration projects in Central America) • "It's really important that we don't have people who are living in food poverty. A lot of them are using our service and they're getting access to food they couldn't afford, and it's a really meaningful part of their food budget. But we need to be careful for people not to develop a dependency on our company, because there's no guarantee that there's going to be food there" (COO and Cofounder of Company R, a market place for food waste reduction). • "There just aren't enough climate scientists to sit in every single company, there's not enough climate scientists in the world to share even with the fortune 500, automation is fundamental". (CEO of Company D, a company specialised on climate risk management, talking about the need to have solid scientific support for their value offering, the lack of scientists, and the need for automation).
Environmental	• "There are potential risks from this technology that we do know about, changing the soil composition, changing the chemistry of rivers that are leaving the sites… And if there were bad actors or an incompetent actor who put heavy metals on soil, and that might happen so, it could be an unintended consequence of an incompetent actor, but what we try to do is set out the best" (CEO & Founder of Company W, working with enhanced rock weathering, a nature-based carbon removal technology, talking about potential impacts of spreading crushed basalt rock on farmland without due care). • "Actually, if you check all the companies that are actually trading in the voluntary carbon market using blockchain, you will realize that most of them start with technology that is actually very polluting, so in the case of our technology we researched a lot and we made the connection with the developers of a technology called EOS. That is one of the cleanest, let's call it that way. And actually, each transaction consumes less energy than an email" (CEO & Founder of Company V, a firm that uses blockchain technology as a key aspect of their value offering). • "So, this is a good point, because it is something which is very misunderstood, when I explain why we're using blockchain. So traditionally blockchain is seen as an energy power hungry machinery, that is here to create more climate change than reduce climate change, and this is why my expertise in having done three and a half years of blockchain work comes in" (CEO & Founder Company L, a start-up that uses blockchain technology as a key aspect of their value offering).
Misuse of Technology	• "People using the technology for green washing. This is the main drawback we have seen, to be honest. People buying one device to then put a press release out, to say they did all this great stuff, and we are trying to stop this" (Founder & Chief Executive of Company O, which deploys sensors that monitor pollinators in the environment).

Potential Negative Consequences	Quotations by the interviewees:
	• "Of course, all the related with the use of blockchain that someone can get hacked or an error in the code, you know or a bug that can be exploded by someone's, so by a criminal, but these are the consequences that can happen to all the projects related with technology" (CEO & Founder of Company V). • "So, we need camera traps that can normally identify elephants but it can also send the data in an encrypted manner, because we don't want that data to be hacked by poachers to then see where are the elephants. So, we are aware of some of the backlash that could happen from these different technologies, but we're doing our best to try to mitigate them" (CEO & Founder Company L). • "What you will find as well with a lot of digital transition companies, is that a lot of them are trying to create closed ecosystems". (VP Business Development & Strategy Company H, a software platform that provides end-to-end traceability and secure data exchange for industrial supply chains, talking about the need for better collaboration in the development of digital solutions to tackle climate change).

In order to tackle these and other potential concerns (as the examples listed in ***Table 6-17***), DCS should identify the potential unintended consequences resulting from the deployment of their value proposition, quantify them and, if applicable, propose a path for its minimisation. These unintended consequences can be social, environmental, or a mix. One example is the use of blockchain technology, indicated by many as a "power hungry" technology. There are, however, alternative ways to use low energy consumption blockchain options.   Following the proposition for an extended SVC Framework, these unintended consequences should be identified in conjunction with the stakeholder network.

Attribute 3 - Science as an enabler, a key element of the value proposition



A key attribute of sound DCS is the robustness of their value proposition, in terms of counting with "the right" climate science behind. This means having up to date scientific support for the, for instance, algorithms and models developed, for the data used for the calculation of carbon footprint, the right scientific support to calculate climate risks of assets or for deciding where to promote the planting of trees and the monitoring of their actual performance and impact over time, etc. The reason for this is that, with value propositions related to climate change, science plays a fundamental role in them being credible and, above all, meaningful (CC is a highly complex and multidisciplinary phenomena with high levels of uncertainty (Jones, 2000, Kunreuther *et al.*, 2014)). In the same line, start-ups need to also be up to date with new scientific data and new information becoming available, as this may demand for the adjustment and enhancement of their value proposition.

Table 6-18 presents some of the answers provided by the interviewees when ask about the role of science in the development of their value proposition.

Table 6-18: Relevance of science in value proposition of DCS

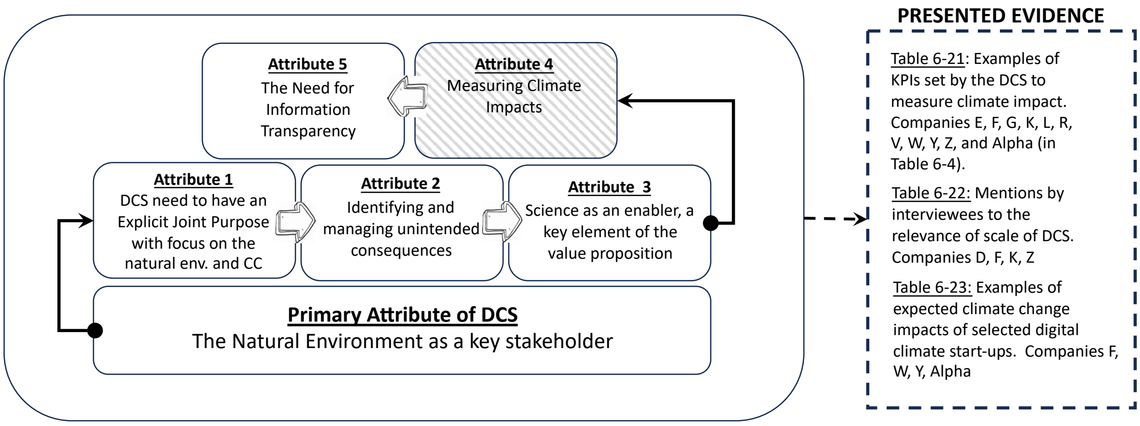
Firm	Interviewee	Relevance of Science in their Value Proposition
C	Co-founder & CEO	"We have a team of eight different scientists working on the methodologies and on the, you know, the structure of how we evaluate, and the end goal is to fully automate that process with the final approval from our scientific advisory board". "This scientific board of advisors and key people are coming from different backgrounds, academic, companies or government". "All academics, from professors to senior researchers,

		have complementary skills, we have an expert in social, an expert in blue carbon, an expert economist… complimentary mix of advisors”.
D	Founder & CEO	“So the independence of our science, of our rating systems is very important to multiple actors, so they can all converge around a common methodology, so no one's saying well this is my view, this is your view… let's negotiate. You can't negotiate science, this is a scientific rating. This is why for us it's important to have the best peer reviewed science feeding into those models all the time and also for us to have a radar on emerging climate models… on who are the best thinkers…”.
F	Director of Digital Climate Solutions	“because of our history and the kind and number of climate specialists that we have, well, our access to climate specialist is much bigger than any other software player in the market. If you look at well the biggest software players, they might have 2 or 3 climate specialists on staff to make sure that their product is sound. We have 150 climate consultants that are working at kind of the cutting edge of climate action, so we're seeing much more than others”.
L	CEO & Founder	“There are 3 pillars to everything we do. The first which we'll spend more time on is science, everything has to be proven by science as much as possible. The second one is technology, is to be able to use the technology to monitor the science… and the third one is ethics, is to make sure that whatever we do in terms of our solution, that it fits within our ethics framework… So everything we do has to be grounded in deep science”.

The stage in which organisations are incorporating science into their value offering cover all the phases: from the design of the product or service, including for example the design of tools, models, algorithms for the analysis and synthesis of complex information, to the implementation phase and monitoring of results. Science may also have input at the strategic level of the organisation, through for example the creation of a scientific board aimed at making managerial decisions aligned with the climate change objectives of the firm, or high-level climate advisory boards to provide recommendations to the firm’s value proposition and performance based on the latest scientific knowledge.

It is also relevant to differentiate in terms of the level of “complexity of the science” behind the various value propositions that were studied. In some cases this level of sophistication can become extremely complex, using digital technologies such as ML, AI, satellite images, mathematical modelling, while in other cases the science behind is less complex, and can be related for example to the management of large data bases.

Attribute 4 - Measuring Climate Impacts



A key aspect of the value propositions of these emerging DCS was expected to be around the definition of their Climate Hypothesis. For the purpose of this research, we have defined the Climate Hypothesis as the expected climate impact of DCS, based on their climate strategies and around the way they measure, monitor, and communicate the benefits to be achieved in the fight against climate change and the explicit goals, KPIs, and ambitions they set in the medium and long term. In the case of the studied companies, though, several of them were still in the process of defining these key aspects. **Table 6-19** below presents some elements mentioned by the interviewees in the sample.

Table 6-19: Examples of Climate Hypothesis and KPIs set by the DCS to measure their climate impact

Company	Climate Hypothesis	
	Climate Strategy/Goals	**Climate KPIs**
E	"So if people come in and use our App and just look at their carbon impact and don't do anything about it, then you know, we're missing out what we're trying to achieve. But if people come in and change their behaviours, or change their purchasing patterns, or you know, become vegan for a week, you know, all these kinds of things we can see that we are actually changing people's behaviours and spending patterns, and as a result reduce their net carbon impact. We will know how many tons of CO_2 our customers have offset". Tech Lead.	Changing people´s behaviour (purchasing decisions) and tons of CO_2 offset.

Company	Climate Hypothesis	
	Climate Strategy/Goals	**Climate KPIs**
F	“Our ambition is to mitigate and compensate a gigaton of CO_2 by 2027 … that's what we're tracking. So, we're tracking the amount of emissions that we are able to reduce with our customers, and the amount of tons of CO_2 that we are either avoiding or capturing through our climate projects and all our activities are supporting that goal”. Director of Digital Climate Solutions.	Carbon avoided, reduced, captured.
G	“Our target is to achieve within 5 years to have 3 million connected vehicles, and from that basis, you can easily calculate the CO_2 savings”. CEO & Manager.	Changing people´s behaviour (better driving); number of vehicles connected to the platform; CO_2 savings.
K	“We will also evaluate the percentage of consumers that actually donate for the offsetting. So, these are the two KPIs, usage of the service, I mean consulting of the functionality within our App, and the second KPI that we will introduce is that the number percentage of donors”. Head of Brand Communication.	Carbon offsetting
L	“How many species can we put on our platform as fast as possible? Right now, we are in the equivalent of 1990s for the biodiversity. So it's still very early days. … by 2030, and this is just, you know, finger in the air, can we remove one Gigaton of carbon, you know, from the atmosphere”. CEO & Founder.	Carbon removal
R	“Well by definition from listings, we can measure and track the carbon emissions that were avoided due to those listings being collected, and so they're not an objective. They're a by-product of listings, you can only have one North Star metric, and so for us it's listings”. COO and Cofounder.	Carbon avoided by avoiding food waste. Number of items listed in the platform.
V	“The performance will be measured in the amounts of ton of CO_2 surrender, compared to the amount of ton of CO_2 equivalent that we're tokenizing, I think that would be one of the main KPIs, and we expect this to be at least over 5%, probably 10%”. CEO & Founder.	Tons of CO_2 surrendered compared to CO_2 being tokenised.

Company	Climate Hypothesis	
	Climate Strategy/Goals	**Climate KPIs**
W	"So by 2,025 we want to remove a 1 million tons of CO_2 from the atmosphere, and in early 2030 we'd like to be removing 1 billion tons of CO2 from the atmosphere per year, a Gigaton, scale impact. So impact is our number one metric, which is not necessarily a measurable event, but the proxy for that is number of tons of carbon dioxide removed". CEO & Founder.	CO_2 removed through their technology.
Y	"In 2,025 we are going to reach more than 1 million trees planted in 3 years. So, for us is one of the first big milestones of our company, and from here, in 5 years, so let's say 2,027, I would like to be able to plant more than 5 million trees, which is something reachable in terms of numbers". CEO & Founder.	Number of planted trees
Z	"In the short-term success is measured by the number of successful customers that we onboard, how much they're using our products, how many tons of carbon we've removed from the atmosphere. In the long-term it goes back to the mission, about making every product climate positive". Co-Founder and CEO.	Carbon removal through offsetting

As expected, the immense majority of KPIs are around carbon capture, removal or avoidance. To further this analysis, Error! Reference source not found. shows a selection of four DCS of the studied portfolio with explicit climate goals for carbon capture and removal. These can be considered their Climate Hypothesis.

Table 6-20: Examples of climate hypothesis for carbon capture and removal

Company	Climate Hypothesis	
	Climate Strategy/Goals	**Climate KPIs**
F	Carbon offset projects. (a cumulative objective to be achieved by 2027)	1.000.000.000 metric tonnes of CO2e (or 1,0 Gt CO2e)
W	Enhanced rock weathering (annual objective to be achieved by 2030)	1.000.000.000 metric tonnes of CO2e (or 1,0 Gt CO2e)
Y	5.000.000 trees planted (*) (a cumulative objective to be achieved in the next 5 years)	300.000 metric tonnes of CO2e (or 0,0003 Gt CO2e)

Alpha	136.000.000 trees planted (*) (already planted in the last 10 years)	8.000.000 metric tonnes of CO2e (or 0,008 Gt CO2e)

NB: (*) These are calculations based on tree seedlings grown for 10 years. Data obtained from the Greenhouse Gas Equivalencies Calculator, US EPA. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results

This strong focus on carbon management (avoidance, capture, removal) has been called by some authors the "carbon tunnel vision" (Deivanayagam and Osborne, 20223, Naess, 2010, SEI, 2022), as there are many other aspects which are relevant in terms of sustainability (e.g. water issues, biodiversity, social justice, etc.). In fact, it is expected that most of these DCS will have a positive impact in other areas as well, for example thinking about the whole set of SDGs. Another option is by looking at the EGD strategy, which in its commitment to tackling climate and environmental-related challenges, has defined six environmental objectives (European Commission, 2019):

1. Climate change mitigation
2. Climate change adaption
3. Sustainable and protection of water and marine resources
4. Transition to a circular economy
5. Pollution prevention and control
6. Protection and restoration of biodiversity and ecosystems

A good example where various sustainability objectives are being highlighted is provided by Company Alpha (see **Table 6-4**). Although it was not possible to interview this company, in their website and various company reports they provide a great deal of details in terms of their BM and CC objectives, as being transparent is a key feature they want to emphasise. Thus, some of the climate and environmental benefits highlighted by the firm include:

- 136 million trees planted,
- 2.5 million tonnes of CO_2 removed from the atmosphere (for every 50 million trees),
- Increased food security,

- Protected water sources,
- Prevented erosion,
- Creation of wildlife habitats,
- Fight desertification.

As can be seen, the benefits of some of the DCS can extend beyond the carbon emissions/avoidance/capture/removal aspects (a priority aspect of the fight against the planetary crisis), and include a diverse set of sustainability indicators. Based on the SDGs, for example, in the case of Company Alpha other relevant indicators are related to SDG 6 (clean water), SGD10 (reduce inequalities), SDG 15 (life on land). In terms of the EGD strategy, this company is contributing to sustainability objectives 1 (Climate change mitigation), 3 (Sustainable and protection of water and marine resources, and 6 (Protection and restoration of biodiversity and ecosystems).

DCS need to have clear and measurable indicators of impact, particularly those in the area of mitigation, as these companies are dealing with the cause of the problem (carbon emissions, carbon capture, carbon avoidance, carbon removal, and carbon storage), while companies working on the adaptation side are more concerned with helping human populations to deal with the consequences of CC. Whether the start-ups working on mitigation of CC are aiming to have a direct impact in the fight against climate change (through for example carbon avoidance or carbon removal) or aiming to act as enablers (through awareness raising or promoting carbon offset projects), in both cases they should have a Climate Hypothesis, i.e., how are they going to contribute to this objective, when, and by how much. As start-ups are at early stages of their business development, potential climate performance can be used instead of achieved climate performance (Leendertse, 2021). This is relevant as it allows potential customers to compare among various similar value offerings, make informed decisions, and make the firms accountable to their promises. As expressed by Upward and Jones (2016) and Freudenreich *et al.* (2016), these impacts can be a net reduction of negative effects (e.g. reduction of carbon emissions) or, ideally, a net positive contribution to the natural environment and society (e.g. reforestation of degraded natural areas of high biodiversity value).

Another relevant element when discussing impact is the scale these DCS can act on. Probably most digital technology-based companies want to grow and “conquer” the world and provide solutions at scale. However, for digital climate start-ups this is even more relevant (given the scale of the global challenge they want to tackle), this is a pre-condition that cannot be avoided, mainly due to the fact that most of these firms declare that their main objective is to contribute to the fight against CC, being their technology and value proposition not an end in itself but a means to achieve this greater goal (i.e. they have a dual objective, being commercially successful while contributing to a societal larger aim).

In fact, many of the interviewed companies identified the aspect of scale as a key factor for the success of their value proposition and for the achievement of their vision. Even some companies initially born as traditional consultancy climate firms, are now trying to migrate to a more digital (and automated) value proposition, as they realised the need for scale.

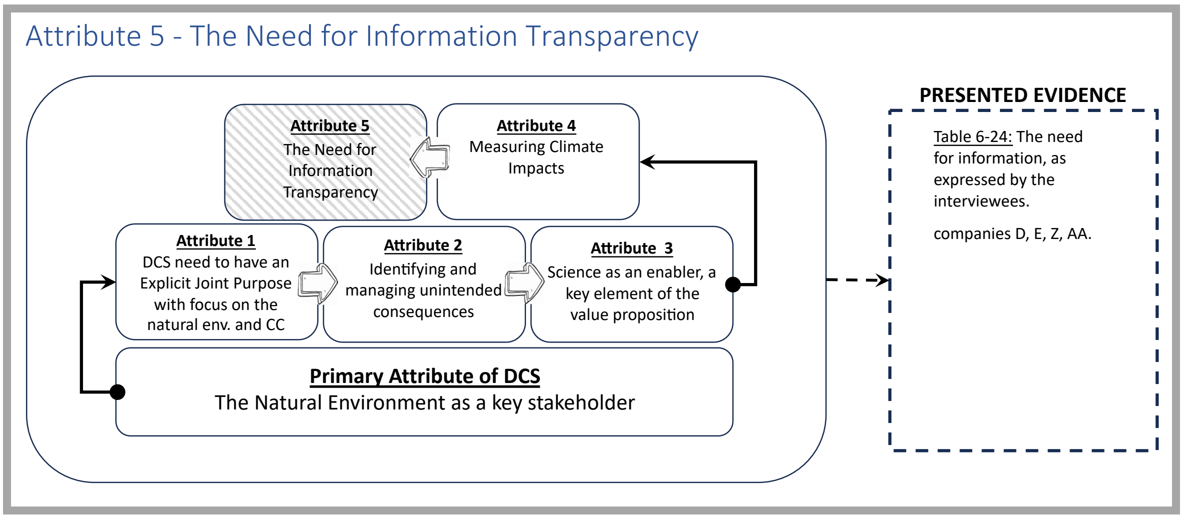
This is explained for example by Company C, a former more traditional consultancy firm specialised on climate offsetting services, that has recently started to migrate to a data-driven value proposition. When asked its CEO if their business model today is a mix of consultancy and digital technology through their newly developed platform, he answered:

“…but we are trying to automate the product as much as possible and move away from consultancy…just to enable us to scale. We have a 10 year´s target to take a gigaton of carbon with nature-based solutions, so to achieve that we're going to need to do things in the most efficient way possible, and consultancy is not really an option to hit those levels of impacts”.

Table 6-21 shows other mentions to the relevance of scale as explained by the interviewees of companies D, F, K and Z.

Table 6-21: Mentions by interviewees to the relevance of scale of DCS

Company	Answer regarding the importance of scale
Company D, Founder & CEO	"And by the way, there're not enough climate scientists in the world to share, even with the fortune 500, so automation is fundamental. There just aren't enough climate scientists to sit in every single company".
Company F, Director Digital Climate Solutions	"Why are we developing a new business model based on digital technologies? Because of the scale. I mean you can only reach so many customers with an advisory consultant-based solution. And to have any chance of staying within planetary boundaries, we need to reach many more companies to take action".
Company K, Head of Brand Communication	"We are a financial organisation with more that 100 million cards issued. This means that every month we can issue not only the card statement, but also the general amount of carbon footprint that the customer has produced …. So hoping they can move to merchant categories that impact less and certainly that they can also take action which is offsetting their carbon footprint… And this is a way for us to move a step forward and say we don't just do what we can as a company, but we try actually to influence as much as possible".
Company Z, Co-founder & CEO	"I always felt like, you know, for climate impact to really scale to the extent that we need it to scale, it needs to be fully automated". "So you know some of these more novel technologies of seaweed sequestration, or technological direct air capture or biochar, or enhanced weathering, and so on, and so forth. These are very novel methodologies to capture and sequester carbon and we act as way to help them scale, because we partner with them and give them access to financing through our customers".



There are at least three aspects related to information transparency that have been identified in order to build a reliable ecosystem of DCS: one related to the carbon footprint calculation of individuals and products, a second aspect related to the expected positive impact of DCS, and the third referring to the climate offsetting measures being proposed.

A well-known quote by Peter Drucker said "if you can't measure it, you can't manage it" (Drucker, 2015). This is also true when dealing with climate impacts, both at individual level (i.e. citizens) and organisational and corporate level. The complexity of the issue of CC, its multidisciplinary nature and the highly technical and sophisticated language used by the CC community, very often makes the message particularly complex. Due to this, knowing the carbon footprint of individuals and organisations and understanding the impacts and consequences of this carbon footprint may be a first step if they are to move to a low carbon economy.

Thus, having access to transparent and reliable information should be an essential aspect of the new low carbon economy. This is probably the reason why a significant number of DCS are focussing on the niche of carbon management, understanding this as providing information about the carbon footprint of products and services, as well as, very often, providing options for offsetting this footprint.

The provision of reliable and transparent information (and with the right level of granularity) is a complex endeavour due to the nature of the problem. For example, in the area of carbon management, the carbon calculations provided are general estimations based on pre-established categories, so they may lack accuracy (over or under estimations). For instance, if we bought a pair of jeans with the debit card from company E (or any other company for this matter), the monthly statement will probably refer to a standardised database to indicate the carbon footprint of the purchased item, without paying attention to the specificities of the brand of jeans (traditionally jeans use a significant amount of water in their manufacturing process; today, however, some brands are producing jeans with near zero water consumption). As expressed by the CEO and Founder of Company AA:

"there must be the right level of granularity in the data, and this should be constantly improved". And then he added "I guess by the very nature of what we are doing we are adding a level of granularity to our clients, that occasionally they don't know what to do with, to be honest".

A second dimension related to data transparency refers to the disclosure of the data and assumptions that were used by the firms to quantify their expected climate impacts (their climate claims). As already explained, companies need to have a Climate Hypothesis in order to show and communicate a meaningful commitment to the fight against climate change to their customers (see Attribute 4: Measuring climate impacts), and this hypothesis needs to be well explained and transparent.

One final element in relation to transparency has to do with the measures and actions being proposed by DCS to avoid or mitigate CC impacts of their clients. For example, when dealing with offsetting measures, for these measures to be effective, the options provided need to be properly quantified and must be in accordance with the climate change impacts being targeted.

Table 6-22 presents some of the comments provided by the interviewees in relation to this attribute.

Table 6-22: The need for information, es expressed by the interviewees.

Company	Quotes from Interviewees
Company D Founder & CEO	"I think, what is key for us is also helping the ecosystem become more climate aware. So part of our role actually is building up a knowledge base on the platform to start, not in a patronizing way, but in a way to start educating our end users because a lot of them just don't know where to start.
Company E Tech Lead	"one of the challenges for people to manage and reduce their carbon impact is the lack of information regarding what makes their carbon impacts; the information that they require to reduce it and the easy access and ability to offset it, and that is what we are trying to do with our market offering, is to solve those three problems to deal with track, reduce, and offset, by allowing people to see the carbon impact that their spending has".
Company Z Co-founder & CEO	"What market need we tackle is that, on the one hand, consumers everywhere want climate-friendly products and services and businesses have started waking up to that… and what we do is to make it really easy for them to integrate climate impact into their customer experience, starting with carbon emissions calculations and carbon offsetting, carbon removal".

In conclusion, this section "Result 2 - Improving the value creation potential for the natural environment" has addressed RQ2: How can digital climate start-ups improve their value offering for the natural environment as a key stakeholder?

For this, a primary attribute and five secondary attributes have been proposed, providing evidence to justify their selection. Other elements/attributes could have been added, such as technology aspects, long-term vision of the company, motivation behind the value proposition, however not enough evidence supporting them was found. Furthermore, in the case of the technology aspects, given that the value proposition of DCS is built around one or a combination of digital technologies (aspect covered in 6.1 Stage One – The Landscape of DCS, see **Table 6-1**), in this research this was considered to be a given for these firms, so was not considered as an attribute for them to work on (this is in line with the proposed Taxonomy Framework, which concentrates on CC objectives and strategies of DCS, instead of the type of technologies they are using). However, given that the digital technology aspect is a *sine qua non* condition of DCS, **Figure 6-18** shows a modified version of the conceptual map of attributes of DCS, where the digital technology component is shown as a primary attribute, at the same level of "the natural environment as stakeholder".

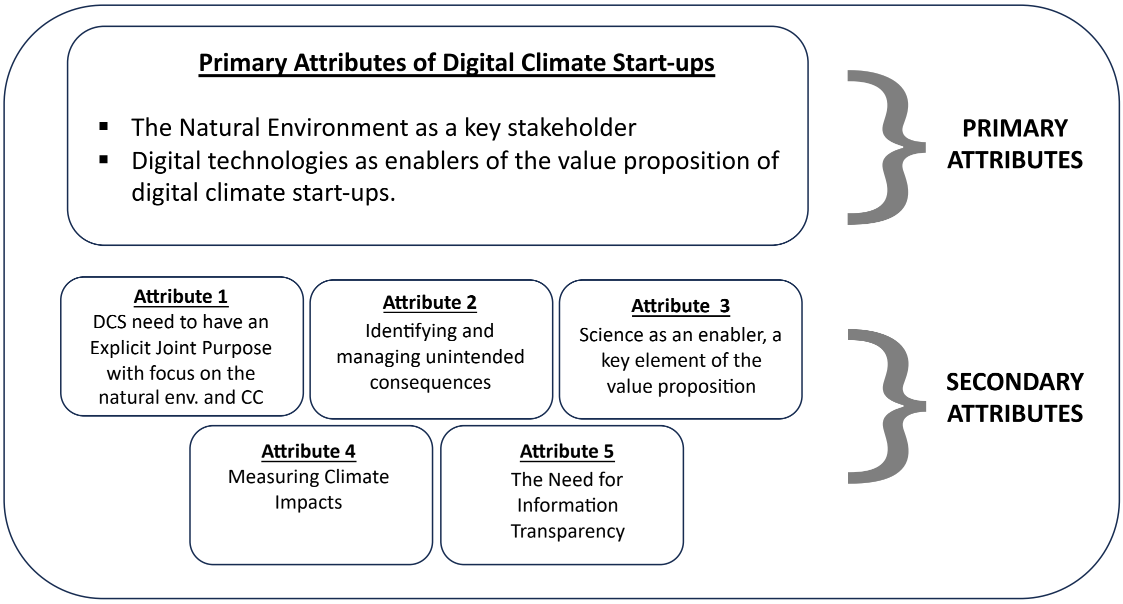


Figure 6-18: Modified conceptual map of the attributes of DCS

iii- Development of a value mapping tool

A third outcome of this research related to RQ2 was around the development of a practical tool that could contribute to one of the objectives of this investigation: improving the value proposition of DCS. In fact, one of the areas for future research identified by the Freudenreich *et al.* (2020, p.15) study was: *"How can the stakeholder value creation framework be used as a design tool in sustainability-oriented business modelling to create more stakeholder-sensitive and inclusive business model designs*?"

Thus, based on the attributes derived in the previous section (including the digital technology dimension), in this section a tool is proposed to assist DCS in identifying opportunities to improve and innovate in their value creation potential (a complement to the VCS Framework). As shown in **Figure 6-19**, the several elements and attributes previously explained are displayed in a BM canvas style tool. These elements can be considered a key part of the climate credentials of these companies and entrepreneurs should pay special attention to them when developing their value proposition. The other elements of a BM, like value capture, value creation and value delivery are not included, as this tool focusses exclusively on the value proposition dimension and on how to increase the value creation potential for the natural environment.

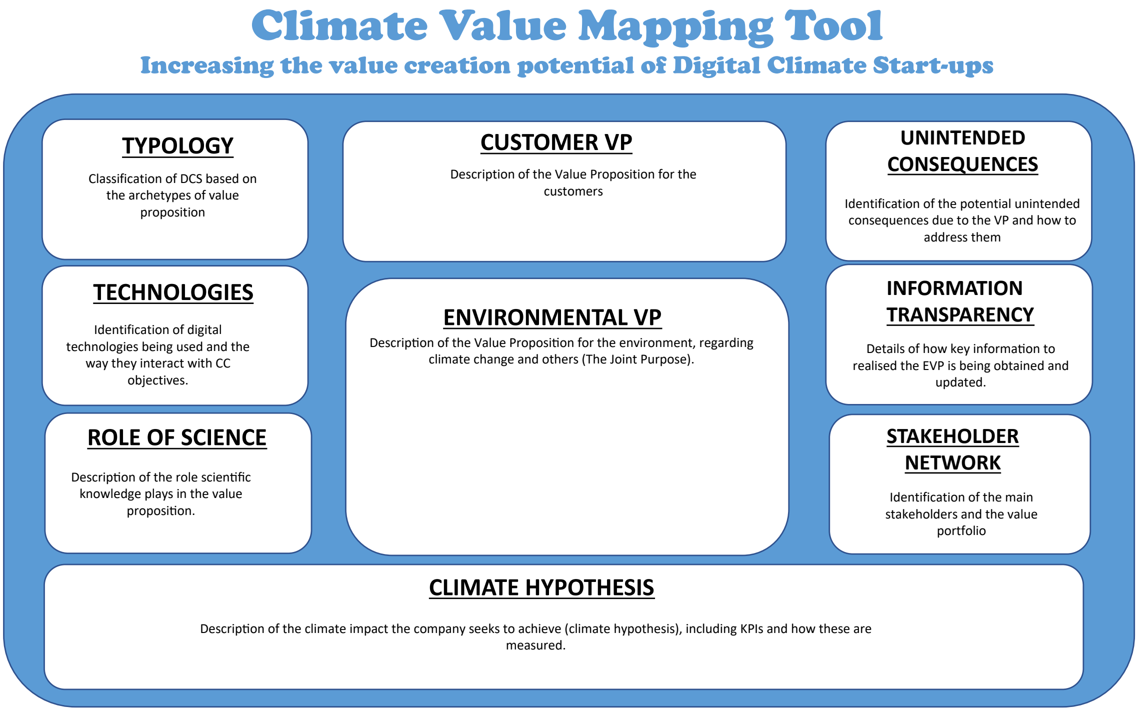


Figure 6-19: Value mapping tool based on the main attributes of digital climate start-ups

By considering aspects such as the environmental value proposition, the climate hypothesis, the stakeholder network, and unintended consequences, this tool recognises a system perspective of the BM, as BMfS need to consider both, the firm-level perspective as well as the broader system (Stubbs and Cocklin, 2008). These elements differentiate a climate start-up (regardless of its condition of digital firm) from any other more “traditional” start-up, as tackling CC is at the heart of their value proposition.

This is a simple tool for companies to look into these key nine aspects and identify potential areas for improvement. It can also contribute to improve their message to the wider stakeholders by identifying areas where communication may be lacking. Below two examples are provided, one coming from Company Z and a second application to the Company Alpha (a company that was analysed on Stage 1 of this research, but that was not interviewed, showing that this Value Mapping Tool can still be applied based on publicly available information).

Thus, **Figure 6-20** shows the answers provided by Company Z under each of the nine categories included in the Value Mapping Tool. In this particular case, there is for example room for improvement in terms of better defining the scientific support given to calculations of the carbon footprint of products; in identifying potential unintended consequences of the value proposition (for example due to under or over estimating the carbon footprint values); and addressing the aspect of information transparency. In addition, the climate hypothesis can be enhanced by setting concrete climate targets.

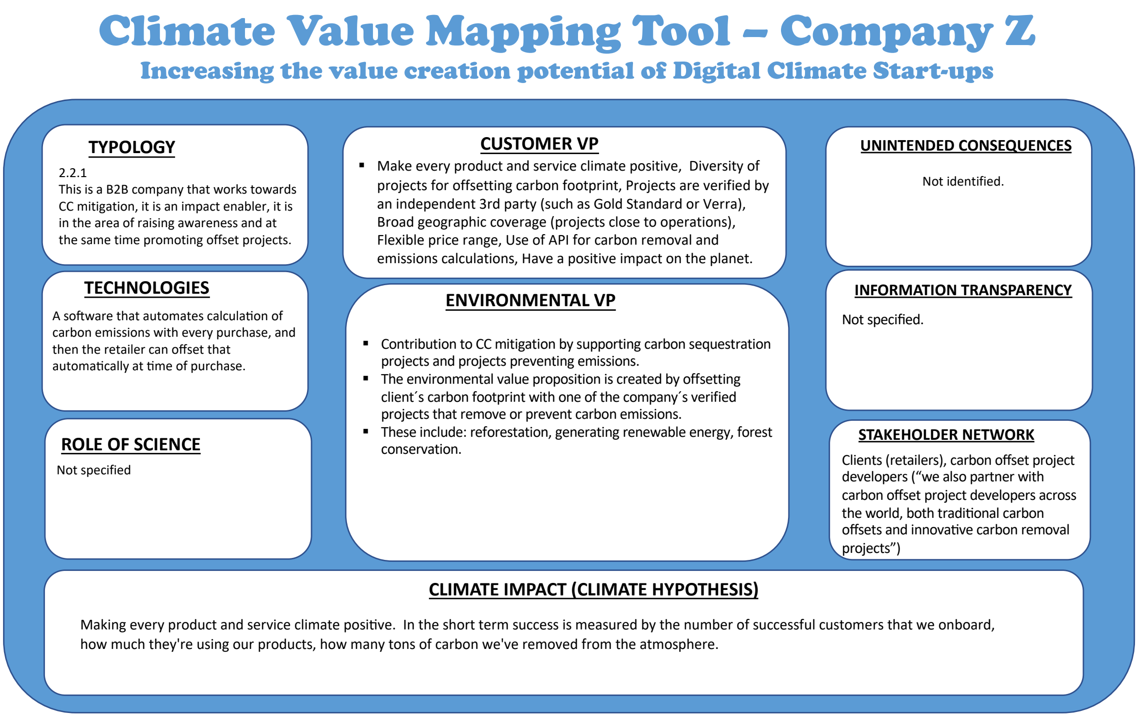


Figure 6-20: Example of climate value mapping tool applied to Company Z.

Figure 6-21 shows an example of this tool applied to Company Alpha. In this case, for example, potential unintended consequences have not been identified, partly explained by the fact that this company comes from the desk-based phase (i.e. it was not one of the interviewed firms). Even though, given the level of transparency advocated by the organisation, it is possible to access to most of the information needed.

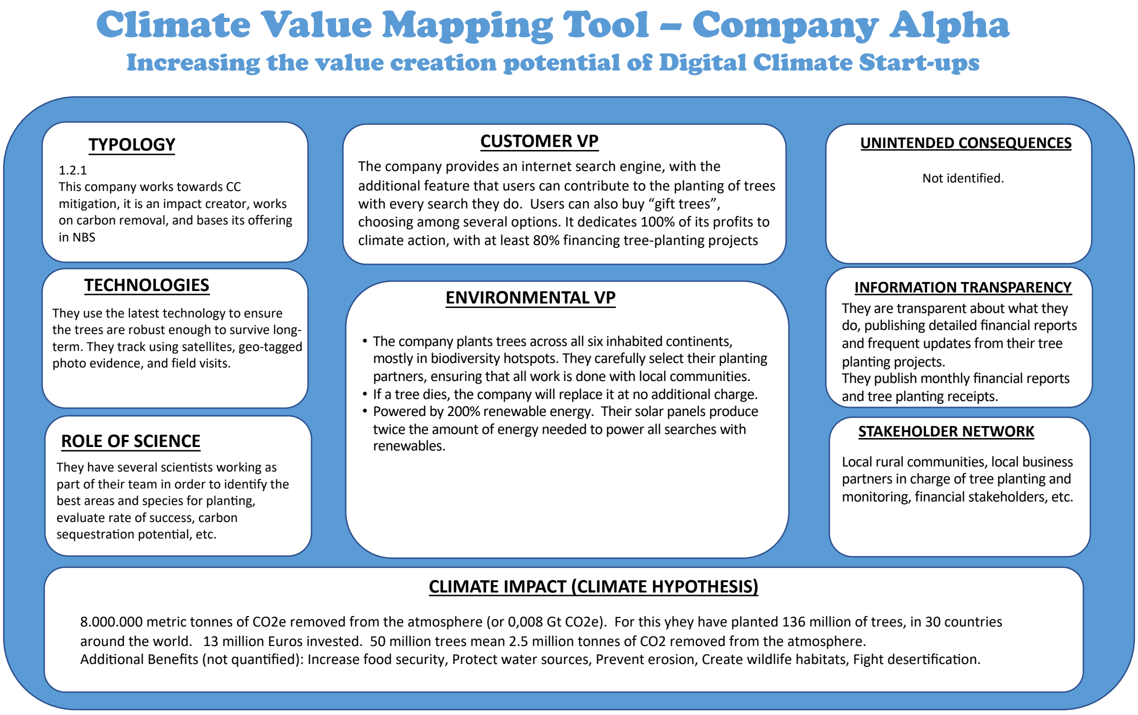


Figure 6-21: Example of climate value mapping tool applied to Company Alpha.

This tool can also be presented in the form of questions, as presented in **Table 6-23**.

Table 6-23: Value Mapping Tool – Related Questions

Topic	Related Questions
Environmental Value Proposition	What is the value for the environment the company is trying to achieve with its products and services? How is the business contributing to the fight against climate change? Can you describe the joint value for the broader group of stakeholders?
Customer Value Proposition	What is the value for the customers?
Stakeholder Network	Can you describe which are the main stakeholders related to the company's value proposition? Can you identify the value for each of them? (i.e. value portfolio).
Climate Hypothesis	Have you developed a hypothesis of how your product/service is going to impact in the fight against climate change? Are the suppositions clearly stated? Have you made this explicit to all stakeholders?
Unintended Consequences	Can you identify some potential unintended (negative) consequences due to the use of the company's service/product/technologies? If so, can you identify specific actions/measures than can be taken to reduce them?
Information Transparency	Have you provided enough details about the sources used for the climate related calculations? (e.g. carbon footprint, carbon removal, species of tree planted, etc).
Role of Science	Can you describe how is the company incorporating scientific knowledge in all the stages of the development of its value proposition? What do you do to keep this knowledge up to date?

Topic	Related Questions
Digital Technologies	Can you describe the different digital technologies the company is using as part of its value proposition? What is the specific role of each of them?
Typology	Can you classify the value offering according to one of the categories of the Taxonomy Framework?

In summary, it is believed that this Climate Value Mapping Tool can provide a valuable guidance for DCS wanting to increase their value offering, particularly from the natural environment perspective, which was the focus of this research.

6.5 Chapter Conclusions

In this Chapter the main results of this investigation were presented. Starting with RQ1, a proposal for an Empirical Taxonomy Framework was introduced, as a first layer for unpacking the value proposition of DCS. A second layer focussed on unveiling the environmental value proposition and its positive feedback loop with the customer value proposition.

The second part of this Chapter focussed on RQ2, centred around the need to consider the natural environment as a key stakeholder of the focal firm. Complementary, five additional attributes were identified as necessary to increase the value creation potential of DCS. Ultimately, a practical instrument was presented, assisting DCS in charting their value proposition and pinpointing potential areas for enhancement.

Thus, some key learning points derived from this research include:

- The overlapping between digitalisation and sustainability has become a relevant area for management research, particularly in the face of the climate change challenge, where great potential exists for scholars, practitioners and policy makers;

- More than focussing on the type of digital technologies being included as part of the value proposition of DCS, in order to improve their value offering, it seems more adequate to focus on the objectives and strategies of these firms, as digital technologies are evolving extremely fast and DCS usually use a combination of them, and,

- Finally, the use of the BMfS approach and the Stakeholder Theory provided a solid theoretical ground for the analysis of DCS.

These aspects are further developed and analysed in the next chapter: Chapter 7 – Discussion.

Chapter 7: Discussion

7- Discussion

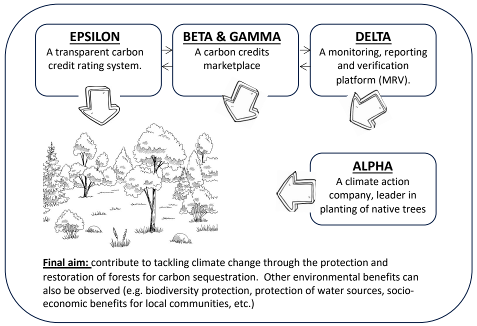
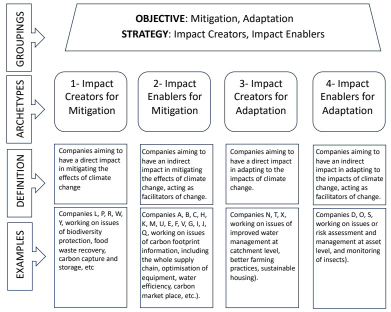
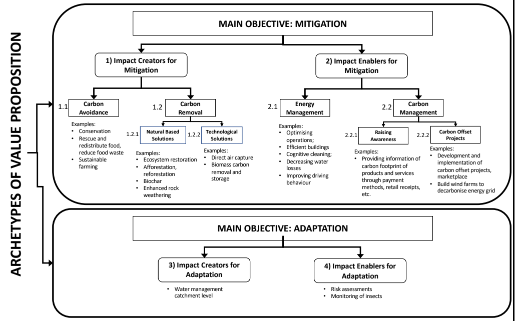
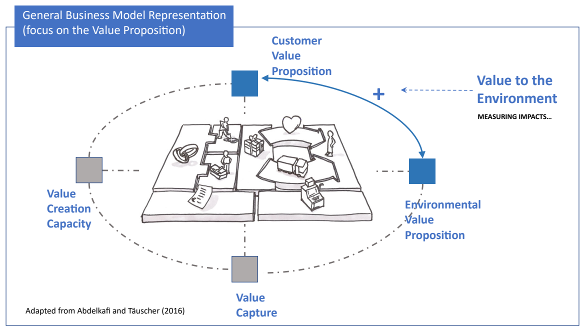
As introduced in Chapter 1, there is an important gap of knowledge and research opportunity in terms of analysing the intersection between new business models aimed at tackling climate change and digital technologies (**Figure 1-1**).

Under this context, the aim of this investigation was to contribute to the research of business models for sustainability (here referred as business models for climate change), with focus on the value proposition of DCS and the natural environment as a key stakeholder. Specifically, this research investigated start-ups from Industry 4.0 tackling climate change with focus on the value proposition for the natural environment. With this objective, two main research questions (RQ) were defined:

- RQ1 - How do we unpack the value proposition of digital start-ups tackling climate change?
- RQ2 - How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?

In order to facilitate the reader to follow the threads of the thesis by "connecting the dots", **Table 7-1** provides a mapping from research questions to contributions, including intermediate results.

Table 7-1: Mapping from the research questions to contributions

RQ and Objectives	Intermediate Results	End Results / Research Contributions
RQ1: How do we unpack the value proposition of digital start-ups tackling climate change? **Objective:** To understand what is behind the value offering of DCS, i.e. what do they want to achieve and how. Additionally, this RQ seeks to contribute to the understanding of the value proposition of DCS for the natural environment and its relationship with the value proposition for clients.	Description of the landscape of DCS, including: ▪ What DT are used and for what objectives, ▪ Market needs been tackled, ▪ Examples of value proposition (based on 5 companies from the desk-based analysis), and ▪ A cross comparison of firms based on CC objectives and strategy (based on the 27 companies that were interviewed). For details, see Tables 6-1, 6-2, 6-3, 6-4, 6-5, 6-6, 6-11 & Figure 6-1. Highlighted images: Figure 6-1. 	Three main results were obtained to address this RQ: ▪ An Empirical Taxonomy Framework based on 4 categories, ▪ A complementary Taxonomy Framework, and ▪ A Model for the description of Value Proposition. For details, see Figures 6-7, 6-8, 6-9, 6-10, 6-11, 6-12, 6-13, 6-14 and Table 6-8. Highlighted images: Figures 6-7, 6-8, 6-9. 

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<tr><th>RQ and Objectives</th><th>Intermediate Results</th><th>End Results / Research Contributions</th></tr>
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RQ2: How can digital climate start-ups improve their value proposition for the natural environment as a key stakeholder?

Objective: To understand the value offering for the natural environment and identifying options for improvement.

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Intermediate results included a cross comparison of firms based on the attributes, applied analysis of the value creation approach and a conceptual map for DCS attributes.

For details, see Figures 6-16, 6-17, and Table 6-10.

Highlighted images: Figures 6-10, 6-11.

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<tr><th></th><th colspan="25">Companies</th></tr>
<tr><th>Aspects for Cross-comparison - Attributes for Value Creation</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>I</th><th>J</th><th>K</th><th>L</th><th>M</th><th>N</th><th>O</th><th>P</th><th>Q</th><th>R</th><th>S</th><th>T</th><th>U</th><th>V</th><th>W</th><th>X</th><th>Y</th></tr>
<tr><td>Having the Environment as a key Stakeholder</td><td>■</td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td></td><td>■</td><td></td><td>■</td><td>■</td><td></td><td>■</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>Having an explicit joint purpose</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>The need for information transparency</td><td>■</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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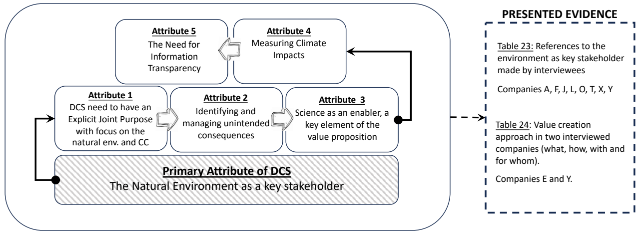
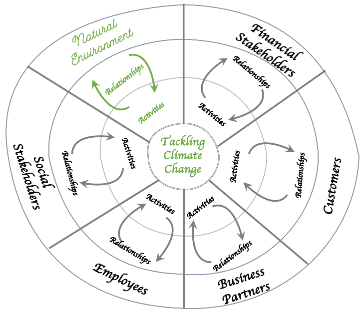
Three main results were obtained to address this RQ:

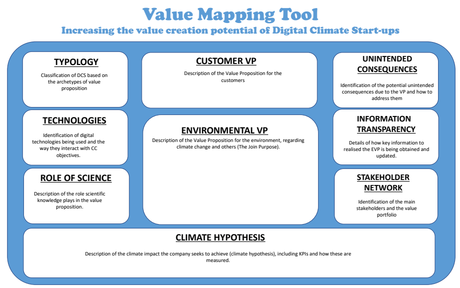
- An extended SVC Framework, including the natural environment as a key stakeholder of DCS,
- Proposal of five attributes to improve DCS value proposition.
- Additionally, a value mapping tool was proposed.

For details, see Figures 6-18, 6-19, 6-20, 6-21, 6-22, 6-23 and Tables 6-11, 6-12, 6-13, 6-14, 6-15, 6-16, 6-17, 6-18, 6-19, 6-20, 6-21, 6-22, 6-23, 6-24.

Highlighted images: Figures 6-18, 6-20, 6-21.







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The relevance of researching this topic can be found in the overlap between digitalisation and sustainability, areas of great relevance in today´s world and with scarce research at their intersection (Feroz *et al.* 2021, Kraus *et al.* 2018, Lenz 2021, Stuermer *et al*. 2017). Furthermore, the aspect of climate change within this overlapping (one of the 17 dimensions of sustainability according to the SDGs and probably the greatest challenge humanity has ever faced) is even less understood, as presented by Vilchez (2023).

The approach taken to answer these questions was the BMfS concept, specifically looking at the value proposition of DCS. BMfS incorporate sustainability as an integral part of the company's value proposition and value creation logic, thus aiming to generate value to both the customers and to the natural environment (Abdelkafi and Täuscher, 2016), in other words, the product and services developed by these DCS seek to create value in absolute terms, and not only in relation to the firm and customers' gains, i.e. the system perspective described by Stubbs and Cocklin (2008).

Thus, as presented by Schaltegger *et al.* (2012, p.97), and Abdelkafi and Täuscher (2016), a key challenge for companies with BMfS is to design a business that creates "economic success through (and not just along with) a certain environmental or social activity". In the case of DCS, this economic success needs to come mainly from the objective of fighting CC.

In order to address the questions, an inductive and qualitative method based on multiple case studies was chosen as the primary source of data. The research examined 27 firms with value offering towards fighting climate change. This Chapter discusses the main results obtained, starting with general findings, then discussing the main contributions to theory and practice, ending with suggestions for future research.

7.1. General Findings

General findings of this research can be summarised in three elements including new propositions emerged (**Table 7-2**):

Table 7-2: General findings of the research and resulting propositions.

Main Findings	New propositions of this Research	Chapter
The importance of the overlapping between digitalisation and sustainability as a relevant area for management research,	▪ A description of the landscape of digital climate technologies, including technologies being used, market needs been addressed, and value propositions being developed. ▪ The case has been made to argue that DCS present specific characteristics and challenges, which differentiate them from other "traditional" start-ups, and thus making the case for more oriented management research.	6.1.1 6.1.2 6.1.3 2.1, 2.2, 2.3, 2.4
The need to focus on the objectives and strategies of these firms instead of on the technologies they use, and	▪ An empirical taxonomy framework of DCS based on CC objectives and strategies followed by the firms. ▪ Application of a modified version of the business model for sustainability diagram proposed by Abdelkafi and Täuscher (2016).	6.4.1, i 6.4.1, ii
The use of BMfS approach and the Stakeholder Theory as theoretical foundation for analysis.	▪ An extended version of the Stakeholder Value Creation Framework for Business Model Analysis (based on Freudenreich *et al.*, 2020), an empirical extension of a theoretically developed framework. ▪ Identification of primary and secondary attributes essential for DCS (two primary attributes and five secondary attributes). ▪ Development of a practical tool ("climate value mapping tool") aimed at improving the value proposition of DCS.	6.4.2, i 6.4.2, ii 6.4.2, iii

First, the overlapping between digitalisation (Industry 4.0), and sustainability (specifically the challenge of climate change) provides a fertile ground for management and business academic research. In fact, as it has been shown throughout this research, the contribution of digital technologies to the fight against climate change can be significant and is already playing an important role in terms of the value offering developed by hundreds of digital climate start-ups around the globe. In a recent applied research project where this PhD student was part of during 2022, a portfolio of 45 start-ups was assessed for their potential climate impact (both digital and non-digital). It was found that nine of these companies, corresponding to digital climate start-ups, represented almost 70% of the forecasted climate impact of the entire portfolio (Roehrer *et al.*, 2023).

Furthermore, it is expected that trillions of dollars will be invested in new technologies that tackle climate change in the coming years, including Industry 4.0 solutions. However, academic research is only starting, with scarce articles having been published, hence, addressing this current research gap needs urgent attention. This is also in-line with the vision of Responsible Research in Business and Management[11], which states that “business and management schools worldwide are widely admired for their contributions to societal well-being, and their scholarship has been central to solving society’s challenges, is timely, cutting edge, and producing well-grounded knowledge on pressing problems”.

Second, given the variety and the dynamic characteristics of digital technologies (permanently evolving), together with the fact that DCS use a combination of them in their value offering, for the study of DCS it seems to be more adequate to primarily concentrate on their objectives and strategies regarding tackling climate change, instead of the type of digital technologies they use. This was in fact one of the decisions that had to be made at the outset of this investigation, when narrowing down its scope, in terms of whether to focus on a given technology (e.g. blockchain), or instead focus on their value proposition as a whole, agnostic to technology solutions. Thus, the climate objectives of mitigation and adaptation resulted the overarching distinctive elements, as most companies will target one or the other. On a second level, several possible strategies to achieve the companies’ goals were identified, including: impact creators, impact enablers, carbon avoidance, carbon removal, energy management, carbon

[11] Responsible Research for Business and Management (RRBM) is a virtual organization initially developed by a group of 24 leading scholars in 5 disciplines at 23 university-based business schools in 10 countries and now joined by a much larger community. Mode details at: https://www.rrbm.network/

management, awareness raising, offset projects, among others. This classification gave space to the development of a taxonomy framework of DCS. This framework is relevant not only to classify these firms and help to decode their value proposition, but also for the process of finding opportunities for improvement.

In terms of unpacking DCS value propositions, the partial use of the Abdelkafi and Täuscher (2016) model, was a valuable complement to the Taxonomy Framework, as this allowed the analysis of the reinforcing loop between customer and environmental value proposition, as explained in the next section (Contribution to Theory section).

Third, in terms of the theoretical approach and theoretical lens selected for this investigation, i.e. BMfS and the Stakeholder Theory, they seem to be adequate to the objectives and the research questions. In fact, this research wanted to shed light on understanding the way digital climate start-ups are effectively contributing to the challenge of fighting climate change. Thereby, examining their value offering, one particular dimension of BM based on Richardson's proposition (2008), provided a solid theoretical ground for the analysis as it pointed to a core element: what is that these start-ups are trying to achieve and how. The second theoretical lens, i.e. the Stakeholder Theory, was an essential complement in order to have a complete analysis. In fact, there was a need to understand the role the natural environment was given by these digital climate start-ups, as improving their value proposition would greatly depend on the relevance of the natural environment within the design of their BM (for example "mission driven" type companies born to tackle climate change, versus more business-as-usual kind of propositions).

Thus, the Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) developed by Freudenreich *et al.* (2020), was an adequate theoretical lens for the analysis of the data emerging from this study, as it allowed to provide a compelling answer to RQ2. It also provided an opportunity to extend this theory, by emphasising the natural environment as a key stakeholder. In fact, the SVC Framework, a theoretically developed framework, has now been empirically expanded by "zoomingin" in one specific component: Societal Stakeholders. In Freudenreich *et al.* propositions, the natural environment is considered part of the societal stakeholders, together with financial stakeholders, business partners, customers, and employees. However, as it has been shown in the case of the studied companies, the natural environment is frequently considered central to their value proposition, hence deserving a special status as a key stakeholder. This is further discussed later in this chapter (Contribution to Theory section).

As mentioned in the Literature Review Chapter, it would have also been possible to explore a combination of theories, as some of the initially assessed theories can complement each other. For example, this is the case with Stakeholder Theory and Paradox Theory. Stakeholder theory focuses on addressing the many (sometimes conflicting) goals of multiple stakeholders, while Paradox Theory provides insights into how these challenging objectives can be accomplished (Pinto, 2019). As it was shown, some of the value propositions developed by DCS can have unintended (negative) consequences, critically jeopardising the value aimed to be created, generating tensions between actors. Paradox Theory could provide avenues to embrace these conflicts and potentially resolve them. As expressed by McMullen and Bergman (2017), "Paradox Theory is ideally suited for examining organisational tensions" (p.245).

Both theories are managerial in nature, as they hold significance for practitioners. Consequently, each theory, as well as their combined application, potentially cover the domain of performance management. Moreover, both theories embrace complexity and the management of conflicting objectives or interests. Rather than seeking to eliminate the source of conflict, they aim to balance these conflicting elements (Pinto, 2019).

Institutional Theory could also provide room for a combined application. Managers face a constant challenge of navigating sustainability initiatives while simultaneously ensuring the economic prosperity of their organization. While market logic prioritises economic behaviour, aiming to maximise profits, sustainability logic is centred around establishing legitimacy among stakeholders. Consequently, the logics of "market" and "sustainability" are often viewed as conflicting or competing ideologies (Herold, 2018). Even though DCS are born with the objective of having a positive sustainability outcome, as their value proposition is contributing to the fight against climate change, they also need to achieve commercial success in order to ensure their long-term survival. Thus, examining how these two "competing" objectives perform in the case of DCS could shed valuable light in management research. The analysis of links between these two theories could also be extended towards the dynamics that allow for heterogeneity, variation and change among DCS.

Competitiveness of DCS is another dimension worth to be discussed, as the value proposition of these firms will influence their overall capacity to compete in the market. In fact, by developing a sound value proposition DCS seek to achieve a favourable competitive position within their industry and develop competitive advantages. As it could be expected, in order for these firms to deliver their value proposition for the natural environment, they first need to be commercially successful. Going back to Porter's framework for competitive strategies (Teti *et al*., 2013), most of the studied firms seem to prefer a differentiation strategy, as opposed to striving for achieving cost leadership.

Furthermore, the definition of value proposition of DCS represents a strategic commitment with significant economic implications for the firms. In fact, companies need to allocate value (from their value portfolio) to their various stakeholders, including the natural environment. This takes us to the discussion of for whom the value is created and the need to prioritise the recipients of value.

A final general aspect that we wanted to bring forward relates to the aspect of scale. As it was shown in the Context Chapter, the scale of the challenge of fighting climate change is significant: the global pledge is reducing GHG emission by 55% by 2030 (this is approximately 30 $GtCO_2e\ yr^{-1}$) to limit warming to 1.5°C (United Nations Environment Programme, 2021). In order to provide a preliminary idea as to whether digital climate technologies can be up to the challenge (i.e. help to reduce emissions by 20% by 2030 as suggested by the WEF, 2022), we can analyse the portfolio of companies considered in this sample, particularly those that provide a concrete mitigation climate change goal (see **Table 6-20:** Examples of climate hypothesis for carbon capture and removal). As it was seen, in some cases these firms refer to cumulative objectives already achieved (Company Alpha), or to cumulative positive impacts to be achieved in the next five years or so (Companies F and Y), while in other cases they propose annual objectives to be achieved in the future (Company W). In all these cases the numbers proposed seem significant, if we compare them for example to the annual GHG emissions of the UK which reached 0,42 $GtCO_2e$ in 2021 or 420.000.000 tCO_2e (for more details see **Table 2-1**). These suggests that DCS, as presented in this research, have indeed the potential to significantly contribute to the challenge of climate change.

7.2. Contribution to Knowledge

a) Contribution to Theory

Following the conceptual framework proposed by Nicholson *et al.* (2018), this PhD research attempts to provide an incremental contribution (**Figure 7-1**), where its originality is based on a "traditional gap spotting approach" to reviewing literature (p.208), therefore having to be measured against existing knowledge, with "its value and importance defended as showing progress over what is currently known" (p. 208). Furthermore, based on the novelty given by the intersection between sustainability, digitalisation and BMfS, the specific approach can be referred to as Type 2.3: New context spotting (region delineated by grey lines). According to these authors, following the Type 2: Incremental contributions approach should be combined with an evaluation of the usefulness in addressing the identified gap (i.e. an assessment of its utility).

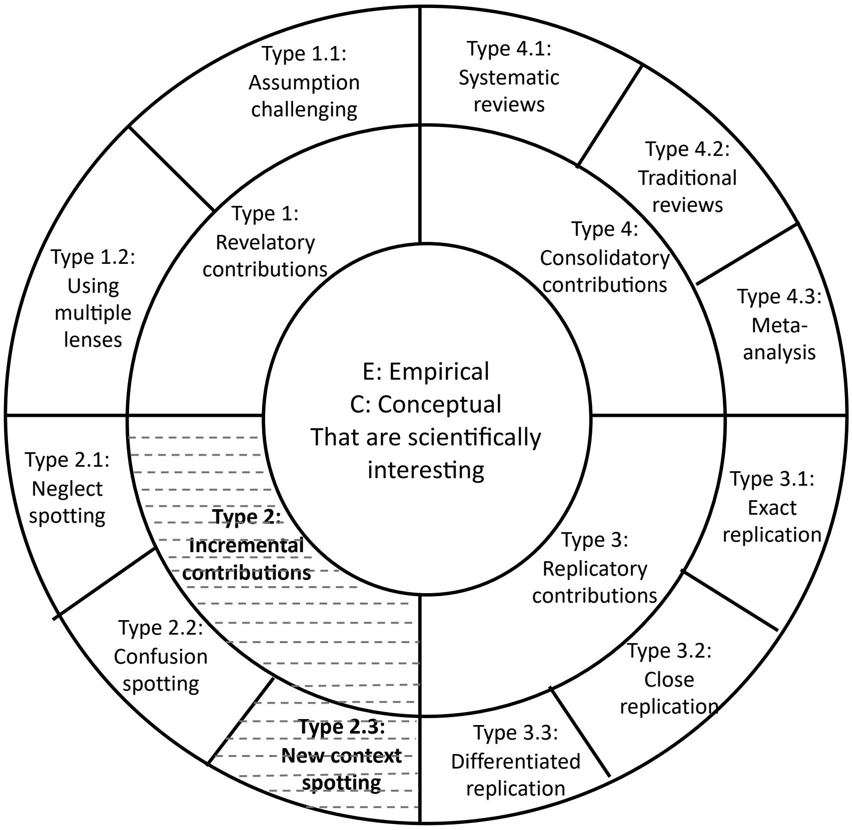

Figure 7-1: Conceptual framework for "research contribution strategies" (Nicholson et al., 2018, p. 210)

To address this aspect of utility, this investigation sought to make contributions to theory and practice. First and foremost, it contributed to the literature on BMfS (and BMfCC) and Stakeholder Theory by means of proposing:

1. A preliminary Taxonomy Framework for categorising digital climate start-ups (please refer to Section 6.4.1, i),
2. An analysis of the reinforcing loop between customer and environmental value proposition (please refer to Section 6.4.1, ii),
3. An extended Stakeholder Value Creation Framework for Business Model Analysis, the SVC Framework (please refer to Section 6.4.2, i),
4. Five secondary attributes (plus two primary attributes) that are considered essential to improve the value creation potential of DCS (please refer to Section 6.4.2, ii), and
5. A climate value mapping tool that could serve the purpose of improving the value proposition of DCS (please refer to Section 6.4.2, iii).

Firstly, a preliminary Taxonomy Framework for categorising digital climate start-ups was created. This framework serves as a valuable instrument for classifying such companies, thereby aiding in the comprehension of their value proposition in the context of combating climate change (i.e. this framework is a first step towards unpacking their value proposition). **Figure 7-2** presents the unified framework based on propositions presented in **Figure 6-7** and **Figure 6-8**. As it can be seen, further detail is provided by DCS working on the mitigation of CC, as greater diversity of value propositions was found.

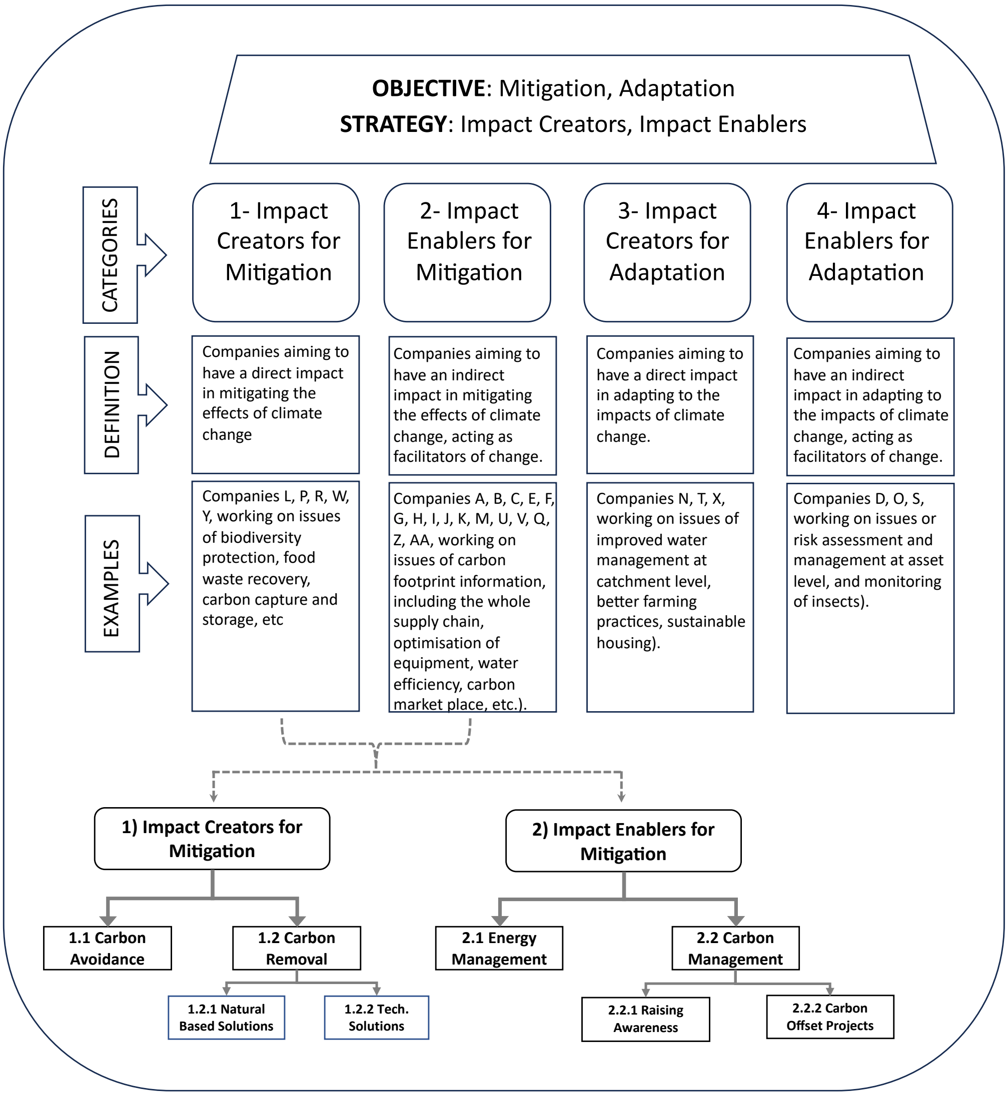

Figure 7-2: Unified Taxonomy Framework for DCS

A second contribution to theory was the analysis, though to a limited extend, of the reinforcing loop between customer and environmental value proposition, using as inspiration the model presented by Abdelkafi and Täuscher (2016). This model draws the attention of entrepreneurs and managers to the environment and the stakeholders who care for it, looking into the relationships between stakeholders, the natural environment, and the focal firm. Nevertheless, as this was not an initial theoretical lens selected, its use was partial, only qualitatively looking into the dynamics between these two components, as opposed to the full model that looks into value proposition, value capture, and value creation, and the flows of stocks among all these components, including the natural environment. In fact, for the effective application of the Abdelkafi and Täuscher (2016) model, four essential criteria needed to be met:

- It had to aid entrepreneurs and managers in comprehending the impact their firm had on the natural environment and in identifying ways to minimize this impact,
- The model had to illuminate how the natural environment affects the firm,
- It needed to clearly define the critical stocks and flows that need to be actively monitored and managed for the performance of the BMfS,
- The model needed to enable the identification of the primary feedback loops both within the firm and between the firm and the environment.

Although the objective for the application of the Abdelkafi and Täuscher (2016) model was to some extend different from the present study (centred around DCS and how these type of companies contribute to tackle climate change through the use of Industry 4.0 technologies), still some elements of Abdelkafi and Täuscher (2016) propositions were considered relevant, particularly those centred around the positive feedback loop between the customer and the environmental value proposition, as previously mentioned, and how these interact with the environment. It could be interesting though to explore other elements of Abdelkafi and Täuscher (2016) model, such as considering the CO_2 concentration in the atmosphere as one of the critical stocks and flows DCS are aiming to impact. Other relevant aspects that could be studied following the four criteria include: understanding the impact of DCS on the natural environment and identifying ways to minimize this impact (the unintended consequences), understanding how the natural environment may affect these firms (if it is the case), and define the critical stocks and flows that need to be monitored and managed for the performance of DCS (**Figure 7-3**).

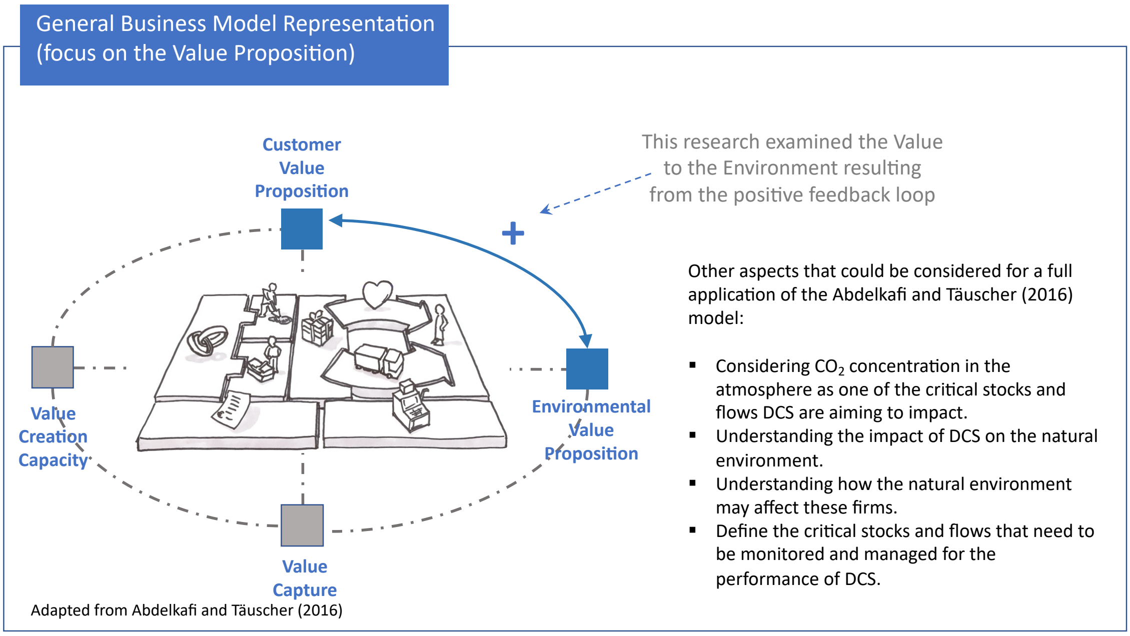

Figure 7-3: Generic Logic of Business Models for Climate Change (adapted from Abdelkafi & Täuscher, 2016), indicating areas for improvement.

A third contribution relates to the proposal of an extended Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) formulated by Freudenreich *et al.* (2020), by considering the natural environment as a sixth explicit stakeholder. Here two aspects/dimensions need to be explained: the need to look at value creation from a stakeholder network perspective, and the need to include the natural environment as a key stakeholder within this network.

The original SVC Framework was developed to enhance business model research by integrating stakeholder theory into the study of stakeholder interactions within a business model, with a particular focus on value creation. By doing this the authors redirected attention to the links among diverse stakeholders, not just clients, emphasising the crucial role each plays in value creation. They stressed the need to use stakeholder theory, shifting from solely creating customer-focused value propositions to producing a variety of outcomes or a value portfolio that is meaningful for various stakeholders.

In the case of value propositions developed by DCS, it was shown that the natural environment is a key stakeholder (or primordial or primary stakeholder). For many authors, however, the natural environment is not a valid stakeholder as there is no economic transaction-based relationship (characterised by cooperation, mutual benefit, and voluntary acceptance of benefits), this would explain the lack of relevance given to non-human natural environment. However, for authors such as Driscoll and Starik (2004) the natural environment should take priority among the firm´s stakeholders. Proponents of this broader definition contend that the concept of dependence has been inadequately addressed. They argue that the survival of organizations is deeply connected with the natural environment, emphasising that the biophysical limitations of the natural environment are directly relevant to business strategy (Haigh and Griffiths, 2009).

In the case of DCS, this relationship between the focal firm and the natural environment is in close dependency by design, as the very purpose of DCS is to improve the natural environment in some way (particularly those working on mitigation), hence depending on achieving this goal in order to achieve their own business goals (including their commercial success). In other words, this research is making the case for the natural environment to be considered a key stakeholder of DCS when developing their value propositions mainly for strategic reasons (more than moral aspects). **Figure 7-4** summarises these aspects.

Key Takeaways:

- The extended Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework) considers the natural environment as a sixth explicit stakeholder.
- Its objective to to enhance business model research of DCS by integrating stakeholder theory and look at stakeholder interactions within a business model, with a particular focus on value proposition.
- For this, the natural environment needs to be considered a key stakeholder (or primordial or primary stakeholder).
- The focal firm and the natural environment are in close dependency by design.
- The survival of organizations is deeply connected with the natural environment (the aspect of dependence).
- Thus, DCS need to consider the natural environment as a key stakeholder for strategic reasons (more than moral aspects).

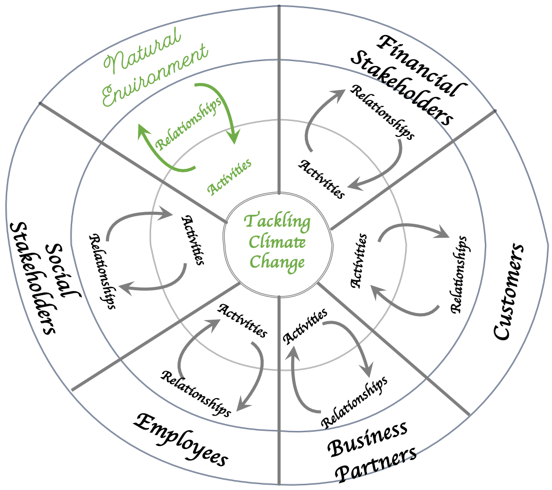

Figure 7-4: Key takeaways in relation to the Extended SCV Framework.

A fourth contribution relates to the development of five attributes that were considered essential to improve the value creation potential of DCS. The five attributes are based on elements that are expected to contribute to increase the value of these types of firms; some of these attributes can also be useful for the identification of other stakeholders that are key in the value creation process of DCS. These attributes are:

- Attribute 1 - DCS need to define a Joint Purpose around the fight against climate change: In Freudenreich *et al.* (2020) framework, the central element is the concept of “joint purpose”, where a value portfolio is generated for multiple stakeholders (and it must be mutually beneficial for all related parties). Thus, DCS need to identify and engage all relevant stakeholders in the value creation process and the joint purpose should be directed towards fighting climate change and explicitly refers to stakeholder contributions to achieve this purpose.
- Attribute 2 – DCS need to identify and manage unintended consequences: According to Bohnsack *et al.* (2022), digital technologies for sustainable development can have consequences which were not initially part of the indented outcome, while Hellemans *et al.* (2021) talk about unforeseen tensions and paradoxical effects that may risk the whole value proposition for the

different stakeholders. Thus, DCS should diligently strive to identify, manage and minimise any potential negative impact derived from their value proposition.

- Attribute 3 – DCS need to use the best available science for their value proposition: Given that climate change is a highly complex and multidisciplinary phenomena with high levels of uncertainty, value propositions developed by DCS need to have a solid base on science, in order to have credible and, above all, meaningful impact. The "science" behind their value propositions should be constantly updated.
- Attribute 4 – DCS need to define a climate hypothesis: DCS need to have clear and measurable indicators of impact (climate KPIs), particularly those impact creators in the area of mitigation. These indicators could be around carbon emissions reductions, carbon capture, carbon avoidance, and carbon removal, etc. Impact enablers also need to define climate KPIs. In some cases, potential climate performance can be used instead of achieved climate performance, particularly on early stages of the start-ups. This is essential for several reasons: to allow potential customers and investors to compare among various similar value offerings, make the firms accountable to their promises, compare alternative scenarios of value propositions and the different expected impacts, improve value offerings, redesign products and services, among others.
- Attribute 5 – DCS need to be transparent about their calculations and expected impacts: Information transparency was identified as key in order to build a reliable ecosystem of DCS. This include for example being open about the way carbon footprint calculation of individuals and products are made, about the way the expected positive impact is calculated and monitored, about the selection and reliability of climate offsetting measures, etc.

As explained in Section 6.4.2.i, considering the natural environment as a key stakeholder can be considered a primary attribute, placed above the other five secondary attributes. Furthermore, the specific digital technologies used by the DCS could also be considered a primary attribute, therefore having a final set of seven essential attributes of DCS, as shown in **Figure 6-18.**

Finally, a fifth theoretical contribution was a value mapping tool that could serve the purpose of improving the value proposition of DCS. This was aligned with one of the areas for future research identified by the Freudenreich *et al.* (2020, p.15): *"How can the stakeholder value creation framework be used as a design tool* in sustainability-oriented business modelling to create more stakeholder-sensitive and inclusive business model designs?" and with a research gap identified by Bocken *et al*. (2014) in terms of the lack of specific value mapping tools to help firms create value propositions better suited for sustainability. Thus, it is expected that the proposed BM Canvas style tool (as well as the additional version here presented in the form of nine guiding questions) will assist DCS in identifying opportunities to improve and innovate in their value creation potential. The tool recognises a system perspective of the BM, as BMfS need to consider both, the firm-level perspective as well as the broader system (Stubbs and Cocklin, 2008). Thus, nine empirically developed categories were included, such as the environmental value proposition, the climate hypothesis, the stakeholder network, and unintended consequences, as shown in **Figure 6-19**.

It is expected that the use of this tool could also have additional benefits for DCS, such as contribute to improving their message to the wider stakeholders by identifying areas where communication may be lacking.

b) Contribution to Practice

It is expected that this research will also have several implications for practice. Key areas where practitioners (both entrepreneurs and policy makers) could transfer some of the findings and lessons learnt in this research into their own activities include:

- It is expected that this research will contribute to entrepreneurs to optimise/improve both their customer value proposition and their environmental value proposition by enhancing the expected outcome. In fact, it is believed that some of the theoretical outcomes of this investigation are also of importance to entrepreneurs working with BMfCC. For example, theoretical propositions such as the reinforcing loop between customers and environmental value proposition and using stakeholder theory as a theoretical foundation, could both contribute to the design and development of sound products and services.

- Similarly, by analysing the five attributes in the context of their own value proposition could contribute to an enhanced value offering, identifying for example areas where their value proposition may be lacking.
- These attributes may also contribute to venture capital (VC) investors who need to understand the true value of these firms in relation to the fight against climate change and thus make investment decisions based on *ad-hoc* criteria, beyond the more traditional decision-making criteria used, e.g. quality and experience of the management team, technology, product or service, market, strategy, competition, customer adoption, business model, among others (Gompers *et al.*, 2020). Thus, these new set of attributes are expected to be a valuable tool for the pre-investment screening phase of VC.
- In connection with the above, the Climate Value Mapping Tool with its nine questions also provides a useful tool for start-ups to evaluate their value offering, as a careful analysis may shed light on areas that can be further improved.
- The outcomes from this study could be used to support other companies to realise uncaptured value in connection to climate change and motivate a change towards business models for sustainability.
- The outcomes of this research can also contribute to policy makers by highlighting the elements that are key for digital climate start-ups in order to have a solid value proposition. This could be relevant for example for governmental programs that want to support entrepreneurs tackling specific outcomes (for instance, carbon removal by Nature Based Solutions).
- Similarly, the empirical Taxonomy Framework may also be relevant for policy makers as this will allow a better understanding of the landscape of technologies and climate goals that are available today.

Chapter 8: Conclusions

8- Conclusions

8.1. Summary

Climate change, the most significant challenge humanity has ever faced, needs a collaborative effort from all sectors of society if it is going to be tackled effectively and timely. In parallel, digitalisation, the other main trend that is shaping societies, is intrinsically interweaved with the future of humanity (and with the fight against climate change). Thus, these are two closely connected dominant processes of social change.

In fact, as it has been shown, digital technologies play a pivotal role in addressing the global challenge of climate change. This industry provides tools, information, insights, and platforms that enable societies to mitigate and adapt to the impacts of climate change more effectively. Some of the ways in which digital technologies assist in this fight against climate change include:

- Sensing and control technologies (e.g. IoT, drones, imaging),
- Decision making technologies (e.g. digital twins, AI, ML),
- Enabling technologies (e.g. 5G, blockchain, VR, cloud),
- Foundational technologies (e.g. measuring & reporting, big data analytics).

In this context, the private sector, and entrepreneurs in specific, have a relevant role to play in the search for innovative solutions to address the challenge of climate change by using digital solutions as part of their value propositions. Entrepreneurs are also actively involved with the development of innovative sustainability-driven business models (or as suggested in this research, Business Models for Climate Change), where the focus shifts from focusing only on reducing the negative social and environmental impacts of business activity, to the creation of social and environmental improvements through their products and services.

The academic literature on the overlapping space of these two phenomena is still scarce, even though their relevance. Usual questions that emerge are: what do we talk when we talk about start-ups tackling CC? What do we mean by tackling CC in a Sustainable Business Models framework? What are their main attributes of these start-ups? How do they measure their contribution to CC? among others.

DCS are in fact companies born with the aim of having a positive outcome in the natural environment, as their main business goal is contributing to mitigating the impact that climate change is having on the planet (together with being economically viable). For this, DCS need to integrate into managerial decision-making the relationship between the business and the environment, in other words, the natural environment becomes a key stakeholder for these organisations.

Thus, this research examined some of these new players entering the space of climate solutions, describing the landscape of solutions being developed and their expected contribution, thereby proposing a list of attributes these companies should have. This research also contributed with insights on how digital climate start-ups are enabling new value propositions that incorporate ecosystem services (such as carbon sequestration) as part of innovative business models for sustainability (the natural environment as stakeholder), and how these business models add to planetary value such as protection of water resources, biodiversity and increased food security.

After analysing more than 200 companies, it has been found that there is a broad range of digital climate solutions being developed and launched, each of them addressing a specific market need. In some cases, these solutions focused on the adaptation side, while the immense majority of the analysed cases were concerned with mitigating climate change through some type of carbon management offering. The range of identified solutions ranged from measuring the carbon footprint of products, services, consumers, and software design, to providing options for offsetting the carbon footprint of both individuals and companies. Some of these solutions promise to evaluate and transparent the “climate credentials” of companies.

When it comes to compensating carbon impacts, the analysed solutions in the end relied on the capacity of ecosystems to fulfil the promise of their value proposition (i.e. carbon sequestration or removal done by nature). In fact, as it has been shown, for DCS the natural environment is a key stakeholder, or a primary stakeholder according to Haigh and Griffiths (2009), having a closer relationship with nature, or as expressed by Gladwin *et al.* (1995, p. 898), DCS may have a "natural contract with the biosphere" (beyond the more traditional "social contract" between the firm and society).

Another key finding was that most of the interviewed companies claimed to support their value proposition based on science by, for example, having a scientific board as part of their organisational structure.

8.2. Contribution to knowledge

a) Contribution to Theory

This research is a contribution to scholarship by developing and proposing five elements:

- A preliminary Taxonomy Framework for categorising digital climate start-ups (please refer to Section 6.4.1, i),
- An analysis of the reinforcing loop between customer and environmental value proposition (please refer to Section 6.4.1, ii),
- An extended Stakeholder Value Creation Framework for Business Model Analysis or SVC Framework (please refer to Section 6.4.2, i),
- Proposition of five secondary attributes (plus two primary attributes) that are considered essential to improve the value creation potential of DCS (please refer to Section 6.4.2, ii), and
- A climate value mapping tool that could serve the purpose of improving the value proposition of DCS (please refer to Section 6.4.2, iii).

The positive impact of these DCS could also extend beyond the "carbon" dimension (i.e. carbon avoidance and carbon sequestration) and include several other dimensions of sustainability (e.g. water aspects, biodiversity protection, land management, social aspects, etc.). Having said this, measuring the actual impact is not always straight forward, as very often these DCS act as enablers of impact, where the final impact rests on the actions taken by a third party (e.g. the customers, a developer of a conservation project for carbon credits, a developer of a wind farm, etc.)

Some of the barriers identified to further develop DCS included: the need to build credibility and climate literacy, the ability to collect the best possible data (and with the right granularity), the uncertainty inherent to this complex challenge, the need to have adequate legal, policy and economic instruments to promote some of these innovations, plus aspects of data protection, and confidentiality.

To conclude, it can be argued that DCS present specific characteristics and challenges, which differentiate them from other "traditional" start-ups (and thus make the case for more oriented research). The most relevant aspect is the magnitude of the problem they seek to contribute to. In fact, these are companies born to contribute to a livelihood challenge of humanity (a planetary emergency as recently indicated by Rockström, 2023). For this, these firms base their value proposition on the use the best available digital technologies (which are permanently and rapidly evolving). Additionally, their offering has two equally important components: a value offering for their clients (and the stakeholder network) and a value offering for the planet.

Finally, according to Driscoll and Starik (2004), when management theories such as stakeholder theory were first developed, there was less understanding of the interdependence between the firm and the natural environment. Today the situation is dramatically different, with a wide recognition of interdependencies. According to Suzuki (1997, p. 12), "[i]n such an interdependent universe . . . every action has repercussions that reverberate far beyond the moment." For example, financial risks and ecological risks are recognized as being interdependent, as expressed by Ryland (2000, p. 397), "when money is replaced with a concern for life, the time frame for decision making automatically shifts away from the nanoseconds of the financial markets to a concern for future generations. The economic dynamics of growth, accumulation, and competition are replaced by balanced interdependence, distribution, and cooperation." The focus then is on both current and future generations and both the short- and the long-term impact of decisions on the natural environment (Driscoll and Starik, 2004).

b) Contribution to Practice

The outcomes of this research are expected to be relevant for entrepreneurs through an improved understanding of their value proposition. By using the tools here presented, climate entrepreneurs may find a way to transparent their climate credentials to their clients, i.e., describe the concrete expected outcomes of their value offering, which in the end may also contribute to improved access to capital, access to markets, reputation, legal commitments, attraction of talents, etc. Specifically, by looking at their business model, it is possible to understand the value offering for both the customers and the planet, in what can be considered as a virtuous relationship. The five essential attributes here proposed (i.e. define a joint purpose, identify unintended consequences, use of best available knowledge, develop a climate hypothesis, and ensure information transparency) are also expected to be useful insights for entrepreneurs when designing (or re-designing) their value offering, in understanding the positive and negative aspects of their value proposition, and in the identification of conflicting values (i.e. the unintended consequences). These attributes may also contribute to venture capital investors who need to understand the true value of these firms in relation to the fight against climate change and thus make investment decisions based on *ad-hoc* criteria. Furthermore, the Climate Value Mapping Tool contains key elements that can describe the types of firms, namely: taxonomy, technologies, business model, impact, and other general attributes.

This research is also expected to be valuable for policy makers who want to understand the landscape of emerging firms with these characteristics, with the final aim to develop or adapt policy instruments to further promote their development.

8.3. Limitations of the Study

The ontological definition of this investigation was well suited for qualitative research, as it was about understanding the aspect of interconnections and value for multiple stakeholders, and also for being this a new phenomenon with not enough previous research. Thus, applying a qualitative research design was expected to enable an adequate study and description of the complex relationships between customer and environmental value proposition, as well as understanding the role of the natural environment as a key stakeholder of DCS. Similarly, the goal of this research was to expand and generalise theories (analytic generalisation) and not to enumerate frequencies (statistical generalization) (Yin, 1992).

Still, it has been widely recognised that this philosophical stance is more subjective and prone to biases, making it less generalisable compared to the way positivist research can be. In fact, the underlying idea of the interpretivist approach is that the researcher is part of the research, interprets data and as such can never be fully objective and removed from the research. In this sense, the cross-case analysis was used in this research as an approach to enhance the generalisability of the findings. Similarly, the use of knowledgeable agents as interviewees was key to tackle this potential shortcoming.

The results may also be influenced by the researcher's ability and experience in conducting interviews and processing this type of data, as well as the potential inclination of the interviewees to "oversell" their value proposition. As a way of counteracting this later element, the researcher used secondary sources of information, as companies' websites and other public documents.

Although the number of interviewed companies seemed to be adequate, specially given that saturation was reached after 16 interviews, the comparison among the companies was still on the surface. It would have been desirable for example to go back to each of the companies once all the data had been processed and put forward a second set of questions, focussing on aspects of the framework, the natural environment as stakeholder, the value mapping tool, among others.

In terms of the sample of companies, they are all from Europe. This could also be a limitation, as having greater diversity from other continents could have added new insights. Particularly adding companies from countries like Australia, Canada, China, India and, above all, USA, given the relevance of these countries in the entrepreneurial arena (particularly USA).

8.4. Suggestions for Future Research

As this research was exploratory in nature, there are many new research opportunities that have become apparent through its development. **Figure 8-1** shows some potential research direction that the findings of this research could take.

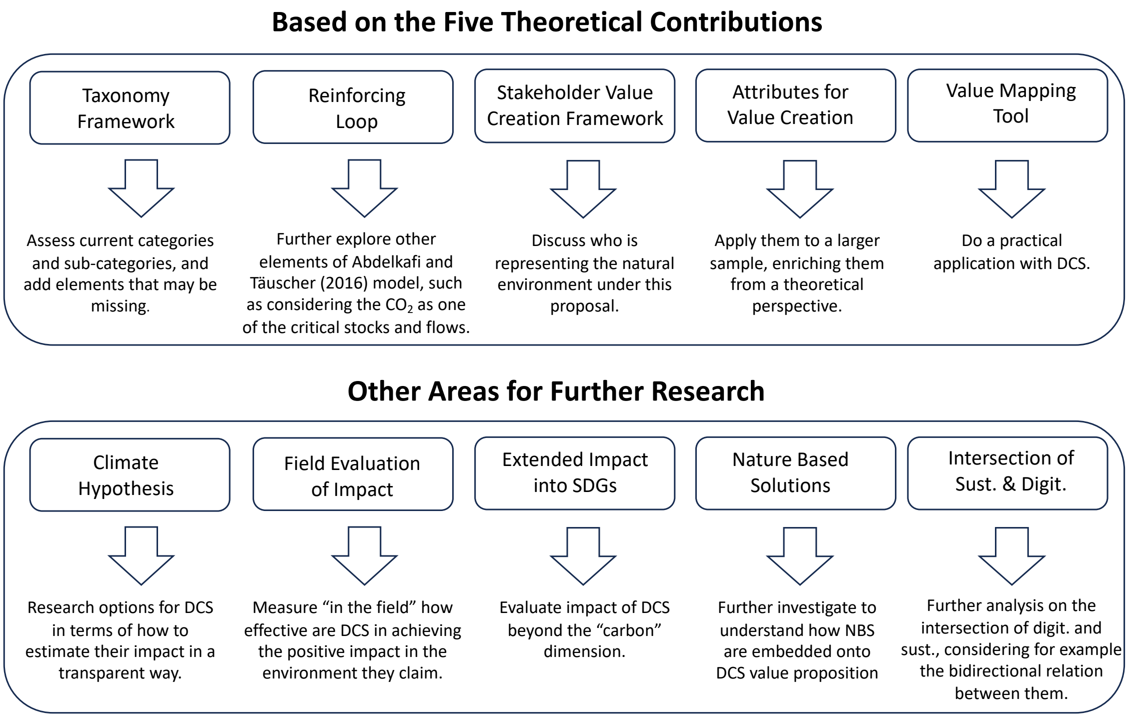

Figure 8-1: Suggestions for future research

As seen in **Figure 8-1**, the five contributions to theory previously presented can give space for further research, as explained below:

- The preliminary Taxonomy Framework for categorising digital climate start-ups: this framework can be further developed, assessing the current categories and sub-categories, and adding elements that may be missing. It could be applied to a larger sample of companies.
- The analysis of the reinforcing loop between customer and environmental value proposition: It could be interesting to further explore other elements of Abdelkafi and Täuscher (2016) model, such as considering the CO_2 concentration in the atmosphere as one of the critical stocks and flows DCS are aiming to impact. Other relevant aspects that could be studied following the four criteria identified by these authors include: understanding the impact of DCS on the natural environment and identifying ways to minimize this impact (the unintended consequences), understanding how the natural environment may affect these firms (if it is the case), and define the critical stocks and flows that need to be monitored and managed for the performance of DCS.
- The extended Stakeholder Value Creation Framework for Business Model Analysis (SVC Framework): the extended framework here proposed is open to discussion. In fact, many scholars would argue that the environment was already embedded in the original framework, as part of societal stakeholders. The relevance of making it explicit is a way to focus the attention on the natural environment, as DCS and their value proposition need to emphasise this aspect. Similarly, the four theoretical propositions and the eight questions put forward by Freudenreich *et al.* (2020) for the creation of stakeholder value through BMfS could be applied in the context of DCS, as all the questions seem relevant in this context. Furthermore, It would be interesting to take this proposition one step further by, for example, discussing who is representing the natural environment under this proposal (an aspect that was not discussed here) or how can it be operationalised (i.e. look into the distinction between human representatives of the natural environment and the natural environment itself, as expressed by Haigh and Griffiths, 2009 and Driscoll and Starik, 2004). Equally important would be to further explore the attributes of power, legitimacy, urgency, and proximity for the natural environment in the case of DCS, as presented by Driscoll and

Starik (2004) and the concept of dependent stakeholder from Mitchell *et al.* (1997).

- The five attributes that are considered essential to improve the value creation potential of DCS: as these attributes were empirically developed base on 27 interviews, it would be valuable to revisit them by applying them to a larger sample, or by enriching them from a theoretical perspective.
- The value mapping tool that could serve the purpose of improving the value proposition of DCS: an aspect that was missing from this investigation was the possibility to test this tool, by discussing it with the studied companies. Thus, it would be extremely valuable to carry out workshops with DCS or entrepreneurs interested in developing solutions for climate change to discuss this tool, thereby identifying areas for improvement.

In addition, other areas for future research may include:

- Further develop the concept of Climate Hypothesis, presenting options for DCS in terms of how to estimate their positive impact in the fight against climate change in a transparent way. Similarly, given that digital technologies could have negative unforeseen impacts, that could even risk the whole value proposition of the DCS for the different stakeholders, an analysis of this aspect is required (potential conflicts and trade-offs).
- Similarly, it would be relevant to carry out a research to measure “in the field” how effective are DCS in achieving the positive impact in the environment they are claiming (i.e. are they delivering the promise?).
- As the positive impact of these DCS could also extend beyond the “carbon” dimension (e.g. carbon avoidance or carbon sequestration), research could be conducted to include several other dimensions of sustainability (e.g. water aspects, biodiversity protection, land management, social aspects, etc.).
- Nature Based Solutions play a key role in the value proposition of most DCS; the studied start-ups enable new value propositions that incorporate NBS and ecosystem services in general as part of innovative business models for

sustainability. It would be valuable to further investigate this interconnection and understand how NBS are embedded into their value proposition and how they add value to the planet, such as protection of water resources, biodiversity and increased food security. In fact, it was seen that DCS have a closer relationship with nature, or as expressed by Gladwin *et al.* (1995, p. 898), they may have a "natural contract with the biosphere", aspect that provides a fertile ground for management research.

- Further the analysis on the intersection of digitalization and sustainability. The studied firms are shifting the focus from concentrating only on reducing the negative social and environmental impacts of business activities, to the creation of social and environmental improvements through their products and services, aspect that deserves further attention. Similarly, the bidirectional relation between digital technologies and sustainability at organization level, taking into consideration both positive and negative aspects, is also a rich area for further investigation. Furthermore, it is believed there are significant opportunities in this space, as digitalisation and CC are closely linked to the future of humanity, where digital technologies will play a pivotal role in addressing this challenge.

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Appendices

Appendix 1: Example of preliminary dataset of studied DCS

Company Name	City (UK)	Type of Company	Tech Nation Cohort	100% Dig.?	Sector	Sub-sector	Mitigation/ Adaptation	Value Proposition
Ambue	Oxford	software	2	100	Energy	E efficiency housing	M	B2C
Bx Technologies	London	software	2	100	Food - Offse	Agriculture	A	B2B
Categen	Belfast	software	2	100	Transport	Monitoring Air pollution	M	B2B
Earth Block	Edimburgh	software	2	100	Monitoring	Monitoring	A	B2B
Emsol	London	software	2	100	Transport	Monitoring Air pollution	M	B2B
Gardin	Oxford	software	2	100	Food	Agriculture - Monitoring	A	B2B
measurable.engy	Reading	software	2	100	Energy	E efficiency Buildings	M	B2B
Paua	London	software	2	100	Transport	electric cars charging	M	B2C
Powermarket	Oxford	software	2	100	Energy	Solar Energy	M	B2B
Qflow	London	software	2	100	Construction	waste management	M	B2B
Ripple	London	software	2	100	Energy	Energy - Wind	M	B2B/B2C
Sage		software	2	100				
SatelliteVu	London	software	2	100	Construction	Cities - Buildings	M	B2B
Spherics	Bristol	software	2	100	all	https://www.treeconomy.co/	M	B2B
Supercritical	London	software/product	2	100	all	carbon footprint	M	B2B
Sylvera	London	software/product	2	100	Carbon Captu	Carbon offset	M	B2B
Zuos	Edimburgh	software	2	100	Energy	Electric delivery system	M	B2B/B2C

Full list of Companies Preliminary Considered in the study

- 2Zero
- ACT Blade
- AgriSound
- Akiita
- Ambue
- Angara Global
- Artemis
- Artus
- Better Origin
- Blue Sky Analytics
- Blumethane
- Buntplanet
- Bx Technologies
- CAE Tech
- Callirius
- Carbon Infinity
- Carbon Re
- Categen
- Cervest
- Circularise
- Circulor
- Ember
- Emsol
- Enso
- Envirly
- EnviroDNA
- EO2.earth
- Etopia
- Evjia
- EXOE
- Farad.ai
- foldAI
- Foodsteps
- Gardin
- Giki
- Global Enabling Sustainability Initiative (GeSI)
- Globhe - Sweden
- GoCodeGreen
- Google
- Greenbiz
- Greyparrot

- Clarity AI
- Clim8
- Climate City
- Climateseed
- Climax
- Climony
- Connecterra
- Cupclub
- Dataiku
- Dynamhex
- Earth Block
- Earthly
- Eav
- Ecologi
- Ecological.earth
- Ecosia
- Ekoru
- Elaniti
- Electron
- Elmo

- Hark
- HumanForest
- Ikig.ai
- Infogrid
- Infyos
- Insenti
- Kita
- Koolock
- Lancey Enerygy Storage
- LettUS Gow
- Limetrack
- Livedrive
- Lixea
- Loopcycle
- Lune
- Magway
- measurable.engy
- MetroPolder
- Miralis
- Mosan
- Nadar

- Naked Energy
- New Intelligence Group
- Nexigroup
- Oceanhero
- Oka
- Olio
- Opna
- Optishower
- Oxfordeo
- Oxwash
- Pachama
- Paradigm
- Patch
- Paua
- PCI Technology Investments Ltd
- Petalite

- Space Intelligence
- Space4good
- Spark
- Sphera
- Spherics
- Sunswap
- Supercritical
- Surple
- Sylvera
- Taptree
- Tepeo
- terrafuse
- Thallo
- The Small Robot Company
- The Tyre Collective
- Theclimatechoice

- PhycoWorks
- Pivot
- Powermarket
- Productive Machines
- Qflow
- Qio
- RanMarine Technology
- Reath
- Rebalance Earth
- Recarb
- Reforest
- Ripple
- risQ
- Riversimple
- Route Konnect
- Sage
- SatelliteVu
- Sero
- SGPR.TECH
- Signol
- Small Robot Company
- Solar Polar
- Solivus
- Sourceful
- South Pole
- thefutureforestcompany
- theoceancleanup
- Tomorrow
- Topolytics
- Tred
- TRED
- Treeconomy
- TreeNation
- Treeo
- Treepoints
- Turation
- UNDERSEE
- UNDO
- Unicorn
- Viridis Terra
- Viriland (Farad.ai)
- Wheather Trade Net
- Winnow
- Wondrwall
- Xampla
- yaiLab
- Zeigo
- ZeroCO2
- Zeti
- Zoa
- Zuos

Appendix 2: Ethics Approval

The Ethical approval documentation has 4 documents:

- ELMPS Ethics Committee Application Form,
- Consent Form for Participants,
- Data Protection Impact Assessment (DPIA) Screening Questions, and
- Participant Information Sheet.

As mentioned before, there were two stages in the Ethical approval process; initially approval was sought for the pilot interviews, and subsequently approval was sought for the full set of interviews. The application forms for this final request are presented in the following pages. Final approval was given on 16th of March 2022 by Prof. Tony Royle, Chair of the Committee.

THE UNIVERSITY *of York*

ELMPS Ethics Committee Application Form

(Version: 18 October 2021)

This form is for all *staff and PhD candidates* in the five departments (Economics, Law, Management, Politics and Sociology), and two research centres (Centre for Human Rights and the Centre for Women's Studies). ***Please note: Masters and UG research is dealt with at department level***

Your ELMPS application is intended to ensure that your research will be compliant with the University codes of practice, ethical guidelines on research integrity and the General Data Protection Regulation (in line with University Data Management Policy) as well as any relevant professional guidelines for your discipline (e.g. the Statement of Ethical Practice for the British Sociological Association) or funding organisation (e.g. ESRC Framework for Research Ethics). Useful links in this regard include:

https://www.york.ac.uk/staff/research/governance/policies/ethics-code/
https://www.york.ac.uk/staff/research/governance/policies/research-code/
http://www.esrc.ac.uk/about-esrc/information/framework-for-research-ethics/
http://www.britsoc.co.uk/about/equality/statement-of-ethical-practice.aspx
http://www.york.ac.uk/about/departments/support-and-admin/information-directorate/information-policy/index/research-data-management-policy/

Please ensure, **prior to your submission of this form**, that you have consulted the University's guidance on data protection and the General Data Protection Regulation, available at: http://www.york.ac.uk/recordsmanagement/dp/

Internet research may involve new and unfamiliar ethics questions and dilemmas. A good place to start is the Association of Internet Researchers 2002 Guidelines and the BPS 'Conducting Research on the Internet: Guidelines for ethics practice in psychological research online (2007)'.

Note: If you are collecting data from NHS patients or staff, or Social Service users or staff, you will need to apply for approval through the Integrated Research Application System (IRAS) at https://www.myresearchproject.org.uk/Signin.aspx, in which case you do not apply to ELMPS. When your IRAS application has been approved you should email a copy of your completed IRAS form to ELMPS with their approval for our records. Masters and Undergraduate student applications for approval through IRAS should be pre-reviewed by the relevant department level ethics committees.

Completed ELMPS application forms should be submitted by the advertised deadline (see ELMPS webpage). Applications **will not be accepted after the deadline unless the Chair agrees that there are exceptional circumstances. Exceptional circumstances are for example, that the timing of your application is beyond your control and that funding will be lost if you do not get approval before the next ELMPS committee meeting.**

Email one signed electronic copy (including attachments e.g. consent form and participant information sheet) combined into **ONE pdf file** (email to: elmps-ethics-group@york.ac.uk). We no longer require a signed hard copy. Initial decisions will normally be made and communicated to you within two weeks of the Committee meeting.

SECTION 1: ABOUT YOU

1a. Please provide the following details about the principal investigator at YORK

Name of Applicant:	Juan Ramon Candia
E-mail address:	Jcj516@york.ac.uk
Telephone:	07784119263
Staff/Student Status:	PhD Student, second year
Dept/Centre or Unit:	The University of York Management School
Head of Department:	Prof. Mark Freeman
HoD E-mail address:	Mark.freeman@york.ac.uk
Head of Research: (if applicable)	Prof. Federica Angeli
HoR E-mail address: (if applicable)	Federica.angeli@york.ac.uk
If you are a student please provide details about your supervisor(s)	Supervisor(s) Name: Dr. Luisa Huaccho Huatuco & Prof. Peter Ball e-mail address(es): luisa.huatuco@york.ac.uk; peter.ball@york.ac.uk

1b. Any other applicants (for collaborative research projects) Expand as necessary

Name of Applicant:	
e-mail address:	
Telephone:	
Staff/Student Status:	
Dept/Centre or Unit:	

Head of Department:	
HoD e-mail address:	
Head of Research: (if applicable)	
HoR e-mail address: (if applicable)	

SECTION 2: ABOUT THE PROJECT

2.1 Details of Project

Title of Project:	PhD Research Digital Climate Solutions: How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet.
Date of Submission to ELMPS:	09 of November 2021
Project Start Date:	January-Feb 2022 (depending on the date of approval from Ethics Committee)
Duration:	Approximately 6 months of data collection, plus 4 months of data processing and analysis (these may overlap).
Funded Yes/No:	Yes
Funding Source:	Chilean Government Scholarship plus personal financial resources
External Ethics Board Jurisdictions (if any):	None

2.2 Aims and objectives of the research

Please outline the aims of your project and key research questions. Show briefly how existing research has informed the research proposal and explain what your research adds and how it addresses an area of importance (**N.B. Max 300 words**).
OBJECTIVE: This research looks into business-based solutions to the challenge of climate change, specifically from the perspective of digital climate solutions, with focus on new business models being developed by pioneering organisations that have the potential to contribute to enhanced climate actions. RESEARCH QUESTIONS: a) How to assess the interconnectedness between digital climate solutions and climate change from the business and management perspective? b) What new value propositions are being developed by emerging UK companies based on climate technologies? c) How are Digital Climate Solutions (DCS) being used to support and advance the UK's CC Goals in the future? RATIONALE: There seems to be a broad consensus that sustainable development cannot be achieved without having more sustainable businesses. However, the business models (a key component of enterprises) have just started to receive attention from sustainability management research (Schaltegger, 2016). Complementary, according to George et al (2019), management scholars have yet to embrace the urgency of climate change and sustainable development in their work, identifying as one of the main avenues for future research the need to look into new innovative business models for sustainability (BMfS). Furhermore, it is expected that digitalisation and transformation of existing traditional businesses will play a major role in the search for a more sustainable planet (Bican & Brem, 2020). In their research, Gregori and Holzmann (2020) argue that digital technologies enable novel configurations of sustainable business model components: a blended value proposition, integrative value creation, and multidimensional value capture. However, the relation between business climate change strategies and other organisation theories still appears to be unexplored (Daddi et al, 2018, p.456). In addition, Hanh et al (2010) made clear the need

for proposing innovative theoretical approaches to explain the role of business and management to face challenges such as climate change. Thus, the present submission is a request to perform a multiple case study analysis, as the methodology for this research considers this approach for theory building (Eisenhardt, 1989). This is the second ethics application for this research, following a successful application and approval for a pilot phase in May this year, where four companies were interviewed and which results were used to improve this methodology.

2.3 Methods of Data Collection

Provide a brief summary of the method(s) of the research making clear what it will involve for participants (e.g. interviews, observation, questionnaires). If you (or your research assistants) are meeting face-to-face with research participants, specify *where* you will be meeting them (and you will need to address how any risks associated with this will be managed in Section 2.10)
This phase of the research considers mixed methods for data collection, which are: literature review and semi-structured interviews. A total number between 10 to15 companies will be invited to take part. **Documentation/reporting:** Secondary data is to be collected from publicly available reports, web sites, newspaper and journal articles. No internal company documents will be requested. **Interviews**: semi-structured interviews will be conducted with high level representatives of the selected companies. These are one-to-one interviews that will take place either at the company premises (government guidelines on pandemic allowing) during normal working hours or on Zoom (the latter is the preferable option). Advanced requests to record the interviews will be made. The investigation will focus on the following areas, and examples of the questions are given: **Strategy**: ▪ What was the rationale behind the development of the Business Model for Sustainability or BMfS? (description of the BM trajectory)

- What market needs are being addressed (opportunities and threats in relation to climate change)
- What is the company vision for the next ten years?

Design:

- What are the distinctive characteristics of the BMfS? (value proposition, capture, appropriation, and value discovery)
- Description of the digital sustainability component (s)

Measurement:

- To what extent digital tools are contributing to tackle Climate Change (CC)?
- What is the expected Climate Change outcome?

The exact wording of the final questions will be refined with help from supervisors.

A consent form will be sent formally asking for permission to record prior to the commencement of the interview (following the earlier informal request). The method for recording will be the researcher´s iPhone or via the Zoom feature (I will also be taking some written notes as the interviewees respond to the questions).

It is expected to interview one person per company, unless the company decides to invite another staff member to the interview/meeting (if more than one person is attending the interview, I will get consent from all who attend the interviews, not just the first contact).

In case one (or more than one) interview takes place face-to-face (a less likely option due to safety reasons), I will acknowledge government, university and company guidance on Covid-19 restrictions on face-to-face meetings, take all appropriate hygiene and social distancing measures, and default to zoom or hangouts as the mechanism for meeting if in doubt or that the interviewee could be uncomfortable. Additionally, I will contact the health and safety officer of the company (prior to the arrival if needed), do the proper induction process, and wear the appropriate clothes at all times.

Moreover, in order to ensure the safety of the researcher at all times, a buddy system for interviews will be put in place (in which I will check in and out with a reliable person when doing the interview). Given that all meetings are expected to take place during standard office hours, provisionally this buddy will be Ms. Links Pollen in the Management School PhD support team.

2.4 Sampling and Recruitment of participants

How many participants will take part in the research? How will they be identified – describe your ***sampling*** method? How will they be invited to take part in the study – describe your ***recruitment*** method? If research participants are to receive any payments, reimbursement of expenses or any other incentives or benefits for taking part in the research please give details, indicating what and how much they will receive and the basis on which this was decided.
For this data collection phase, it is expected to interview only one or two people per each company (up to 15 companies). I will be seeking a senior member of the organisation who has a strategic overview, e.g. CEO or general manager. They will be contacted by email, LinkedIn, Zoom or phone. All interviews will be scheduled after the initial contact. I will offer to the participant companies to share the preliminary results in the form of a short report in which all organisations and individuals are anonymised/hidden (information to be provided following ELMPS guidelines). There will be no payment or reward beyond the receipt of the short report. The criteria for selecting the initial sample of case studies (companies) considered the following aspects (where ideally all criteria should be met): o Companies with Business Models (BM) based on digital sustainability, o Companies with BM oriented to tackle CC, o Companies that provide services to others (B2B or B2C), o Highly innovative companies with great potential for growth, o Companies based (or operating) in the UK The company's names may arise from web searches, recommendations, organisations known to the university, etc. Examples of the types of companies to be contacted can be found in those that are part of the Tech Nation Net Zero Program[12]. This Program is a both publicly and privately funded organisation that supports new digital companies in the UK. The Program involves supporting the growth of the UK's most promising scaling tech companies driving down global emissions.

[12] Tech Nation Program. https://technation.io/

2.5 'Vulnerable' Participants

Please indicate whether any research participants will be from the following groups; if so, please explain the justification for their inclusion. In most cases, researchers working with vulnerable people will need to be registered with ISA (www.isa.homeoffice.gov.uk) which has links with the DBS (formerly the CRB). The DBS offers organisations a means to check the background of researchers to ensure that they do not have a history that would make them unsuitable for work involving children and vulnerable adults.

***NB**: If you are collecting data from NHS patients or staff, or Social Service users or staff, you will need to apply for approval through the Integrated Research Application System (IRAS).*

Children under 18	No
Those with learning disability	No
Those who are severely ill or have a terminal illness	No
Those in emergency situations	No
Those with mental illness (particularly if detained under Mental Health Legislation)	No
People with dementia	No
Prisoners	No
Young offenders	No
Adults who are unable to consent for themselves	No
Those who could be considered to have a particularly dependent relationship with the investigator or gatekeeper, e.g. those in care homes	No
Other vulnerable groups (please specify) – discuss the issues this raises	No

If yes to any of the above, do you have Disclosure and Barring Service Clearance?

Yes/No

Describe the procedures you are using to gain (a) consent and/or (b) proxy consent if applicable

Not applicable.

2.6. 'Sensitive' topics

During your study, will anyone discuss sensitive, embarrassing or upsetting topics (e.g. sexual activity, drug use) or issues likely to disclose information requiring further action (e.g. criminal activity)? If so, please give details of the procedures in place to deal with these issues, including any support/advice (e.g. helpline numbers) to be offered to participants. Consider, too, the risks this may pose to the researcher. Note that where applicable, consent procedures should make it clear that if something potentially or actually illegal is discovered in the course of a project, it may need to be disclosed to the proper authorities.

No, the topics to be discussed will focus on the operation of the business as an organisation and will not focus on individual people. I will not ask sensitive, personal, or embarrassing questions.

2.7 Covert research

If the research involves covert data gathering or deception of any kind, please explain and justify the deception. Specify what procedures (if any) will be used to debrief participants after the data have been collected.

Not applicable.

2.8 Informed Consent

Please attach (1) the privacy notice/project information sheet to be given to all participants and (2) the informed consent form. In line with the University's Code of Practice on Research Integrity, participants and/or their representatives should be provided with details of a first point of contact through which any concerns can be raised: this should be your Head of Department (or if you *are* a Head then the Pro-Vice-Chancellor for Research).
i. If you are not seeking informed consent

It is usually the case that informed consent is required for research with human participants. If you do NOT intend to seek informed consent please explain carefully why you believe this is not necessary for your project. You should explain this with reference to the research ethics guidelines for your discipline and cite other recent published research using your methodological approach or ethics discussions about this to support your case. The Project Information Sheet and the Consent Form will be given in advance to the participants.
ii. Please confirm you have included the privacy notice/project information sheet to be given to all participants with your submission to ELMPS. If these have not been attached, please explain why this is the case.
Please find it attached.
iii. Please confirm you have included all the relevant informed consent forms. If these have not been attached, please explain why this is the case.
Please find it attached.
iv. Are the results to be given as feedback or disseminated to your participants (if yes please specify when, in what form, and by what means). If no, why not?
A summary of preliminary findings will be given to each participating company. For this, a short report in Word format will be sent to them by e-mail after data processing has been concluded.

2.9 Anonymity

In most instances the Committee expects that anonymity will be guaranteed to research participant. If anonymity cannot be guaranteed then you must provide a rationale for this and make this explicitly clear in the information sheet to participants that they are consenting on that basis. Please set out below how you intend to ensure anonymity. If anonymity is not guaranteed, then this also has implications that you must address in Section 3 below.

Note: if you are using a transcriber or translator you must have a signed confidentiality agreement with them.
For any reporting of the results of this research project, such as academic papers, the following data will not be disclosed (unless the participant explicitly requests and confirms their approval): participant name, exact job title, company name, company location within UK. The only personal data to be collected includes: name of the interviewees, job title, and business contact details. This data is relevant given the nature of the questions to be asked (need to interview senior managers at the companies with a strategic view regarding the company´s business model, vision, etc.). In terms of anonymity, in order to protect personal information, the company name will not be used (this will be anonymised with mask/code names, such as: Company X) and only a generic description will be provided, the same will be done for individual participants, using their job title and not their name (e.g. Supply Chain Manager in Company X) so it is expected that it would not be possible to uncover the identity of the individual. Finally, according to the General Data Protection Regulation (GDPR) Principles, the data to be collected will be "collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes"; and will be "adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed".

2.10 Anticipated Risks or Ethical Problems

Please outline any anticipated risks or ethical problems that may adversely affect any of the participants, the researchers and/or the university, and the steps that will be taken to address them. (Note: all research involving human participants can have adverse effects.) Please also refer to the University's Health, Safety and Welfare Policy Statement and associated Management Procedures, as well as to any ethical guidelines you have consulted. Where relevant, risk assessments should be carried out not only in relation to the researchers themselves, but also for those participating in the project or affected by its conduct, and in relation to any impact on the environment. Researchers should ensure that appropriate insurance is in place, liaising with the University's Insurance Officer as necessary (via standard departmental procedures where these exist).

Risks to participants (e.g. emotional distress, financial disclosure, physical harm, transfer of personal data, sensitive organisational information…)
Low risk. Personal data will not be collected (except for the name of the interviewees, job title, and business contact details, as explained in Section 3.1). Financial data would not be collected, unless it is publicly available. No company confidential plans will be recorded. Risk of disclosure would be minimised by discouraging the exchange of sensitive documents, password protecting documents if appropriate, storing data on York google drive, using pseudonyms for disguising company identifiers. Audio recording will be on a password protected device and moved to password protected university filestore as soon as is practically possible.
Risks to researchers (e.g. personal safety, physical harm, emotional distress, risk of accusation of harm/impropriety, conflict of interest…)
Low risk. Risks would be reputational and accusation of impropriety. If the meeting takes place at a company premises, local H&S rules will be followed and safety inductions will be completed as required.
University/institutional risks (e.g. adverse publicity, financial loss, data protection…)
Low risk. Risk would be reputational. Risk is minimised by collecting coded/anonymised data and following protocol on the storage of data. There will be no external data share. I will conduct myself respectfully, professionally and with transparency at all times. I will adhere to strict ethics and guidelines in accordance with data protection. I will consult with my PhD project supervisors for clarification on any matter if needed. Also, my previous professional experience of over 25 years working with industry of all types and sizes can significantly contribute to diminishing these risks. As an example, between 2019 and 2020, I carried out more than 30 semi-structure interviews with high level company representatives (very often multinational enterprises), government officials, and high-profile environmental professionals, and

conducted dozens of workshops with more than 1,000 participants, all of these as part of two applied research projects in Chile (carried out on behalf of the Ministry of Public Works, Interamerican Development Bank and The Nature Conservancy). In addition, in June-July this year I already conducted four interviews with UK companies as part of the pilot phase of this research. The development of this pilot phase counted with the previous approval of the ELMPS (approval dated on 11th of June).
Financial conflicts of interest (e.g. perceived or actual with respect to direct payments, research funding, indirect sponsorship, board or organisational memberships, past associations, future potential benefits, other…) None. There are no conflicts of interest between the researcher and the companies.

2.11 Research outside the UK

If you are planning research overseas, you should also take account of the ethical standards and processes of the country/countries in question as well as those of the University. If the research is being conducted outside the UK please specify any local guidelines (e.g. from local professional associations/learned societies/universities) that exist and whether these involve any ethical stipulations beyond those usual in the UK. Also specify whether there are any specific ethical issues raised by the local context in which you are conducting research, for example, particular cultural sensitivities or vulnerabilities of participants. Not applicable.

SECTION 3: General Data Protection Regulation

3.1 DATA PROTECTION

All personal data (e.g. names, contact details) must be collected and used in accordance with the UK General Data Protection Regulation (UK GDPR) 2018, the UK Data Protection Act (DPA) 2018, the University's Data Protection Policy and the University's research data management (RDM) Policy.

Personal data which have undergone pseudonymisation (e.g. replacing names or other identifiers which are easily attributed to individuals with a code) will still remain personal data and within the scope of the UK data protection law (particularly while the code can be tied back to the individual).

Before completing this section, please ensure that you have read the University's data protection and research data management guidance.

Does your project involve personal data as defined by the UK GDPR?

X Yes ☐ No

If you answered No, go to [next section].

<table>
<tr><td colspan="2">Data categories and subjects</td></tr>
<tr><td colspan="2">What types of personal data will you be processing? Tick all that apply.
● Personal data X
● Special category personal data ☐
● Criminal offence or conviction data ☐
● Data of children (under 18s) or of otherwise vulnerable individuals (e.g. elderly individuals or individuals with certain disabilities) ☐
● Pseudonymised data (e.g. an NHS Digital dataset) ☐
● Anonymised data where there is a risk of re-identification ☐</td></tr>
<tr><td>Describe the nature of the personal or special category data you will be collecting or using (e.g. opinions, contact details, financial information, health data, information on beliefs)?</td><td>The personal data to be collected includes: name of the interviewees, job title, and business contact details. This data is relevant given the nature of the questions to be asked (need to interview senior managers at the companies with a strategic view regarding the company´s business model, vision, etc.).</td></tr>
</table>

If the data is from NHS Digital, a registry (e.g. Eurostat) or organisation, give the identifiers for the datasets and/or reference the sharing agreements.	Not applicable

Data protection by design and default	
Will you be collecting the minimum amount of personal data necessary for the specified research purpose e.g. gathering anonymised data at source if person-identifiable information is not needed and ensuring all data to be captured can be justified?	**X** Yes ☐ No
Will you use the data only for the purposes of this research project? If you plan to use the data for additional purposes, will you bring this to the attention of the research participants at point of data collection or, where this is not possible, the University's Data Protection Officer?	**X** Yes ☐ No
Will you anonymise personal data wherever and as soon as possible: either at point of data capture, collation, analysis or output?	**X** Yes ☐ No
Will you use pseudonymised data wherever possible in cases where information cannot be anonymised e.g. will you separate research participant contact details from the data to be analysed and/or remove identifiers e.g. specific date of birth and replace with age within a date range?	**X** Yes ☐ No
Confirm you will issue research participants with a GDPR compliant participant information sheet/privacy notice at the point of data collection if you are gathering personal data?	**X** Yes ☐ No
Will the research cause substantial damage or substantial distress to research participants?	**X** No – not likely ☐ Yes – likely
Will you process personal data to take 'measures or decisions' about particular individuals? [An exception can apply in the case of (NHS REC) approved medical research].	**X** No ☐ Yes
Where you are working collaboratively, will you document data flows between the various research partners (e.g. in a basic data flow diagram) and retain a copy of this document with your ethics application?	☐ Yes **X** No
Where you are working collaboratively, will you ensure the Research and Knowledge Exchange Contracts Team are consulted before any data is gathered or shared to ensure appropriate contracts and/or data sharing arrangements are in place?	☐ Yes ☐ No **X** Not

	applicable
Where you are looking to engage third party services such as a transcription service, will you ensure the Research and Knowledge Exchange Contracts Team are consulted before any data is gathered or shared to ensure appropriate contracts and/or data sharing arrangements are in place?	☐ Yes ☐ No **X** Not applicable
Where you are working collaboratively, will you ensure data transfers to the collaborators are undertaken in accordance with [IT guidance]?	☐ Yes ☐ No **X** Not applicable
Will data subjects be identifiable in the final research output / data publication(s)? E.g. Publication of direct quotations from respondents, publication of data that might allow the identification of individuals.	☐ Yes **X** No
Where you have answered 'no' to any of the questions above or 'yes' to the questions around causing substantial damage or distress or using data to take 'measures or decisions', please confirm that you have consulted the University's Data Protection Officer and obtained any necessary approval. (Note: I have consulted with Dr Ariadne Kapetanaki, and based on my answers above, she agrees that, in principle, there is no need to consult with the Officer. Then she added: "However, keep in mind that your application will be thoroughly reviewed by a panel and will be discussed during the ethics committee meeting and if, for any reasons, it is necessary to consult with the Data Protection Officer, you will be asked to do so before you commence any data collection".	☐ Yes

3.2 Data Security

How will the data be collected and stored electronically?	a) Email. These will remain until the end of the research. Any emails that contribute to the research findings will be extracted and stored. It is not anticipated that the email exchanges will be valuable to preserve, and on conclusion of the research the email history could be deleted. b) Recorded participant interviews will be password-protected and encrypted on my audio device and transferred as soon as possible after the interviews to files in my personal computer. Files will also be password-protected and encrypted, and backed up on the

	University of York Google Drive, password-protected and encrypted. Once audio files are transferred to a file, they will be permanently erased from my audio device. When I have transcribed audio recordings from my files, audio recordings will be deleted and the transcripts retained and stored securely until the completion of my thesis and my project has ended. c) My research data will be stored in my home personal computer files, password-protected and encrypted until the completion of my thesis and end of my project. My secure files will be backed up in the University of York Google Drive. At the end of my research project my research data will be deposited and archived at Research Data York and comply with the legal obligations and university policy that apply to data management.
Please detail who will have control of, and act as custodian(s) for, data generated by the study.	I will have control of data generated by the study; I will be the custodian of the data. This information (anonymised data) will only be shared with my research supervisors; if requested by my research supervisors, also the coding to company/person links will be shared.
Will you use University approved software?	**X** Yes ☐ No (if no, please provide further details and consult IT Services before proceeding)
Will you use University approved file storage (Google Drive, University networked storage, research computing)?	**X** Yes ☐ No (if no, please provide further details)
Will you store personal or confidential data on laptop(s) with appropriate device encryption?	**X** Yes ☐ No (if no, please provide further details)
If capturing audio, will you use an encrypted device for recording (e.g. an Apple iOS device or encrypted voice recorder)?	**X** Yes ☐ No (if no, please provide further details)

Where data is held on an encrypted portable device (e.g. laptop, tablet) will you back it up to a University approved service as soon as possible and perform periodic checks to ensure data is being backed up appropriately?	**X** Yes ☐ No ☐ N/A
Will you ensure confidential information is encrypted before it is transmitted /shared digitally?	**X** Yes ☐ No
Please detail what other protections will be used for digital data (e.g. access/edit permissions, procedural safeguards re downloads/making copies, remote access via VDS/VPN, 2 factor authentication)?	All data will be protected by ensuring all the checks for access/edit permissions are in place. Two factor authentication for University of York's email and google drive will be put in place.
Confirm you have reviewed the user commitments under the Policy for the safe use of University information on devices. Detail anything in the user commitments that will pose a challenge in carrying out your proposed research.	**X** Yes ☐ No [Text]
How will hard copy/analogue data (e.g. in paper form) be collected, sent and stored?	No hard copies of data are considered

Will you ensure that personal data or confidential data held on paper are stored in a lockable filing cabinet or container, and/or a locked room in secure premises?	☐ Yes **X** N/A (will not create/hold paper copies personal or confidential data) ☐ No (if no, please provide further details)
How will devices be physically protected (e.g. in transit, when not in use or left unattended)?	Laptop will be carried in a bag with a security lock. All personal devices which can potentially access the research data will be password protected.
Will you ensure the device(s), accounts, or storage area(s) used to store data are not accessible to any unauthorised parties?	**X** Yes ☐ No
Set out any other measures or procedures for maintaining the confidentiality of information about the participant and information that the participant shares (e.g. other methods of anonymisation).	Research participants will be given pseudonyms, no real names be used, to guarantee confidentiality and anonymity (unless otherwise is requested by the interviewees); all data will be stored on my home personal computer and password-protected and encrypted and backed up on the University of York's Google Drive also password-protected and encrypted. I will not verbally disclose information that would identify research participants. The participants will be randomly coded, the interview records only identified by the code and that the look up table between individual identity and code are stored in a separately located password protected file

3.3 Data Retention

How long will you keep personal data after the project, in what form and for what reason? https://www.york.ac.uk/library/info-for/researchers/data/sharing/ [Data retention may be set by University policy, a data sharing agreement/data provider, be based on professional guidelines, or be approved by a York ethics committee. If the data is not going to be destroyed within a set time-scale please include a justification for this. The University's Research Data Management (RDM) policy applies to research undertaken by postgraduate research students and research staff only. This recommends retaining important data for a period of 10 years. Taught postgraduates should retain such data until their degree is awarded].	The data will be kept until the end of my research project and PhD studies. Data retention beyond that date will be made accordingly with University policy.

When will the research data be destroyed, by whom, and how? https://www.york.ac.uk/library/info-for/researchers/data/sharing/#tab-2	This will be done according with University policy.
Will any personal or special category data (i.e. data that is not truly and irrevocably anonymised) be deposited in an archive or external repository? https://www.york.ac.uk/library/info-for/researchers/data/sharing/#tab-4	☐ Yes **X** No ☐ N/A
Where personal data are to be transferred to an archive or repository, please confirm that your information sheet or privacy notice will: (i) cover the archiving and reuse of any personal data and participant agreement to this, (ii) explain to participants the benefits of any data sharing, (iii) indicate where possible whether research data will be deposited in a named, recognised repository (e.g. Archaeology Data Service, UK Data Service, York's institutional repository, etc.)	☐ Yes ☐ No **X** N/A [Text]
Where you have special category personal data or criminal data, will it be destroyed in line with an agreed retention policy (set by the University, the data provider, or approved by this ethics committee)?	☐ Yes ☐ No **X** N/A
Where will results that include/may include personal data be reported and disseminated (e.g. reference data output, research publication)?	No personal data is to be published.

3.4. DPIA Screening Questions (Data Protection Impact Assessment)

A DPIA should be undertaken for data processing likely to be high risk under the GDPR. The Regulation does not define 'high risk', but the Information Commissioner's Office has produced a checklist for determining when assessments should be undertaken. This is available on the ELMPS website DIPA Screening Questions (MS Word, 15kb).

Please consult the University of York's guidance on DPIAs prior to completing the declaration below. This is available at: https://www.york.ac.uk/records-management/dp/dataprivacyimpactassessments/

It is your responsibility to ensure that a DPIA is undertaken if it is required for your research project. Please tick **ONE** appropriate statement below:

Declaration	Agreement
1. I have completed the DPIA screening questionnaire and consider that a DPIA **is not required** as the data collected is not ‘high risk.’	☒
2. I have completed the DPIA screening questionnaire and consider that a DPIA **is required** as the data collected is likely to be ‘high risk.’ I have submitted the completed assessment to the University of York’s Data Protection Officer for review and **am awaiting a decision on approval.**	☐
3. I have completed the DPIA screening questionnaire and consider that a DPIA **is required** as the data collected is likely to be ‘high risk.’ The completed assessment is attached to this application and **has been approved** by the University of York’s Data Protection Officer.	☐

SECTION 4: SIGNED UNDERTAKING

In submitting this application, I hereby confirm that I undertake to ensure that the above-named research project will meet the University's Code of Practice on Research Integrity https://www.york.ac.uk/staff/research/governance/policies/research-code/.

……………………………… (Signed Lead Researcher/Principal Investigator)

………09.11.21………………….. (Date)

PhD Supervisor (for all PhD applications)…I confirm I have carefully read and approved this application

(*Electronic signature required*)

……………………..

(Date) ……8/11/21…..

Submission Checklist for Applicants

One signed <u>electronic</u> copy (including attachments) in **one pdf file** to: elmps-ethics-group@york.ac.uk

- [x] ELMPS Application form
- [x] Consent form for participants
- [x] GDPR compliant participant information sheet
- [x] ELMPS Compliance form

Consent Form for Participants

"Digital Climate Solutions: How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet".

Juan Ramón Candia, PhD Research Student, The York Management School, University of York

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Have you read, or has someone read to you, the 'Information Sheet' about the project?

Yes ☐ No ☐

Do you understand what the project is about and what taking part involves?

Yes ☐ No ☐

Do you understand that if you take part in the research that your words will be used but you will not be identifiable in any way. A pseudonym will be used and no other identifying data will be included?

Yes ☐ No ☐

Do you understand that the information you provide may be used anonymously in future research?

Yes ☐ No ☐

Do you know that if you decide to take part and later change your mind, you can leave the project up to one month after your interview without giving a reason?

Yes ☐ No ☐

Would you like to take part in the project "Digital Climate Solutions: How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet?"

Yes ☐ No ☐

If yes, is it okay to record your interviews?

Yes ☐ No ☐

Please write your name here (in BLOCK letters): ______________________________

Please sign your name here: ____

What is your position in the Company: ______________________________________

Company Name: ____

Date: ____

Interviewer's name: Juan Ramón Candia

Data Protection Impact Assessment (DPIA) Screening Questions

DPIAs should be undertaken for processing likely to be high risk. The Regulation does not define 'high risk' but the Information Commissioner's Office has produced the checklist below for determining when assessments should be undertaken.

We will conduct a DPIA if we plan to do any of the following:

	Tick
Use systematic and extensive profiling or automated decision-making to make significant decisions about people.	N/A
Process special category data or criminal offence data on a large scale.	N/A
Systematically monitor a publicly accessible place on a large scale.	N/A
Use new technologies.	N/A
Use profiling, automated decision-making or special category data to help make decisions on someone's access to a service, opportunity or benefit.	N/A
Carry out profiling on a large scale.	N/A
Process biometric or genetic data.	N/A
Combine, compare or match data sourced from multiple organisations.	N/A
Process personal data without providing a privacy notice directly to the individual.	N/A
Process personal data in a way which involves tracking individuals' online or offline location or behaviour.	N/A
Process children's personal data for profiling or automated decision-making or for marketing purposes, or offer online services directly to them.	N/A
Process personal data which could result in a risk of physical harm in the event of a security breach.	N/A

We will consider carrying out a DPIA if we plan to do any of the following:

	Tick
Evaluation or scoring.	N/A
Automated decision-making with significant effects.	N/A
Systematic processing of sensitive data or data of a highly personal nature.	N/A
Processing on a large scale.	N/A
Processing of data concerning vulnerable data subjects.	N/A
Innovative technological or organisational solutions.	N/A
Processing involving preventing data subjects from exercising a right or using a service or contract.	N/A

Participant Information Sheet

"Digital Climate Solutions: How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet"

Background

I would like to invite you to take part in a research project, which aim is to promote an understanding of how innovative Business Models are contributing to enhanced Climate Action. The research is also focussing on understanding the digital dimension, as a relevant component of the business offering.

Name of Researchers	**Affiliation**
Juan Ramón Candia	PhD Student, The York Management School (TYMS)
Dr. Luisa Huaccho Huatuco	Project Supervisor, TYMS
Professor Peter Ball	Project Supervisor, TYMS

Before agreeing to take part, please read this information sheet carefully and let us know if anything is unclear or you would like further information.

What is the purpose of the study?

This research explores the current trends of digital climate solutions (DCS) developed in UK-based organisations that contribute towards tackling climate change. This will be done in combination with the analysis of their business models and their expected outcomes, with a particular focus in their value proposition (Richardson, 2008).

This research aims to help both, companies and policymakers, especially those operating within the climate change space, to tackle more effectively the challenges and opportunities offered by digital technologies. It is expected that the empirical cases and the theoretical framework developed can be used in guiding policy interventions and can also advance and stimulate new innovative approaches in the field of Digital Climate Solutions.

Thus, this research project is designed to include interviews and analyse secondary data from outstanding organisations where these components (climate change, digital sustainability, and innovative business models) are central to their offering and to their vision.

Why have I been invited to take part?

You have been invited to take part because according to our survey your company embraces all of these components and has the potential to lead the way in your field.

Do I have to take part?

No, participation is optional. If you do decide to take part, you will be given a copy of this information sheet for your records and will be asked to complete a participant information form. If you change your mind at any point during the study, you will be able to withdraw your participation without having to provide a reason.

What does it involve taking part in the project?

Basically, if you agree to participate, an interview will be scheduled according to your time availability (a second interview could be necessary, depending on each case). The interview will last between 30 and 45 minutes, and will preferably take place on-line (via Zoom). The interview will be led by the PhD student Juan Ramón Candia. An outline of the potential topics for the questions will be sent to you beforehand.

On what basis will you process my data?

Under the General Data Protection Regulation (GDPR), the University has to identify a legal basis for processing personal data and, where appropriate, any additional condition for processing special category data. In line with our charter which states that we advance learning and knowledge by teaching and research, the University processes personal data for research purposes under Article 6 (1) (e) of the GDPR:

- *Processing is necessary for the performance of a task carried out in the public interest*
- Special category data is processed under Article 9 (2) (j):
- *Processing is necessary for archiving purposes in the public interest, or scientific and historical research purposes or statistical purposes*

Research will only be undertaken where ethical approval has been obtained, where there is a clear public interest and where appropriate safeguards have been put in place to protect data. In line with ethical expectations and in order to comply with common law duty of confidentiality, we will seek your consent to participate where appropriate. This consent will not, however, be our legal basis for processing your data under the GDPR.

How will you use my data?

Data will be processed for the purposes outlined in this notice.

Will you share my data with 3rd parties?

No. Data will be accessible to the project team at York only.

How will you keep my data secure?

The University will put in place appropriate technical and organisational measures to protect your personal data and/or special category data. For the purposes of this project, information will be treated confidentiality and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project. In addition, we will anonymise or pseudonymise data wherever possible.

Will you transfer my data internationally?

No. Data will be held within the European Economic Area in full compliance with data protection legislation.

Will I be identified in any research outputs?
No, unless agreed differently with the company´s representative.

How long will you keep my data?

Data will be retained in line with legal requirements or where there is a business need. Retention timeframes will be determined in line with the University's Records Retention Schedule.

What rights do I have in relation to my data?

Under the GDPR, you have a general right of access to your data, a right to rectification, erasure, restriction, objection or portability. You also have a right to withdrawal (up to a maximum of 3 months from date of interview). Please note, not all rights apply where data is processed purely for research purposes. For further information see, https://www.york.ac.uk/records-management/generaldataprotectionregulation/individualsrights/.

Questions or concerns

If you have any questions about this participant information sheet or concerns about how your data is being processed, please contact the following people in the first instance.

- Juan Ramón Candia, PhD Student, jcj516@york.ac.uk
- Dr. Luisa Huaccho Huatuco, Project Supervisor, luisa.huatuco@york.ac.uk
- Prof. Tony Royle, Chair of ELMPS Ethics Committee, tony.royle@york.ac.uk,
- elmps-ethics-group@york.ac.uk

If you are still dissatisfied, please contact the University's Acting Data Protection Officer at dataprotection@york.ac.uk.

Right to complain

If you wish to make a complaint or raise concerns about any aspect of this study and do not want to speak to the researcher(s), you can contact:

Professor Mark Freeman

Dean

The York Management School

University of York, York, YO10 5GD, UK

mark.freeman@york.ac.uk, 01904 325060

Alternatively you may contact the Chair of the Economics, Law, Management, Politics and Sociology Ethics (ELMPS) Committee, Research Centre for Social Sciences, University of York, 6

Innovation Close, Heslington, York, YO10 5ZF, Telephone: 01904 321458, Email: elmps-ethics-group@york.ac.uk

If you are unhappy with the way in which we have handled your personal data, you have a right to complain to the Information Commissioner's Office. For information on reporting a concern to the Information Commissioner's Office, see www.ico.org.uk/concerns or e-mail to: elmps-ethics-group@york.ac.uk

Thank you for taking the time to read this information sheet

Appendix 3: Interview protocol Version 2.0

Digital Climate Solutions: "How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet".

School for Business and Society - DOCTORATE RESEARCH

A) General Aspects:

Date:

Interviewee: Position in the company:

Numbers of employees in the company: Year of Foundation:

Location (Where is it based?):

Would you say this is a climate technology?

Is it also a digital technology?

B) STRATEGY - General Introductory Questions

1. Why is your company in business? What specific market needs (problems) is your company's product/service addressing?
2. To what segments? (target audience, beneficiaries), sector specific or sector agnostic.
3. Who are its ideal customers?
4. Is it B2B, B2C ? Focussing on Mitigation or Adaptation? carbon management?
5. Is this a software company? (If so, Open and inter-operable vs closed and proprietary systems and why) is a climate technology?
6. At what stage is your business? (e.g. development, entering the market, scaling, mature)

C) VALUE PROPOSITION

1. How would you describe your company's value proposition? (for both customers and the planet)
2. What would you say is the main innovation of your BM? Can you describe it? (distinctive characteristic); is IP involved? (technology, software, algorithm, methodology)
3. How does the company capture value? (revenue model, how do you monetise your offering)
4. What was the rationale/motivation behind the development of the Business Model for Sustainability or BMfS?
5. What is the company's vision for the next ten years?
6. How relevant is Science for your offering and how is it used?

D) PERFORMANCE: KPIs

1. How do you measure performance in your company? What are criteria for success? (in general terms)
2. Are climate change objectives part of your KPIs? (How would you describe the expected impacts of your company in terms of contributing to tackle CC).
3. Do you have a way to quantify the expected Climate Change outcomes? (i.e. do you have an estimation of potential GHG reduction (or the potential total benefit) through the use of your technology? Or value proposition?)
4. Do you have examples of the CC impacts you want to reduce?
5. Do you have a particular method/tool to forecast the benefits to be achieved by your company regarding tackling CC?

E) TECHNOLOGY & BARRIERS:

1. In terms of the digital component that are part of your value proposition: Could you list what are the main technologies being used? (IoT, blockchain, etc.)
2. Is there any unintended consequence due to the use of these technologies? Is there any potential rebound effect by the use of your technology?
3. How does your company proof its technology? (e.g. through experimentation) how does your company demonstrate its value? How does it obtain credibility? Specially in the early stages.
4. What would you say are the main barriers for success for your company? (both financially and in terms of CC impact).
5. Can you think of any external variables can influence the results you are expecting? (uncontrollability and unpredictability of external variables, policy, regulations, market)
6. How scalable is your technology?

F) NATURE BASED SOLUTIONS

1. Are ecosystem services (or Nature Based Solutions) part of your company's value proposition? In what way?
2. If the answer is yes, how far do you get into monitoring the effectiveness of Nature Based Solutions or NBS?

- If needed, can I contact you again later in this research? (In case there is a need for a more in-depth conversation or additional information requirement)
- Any other comments you may have?

____

Juan Ramón Candia

Doctoral Researcher

Graduate Teaching Assistant

MSc, PGDip, BSc

University of York, School for Business and Society

Heslington, York, YO10 5GD, UK

Appendix 4: Example of dataset of companies contacted via Linked-In

Company	Person Contacted	Position	Date of first contact	Followup
Treeconomy	Harry Grocott	CEO & Co-Founder at Treeconomy	06.10.22	accepted, sent a new message asking for email
AgriSound	Casey Woodward	AgriSound Founder | Innovation Consultant | Agri-food Enthusiast	06.10.22	sent an email
Viriland (Farad.ai)	Ali Safari	Founder & CEO at Farad.ai -	06.10.22	ask por email
Foodsteps	Anya Doherty	Founder & CEO at Foodsteps	06.10.22	no answer
Infyos	Sarah Montgomery	Building sustainable battery supply chains | Cofounder at Infyos | Co-Head at Young China Watchers	06.10.22	no answer
Kita	Natalia Dorfman	CEO and Co-Founder, Kita	06.10.22	accepted, sent a new message
	Kat Bruce			no answer
Envirly	Weronika Czaplewska			accepted
	Nathalie Seddon			no answer
	Chris Coleridge	Associate Professor, Strategy & Entrepreneurship Management Practice, U of Cambridge; Founder & CEO, Carbon13		accepted, sent a new message; he hs no time, but offered help to contact companies
	Danny Attias			accepted, sent a new message
Wheather Trade Net	Elena Maksimovich	CEO - Lead Founder - Climate Scientist - PhD in Geophysics		send email with details, interview agreed
Space Intelligence Ltd	Murray Collins, PhD	CEO, Founder	11.10.22	
Zoa	Isabella West	CEO & Founder at Hirestreet Limited and Zoa Rental | Forbes 30	11.10.22	
Zeti	Dan Saunders	Founder & CEO, Zeti: revolutionising transport finance for good. Fintech for clean mobility & energy.	11.10.22	
Signol	Natasha Gedge	Chief Operating Officer at Signol	11.10.22	
PhycoWorks	Stefan Grossfurthner	Co-founder & CEO at PhycoWorks	11.10.22	accepted, I asked for email
TreeNation	Maxime Renaudin	CEO & Founder of Tree-Nation	11.10.22	
Insenti	Andrew Dunn	CTO	19.10.22	sent, pero me pdió email el sistema
Kita				
Limetrack	Andy King	CEO | Entrepreneur	19.10.22	sent invite,acepted, sent email
Blumethane	Louise Parlons Bentata	CEO and Founder at Bluemethane	19.10.22	sent invite, accepted; sent more info
Elaniti	Scott Jarrett	CEO	19.10.22	sent invite
Paradigm	Jerome Maas	CEO & Co-Founder @ Paradigm -	19.10.22	sent invite
Thallo	Joseph Hargreaves	Co Founder @ Thallo.io.	19.10.22	accepted, now sent more details
Thallo	Ryan Gledhill	CEO and Co Founder	24.10.22	accepted, now sent more details; he answered, gave another email
Thallo	Hayley Moller			
Globhe - Sweden	Yambot Aguilera Bezrokov		19.10.22	sent message to define day
Global Enabling Sustainability	Luis Neves	CEO		answered, he has no time
Ecosia	Stuart Johnson	Product Lead for Search at Ecosia	21.10.22	sent invitation (he studied in York)
Ecosia	Pieter Van Midwoud	Chief Tree Planting Officer at Ecosia	21.10.22	sent invitation
Ecosia	Fred Henderson	I met himin York		
Angara Global	Eduard Cherednik	Chief Digital and Sustainability Officer	21.10.22	sent invitation, accepted interview
Blue Sky Analytics	Abhilasha Purwar	Converting Satellite Data to Climate Intelligence | Founder & CEO Blue Sky Analytics	21.10.22	sent invitation
Olio	Saasha Celestial-One	COO and Co-Founder at OLIO	21.10.22	sent invitation, accepted, sent more info; sent an email to set up a meeting
SatelliteVu	Anthony Baker	Founder and CEO	21.10.22	sent invitation, accepted, sent more info
Sero	James Williams	Co-founder and CEO	21.10.22	sent invitation
The Small Robot Company	Ben Scott-Robinson	Co-Founder and CEO	25.10.22	sent invitation, accepted, sent more info - email sent
UNDO	Jim Mann	Founder / CEO at UNDO Carbon Removal	21.10.22	sent invitation, accepted, sent more info- Sent email now
Winnow	Marc Zornes	Founder at Winnow	21.10.22	sent invitation
ZeroCO2	Andrea Pesce	Founder zeroCO2	25.10.22	sent invitation, accepted, sent more info
Spherics	Conrad Langridge	Head of Marketing		sent invitation, accepted, sent more info - email sent
EO2.earth	plinio herrera schuwirth			
Gardin	Sumanta Talukdar	Founder & CEO		
Google	Adam Elman	Sustainability lead at Google | Ex Director/Head of Sustainability at Amazon, M&S (Plan A) and Klockner Pentaplast		
Carbon Re	Aidan O'Sullivan	Associate Professor at UCL | Turing Fellow | Co-Founder and CTO at Carbon Re		accepted, sent new request on 13.12.22
Connecterra	Yasir Khokhar	CEO & Co-Founder	05.01.23	sent invitation
EXOE	Alex Money	CEO & Founder	11.01.23	sent invitation

Appendix 5: Example of invitation to participate in the research (sent by Climate KIC on behalf of PhD researcher)

Dear XXX team,

I hope you are enjoying the RACE to Net Zero Programme so far!

I am reaching out because we would like to invite you to form part of a research that one of our peers is conducting as part of his doctoral dissertation.

The MSc Juan Ramon Candia works as a Senior Expert in Sustainability, Innovation, Management and Entrepreneurship. His research looks into business-based solutions that tackle the challenge of climate change, specifically from the perspective of digital climate solutions. You can read more about it in the attached document titled "Research".

By participating in his research, you are going to receive a diagram showcasing your business model and its contribution to the fight against climate change as well as its value to the planet. You can read more about it in the attached document titled "Results".

If you are interested, the following step would be to schedule a 45-minute interview between May and June 2022.

Looking forward to hearing from you.

Kind regards,

Lia Alvarez

Strategic Programmes - Climate Impact Manager

Climate-KIC Holding B.V.

Plantage Midenlaan 45, 1018 DC Amsterdam

The Netherlands

www.climate-kic.org

Appendix 6: List of 27 interviewees (first and second round of interviews)

Company	Country	Date of Interview	Duration of Interview	Role of Interviewee in the Company
A	UK	09.07.21	46 min.	Head of Energy Applications
B	UK	13.07.21	45 min.	CSR Manager
C	UK	21.07.21	30 min.	Co-Founder & CEO
D	UK	08.07.21	45 min.	Founder & CEO
E	UK	18.02.22	45 min.	Tech Lead
F	Switzerland	18.05.22	30 min.	Director Digital Climate Solutions
G	Portugal	20.05.22	45 min.	Major Shareholder, CEO, Manager
H	The Netherlands	23.05.22	45 min.	VP Business Development & Strategy
I	UK	23.05.22	45 min.	Director of DC (Data Center) and Telecom
J	Spain	10.06.22	45 min.	Key Account Manager, Middle East, Oceania, Eastern Europe
K	Italy	26.07.22	45 min.	Head of Brand Communication for the Italian market and Group Program Strategy for the international market
L	UK	27.07.22	45 min.	CEO & Founder
M	Poland	11.10.22	40 min.	Chief Strategy Officer and Co-Founder
N	UK	19.10.22	35 min.	CEO & Founder
O	UK	20.10.22	45 min.	Founder & Chief Executive
P	UK	20.10.22	45 min.	Co-founder & CEO
Q	The Netherlands	22.10.22	75 min.	Chief Digital and Sustainability Officer
R	UK	08.11.22	30 min.	COO and CoFounder
S	France	21.11.22	45 min.	CEO - Lead Founder
T	UK	15.11.22	50 min.	CEO
U	UK	10.11.22	45 min.	Head of Marketig
V	France	01.12.22	45 min.	CEO & Founder
W	UK	10.01.23	30 min.	CEO & Founder
X	UK	27.01.23	30 min.	CEO & Founder

Company	Country	Date of Interview	Duration of Interview	Role of Interviewee in the Company
Y	Italy	31.01.23	35 min.	CEO & Founder
Z	UK	22.02.22	45 min.	Co-founder & CEO
AA	UK	16.03.22	45 min.	Founder & CEO

Appendix 7: Full list of interviewed companies (27) and their value proposition

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
A	Organisation providing data science and software engineering services to industry, experts in environmental data modelling, performing complex data analysis or undertaking assessments of the impact of weather on infrastructure, supply chains and business operations (focus is the energy sector). Established in 2015.
B	An artificial intelligence and machine learning company founded in 2013, a data science platform enabling data experts and domain experts to work together to build AI into their daily operations.
C	A climate debit card, B2C business. "One of the challenges for people to manage and reduce their carbon impact is the lack of information about what makes their carbon impacts; the information that they require to reduce it and the easy access and ability to offset it". This is what the company is trying to provide: "make people's money work for them and also for the planet". The debit card is only a means to a superior climate change objective. They manage large databases and use machine learning (ML).
D	An open climate risk platform ("climate intelligence"), a B2B business, able to combine and decipher complex scientific information to evaluate risks at asset level; "doing very complicated synthesis of data, data engineering and machine learning". The company uses artificial intelligence (AI) and ML, among others.
E	A platform aiming at preserving and restoring ecosystems and biodiversity, contributing to the carbon market. A B2B firm that helps companies invest in nature through high quality nature-based solutions that remove carbon, restore biodiversity and improve livelihoods. Through their innovative assessment and visualisation tools, businesses demonstrate the value of their investments in nature. To do this they partner with game-changing projects, across ecosystems, around the world. From kelp farms off the UK coast to regenerative farming in Tanzania to rainforests in Peru, all their projects are handpicked for their carbon-busting power and focus on interventions that are invaluable in reversing climate breakdown.
F	A consulting firm that has developed a Carbon Management Software, a B2B company that wants to have the most validated and impactful climate action that is there to keep true climate impact, both on the reduction side, on the mitigation side as on the compensation side. They enable that through projects, advisory and digital solutions. They offer their partners the ability to integrate climate insights and action into their software solutions; "that's where we differentiate from the more suite like climate action software players".
G	A B2B company, aiming at tackling road transport and urban mobility, helping to a more sustainable urban mobility. They intend to do this by combining mobility & behaviour

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	analysis expertise with technology and providing a cultural testimony to the next generations. They want to create 2 concepts, the environmental tachographs, and the safety tachographs (they should be reliable and fraud free).
H	A B2B company that provides Carbon Footprint Information of the supply chain, end-to-end supply chain traceability. They created a software to make products traceable. They want to be the leading software platform that provides end-to-end traceability and secure data exchange for industrial supply chains. The basic thesis of the company is that without traceability and transparency of material supply chains, product development, bill of materials, etc. as well as end of life recovery options, a circular economy in its truest sense, where materials and energy and products flow, will not happen. With this technology, companies can trace products and materials to verify their origins, certificates, CO_2, and other material data. "Our mission is to enable a circular economy".
I	A B2B company focussing on optimising industrial asset performance. They have a suite of applied AI solutions that empowers industrial companies on their journey to sustainability. Simultaneously optimise energy use, carbon emissions, production throughput and quality. They monitor and service assets with prescriptive and predictive insights to maintain optimal Overall Equipment Effectiveness (OEE) and extend asset life. They seek to reduce GHG emissions effectively, and efficiently. They can connect to any device, any asset, in order to improve performance, production, and quality ."The main innovation is our ability to apply our algorithms to pretty much any industrial process, without the need for deploying huge teams of data scientists. So that's the innovation, nobody can do what we can do".
J	A B2B company, aiming at managing water network/assets remotely with the power of Artificial Intelligence and reduce carbon footprint at the same time. They launched a carbon calculator, which is a functionality within their next CP App. Their objective is the reduction of non-revenue waters of utility companies, so the reduction of the physical losses, through the location and identification of the leaks, saving a lot of time, money and water and also the reduction of the commercial losses, which are sometimes hidden and not counted.
K	This is a B2C company, working on carbon management through their credit and debit cards. They have a carbon calculator, they issue monthly card statements that also include the carbon footprint (calculation of individuals carbon footprint based on purchases). "This means that every month we can issue not only the card statement, but also a general amount of carbon footprint that the customer has produced with the choice of the category of merchants. We create something that is extremely, from our standpoint, valuable, to create awareness regarding the carbon footprint. So our consumers and our

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	clients make sure that they are aware of the general impact of consumption". This is a digital payments company. They define themselves as the European paytech. They provide end to end solution for payments, meaning by that payment acceptance terminals (PA terminals) for the smaller and medium clients. So they are on the payment infrastructure also for more than 350 banks, as well as the for central banks, such as European Central Bank, but also for instance, New Zealand or Canada Central Bank and this kind of solutions.
L	A B2B company that offers carbon offsetting through the protection of biodiversity. It is a solution that addresses climate change, the loss of biodiversity, and investing in local communities, "all into one package", by putting an economic value to ecosystem services. "The main thing about what we do is mixing digital technologies and nature technologies". They use technologies such as blockchain to ensure transparency, plus AI, and internet of things (IoT).
M	A carbon management software, B2B company. They have a carbon footprint platform; they calculate, monitor and reduce carbon footprint. It is based on the international standards. The solution is on one hand related to environmental issues to reduce carbon footprint to meet the Paris agreement goals, and the EU goals as well, but on the other hand, it's the answer for regulation regarding carbon reporting, as the biggest companies already have to report carbon emission in EU from 2024 (companies over 250 employees), and it is said that from 2026 most of the companies, also small and medium entrepreneurships, will have to calculate carbon footprints as well.
N	A B2B, B2C company, focussing on sustainable housing. It is a technology company that builds houses. So it is a tech-enabled infrastructure company building houses, providing sustainable and affordable homes at a scale: "Building the Next Generation of Sustainable Homes". Historically the house builders spend 18 months scouting. This technology takes down 18 months to 2 seconds. That's the first innovation. The second innovation is that they built an AI engine which we can predict the likelihood of getting planning permission, "we'll de-risk the planning process, that's the innovation". And then the third one is the automation of the entire operation with the software plan, "so we're doing a job of, you know, 15 operators historically, with maybe you know 3 software engineers and one operator, and then we can scale that. And instead of having 150 operators, we're gonna have 3 technologies and 2 or 3 operators".
O	A B2B firm that provides local sensors to monitor pollinators in the environment, aimed at farmers suffering with suboptimal pollination. The aim being to get pollinators in the right place at the right time to increase yields. The main innovation in the business is the way they process the sound file to give usable insight. So this is where their patent sits (the patent has been filed and is still pending). The business model is a hybrid SAS model, they

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	have a recurring revenue component. Each device they charge £5 a month, which gives access to the algorithms, access to the visualization tools, the data, and they charge £200 for the box as well. So we make a margin on the on the hardware, but the main revenue generated is by the the recurring monthly fees.
P	A B2B company focussing on unlocking the potential of algae; "Produce algae at scale", with machine learning and synthetic biology. So the problem they are addressing is that scaling out the production of algae is costly and complex, and algae has the potential to be a sustainable solution to producing the materials and the chemicals for the food we consume. It is a sustainable alternative to fossil fuel sources, "but it is difficult to compete at scale, because the alternatives is so cheap, so we're trying to make algae productions more competitive, first by using machine learning, optimize production processes and then also by using synthetic biology, that use new strains that can perform better to what is currently available". In the future their ideal customers could be larger chemicals or agriculture companies, "maybe they've got some R&D work with algae in the past, they have some of their products derived from algae, but it´s by no means the entirety of their business model, and then helping that customer to produce more of their products using algae rather than some of the less sustainable methods that I just mentioned". "On the software side of things, I think, we are the only company that I've seen that uses machine learning to predict, and then also to make recommendations on how to optimize algae production at industrial scale, there are companies that have done similar things in conventional agriculture crops and have come to similar things from tissue based technologies".
Q	A software enabled solution for "Cognitive Cleaning" in the oil industry. The company managed to solve a problem which was not solved for more than 100 years in the industry. Basically, the crude oil goes through the network of pipes and in hardware, like heat exchanges. And over time, this is leading to accumulation of unwanted deposits on the walls, and on the surfaces of its hardware, this is leading to some massive problems for the industry "and unfortunately, if you want to remove it, you need to stop the unit, you need to dismantle it to see the hardware, and bring it to the workshop… 95% of the heat exchanges of all oil and gas industry in the crude refining sector are using this old legacy technology". So with this software enabled solution, first you start with a feasibility study, where the client takes some fouling samples. Company Q does some process data analysis to analyse the trends, how much is lost because of the fouling, in terms of the CO_2, or in terms of the costs: this is to de-risk the process.

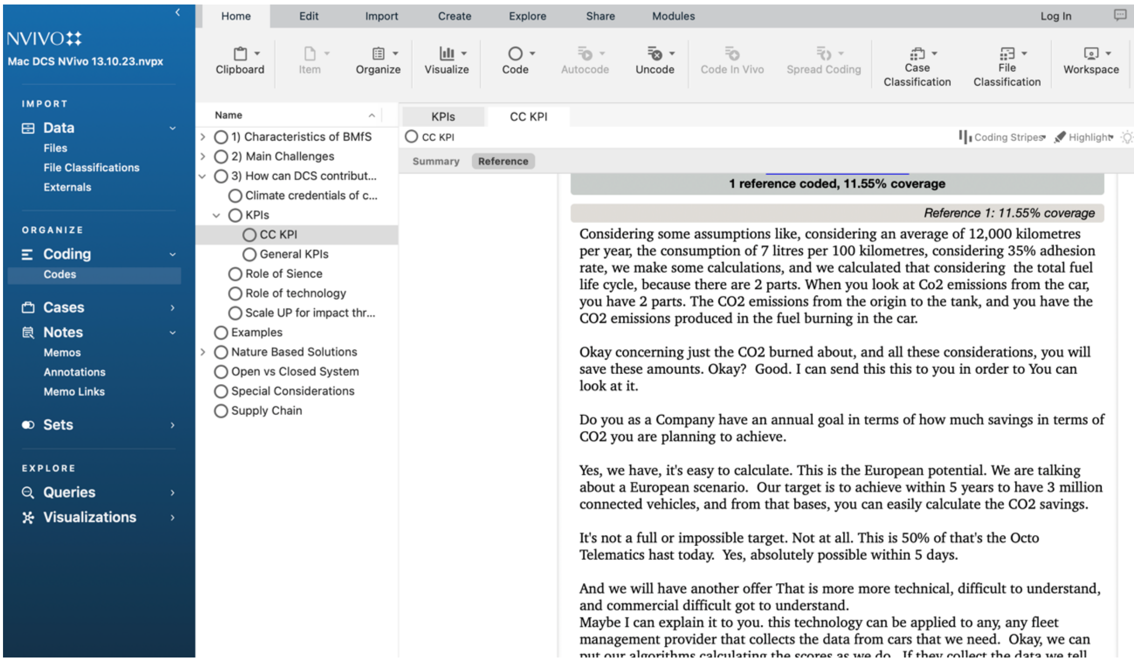
Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	They need to understand the geometrical properties (porosity and permeability numbers). So they send the sample to termography and based on the termography scan obtain a picture of the connectivity through capillary network, thus understanding how much pores are there and how pores are connected (and if bubbles have some space to propagate through this); finally, they do geomechanical analysis with partners laboratories, who tell how strong is the material, how many cycles you have to pass to accumulate for necessary fatigue of the material, and then you combine everything all together simulating the entire process, and you come up with so-called smart recipe, which is tailor made recipe to very specific fouling (selection of the surfactant, selection of the catalyst and the active agent). This must be tailored every time to the actual material.
R	A B2C2C business working to rescue and redistribute food, “unlock the value of the food that is wasted”. Essentially they are a marketplace that connects people in real time with other people near by to facilitate the safe and easy and fast exchange of goods that would otherwise go to waste. So everything on the platform is given away for free, on a neighbour to neighbour capacity, but much of the food is donated by a business, picked up by a neighbour that's trained, and then they donate it to their neighbours from their home. So they are in business to put an end to waste in the home and in the local community. Specifically, “we are tackling food waste. A third of all the world's food that's grown is never eaten and this accounts for 10% of global carbon emissions”.
S	A B2B firm working on risk management due to climate change. “Governments ask companies to evaluate forward looking flood risk and 10 more other risks. This data just doesn't exist. It just literally doesn't exist. So this is the innovation. So it's creating this data, creating the time series of floods and the rest”. They provide the software for companies to get the data from. This is relevant to all companies that have issues with floods, droughts, heat waves, coldness, so potentially all companies, because there is not even one that is not impacted. “So it doesn't matter if you are agriculture, power sector, bank, all are impacted. Banks are impacted because banks need to decide if they give you the money or not, and insurance companies are impacted, asset managers are impacted, basically everybody that is doing something, there is always a transport, there is a supply chain, there is a production chain”. There are 2 parts: Transition and physical risks at TFCD. They focus on the physical climate risk, “because there is literally no offer in the space. So for companies there is nothing they can use to. So basically the regulation says all companies in Europe and the UK need to evaluate the physical climate risk, but the regulators simply forgot how to explain the companies how they should use it, how they should do it”.

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
T	A B2B business that provides sustainable farming robots and AI aimed at making farming more efficient, more sustainable and more productive. "Per Plant Farming for the world's largest crops". The core thing they do is on farming, being able to locate and understand every single point in the field individually, and be able to look after that point, so that farmers can achieve its maximum potential, because it allows them to maximize the potential yield and minimize the amount of inputs. It also allows them to understand every plant in a trial plot or even in the field, for them testing new seeds or chemicals, and see what works or does not.
U	A B2B carbon accounting software. The company helps small businesses measure their carbon footprint in an automated way, "for a small monthly fee". Use of mobile App and a whole set of back-end API's. The company's value proposition is "helping businesses understand where their emissions lie and giving them tools to reduce their impact. And from the planet point o view, is helping people wake up to the problem, so waving the flag for the planet to say: hey, we've got this problem, and the business that you work for is a big part of this".
V	A B2B company working on carbon credits (access to Regulated Carbon Markets). The offer for clients is to offset their carbon footprint without the risk of greenwashing. The problem that they are trying to solve it is that companies currently looking to pursue a sustainable agenda look into the voluntary market to buy the carbon credits, if they want to compensate for hard to abate emissions and several studies have shown that the value that are being delivered by those carbon credits is not really what they promised. And this has exposed companies to greenwashing by investing in carbon credits with a low impact and a very low cost, and making it just for marketing purposes. But there are some companies that are not only for the marketing, but they are really interested in making this and giving their little impact in climate change. But these kind of carbon credits does not work for them. "And this is why we created the firm, to give them the alternative of a carbon offset without the risk of greenwashing". Blockchain doesn't make transparent what is being transactioned, just make transparent the transaction, and the problem with the underlying certificates coming from the forest is that it's very difficult to prove the real impact. "So this is why we realized that was key to have a trustable source of carbon offset. And this is why we went to the regulated carbon market to embed those carbon credits into a blockchain, into a token".
W	A B2B company, working on carbon credits through enhanced rock weathering. They work with agriculture and with mining and quarry operators (these are part of their offering), "but we do that to generate carbon credits, and then we're selling those to whoever wants

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	to remove their carbon footprint". Tipical clients for carbon credits are technology companies at the moment.
X	A B2B business in the area of water management, aiming to improve global water security. They provide a new approach to valuing water, by analysing catchment dynamics through remote sensing and stakeholder engagement. They have on the one hand, a public goods mission which is to reduce information asymmetries, and that means providing information to stakeholders such as communities, regulators, farmers, municipalities, and so forth. In addition, their data is meant to be decision ready for audiences such as companies that are either water intensive or operating in water stress areas, investors, ensurers and other types of types of financial services.
Y	A B2B firm. Their slogan is "Plant a tree, offset your carbon footprint". For them Zero CO_2 means reforestation with a high social impact, they plant trees in different areas of the world to fight the climate crisis and support the development of entire farming communities. They are interested in companies who need to integrate in their business reforestation, CO_2 offsetting, and so on. So the first innovation is about traceability and transparency. They have developed one of the most innovative tools to track the growth for every single tree, and to monitor where it is and how it is growing. The second innovation is more about the commercial strategy, and also about the business model. And that's about the social value they are generating. They are not just reforesting, but also generating social impact through the plantation in farming communities all around the world. And the third one is about their communication strategy, which is quite different, because they do not focused on the product, but on raising awareness about the climate crisis and sustainable development.
Z	A Carbon Management Software, B2B company focussing on the retail sector. "Were on the mission to make every single product and service climate positive by default", this company offers a software solution to make it easy for companies (e.g. retailers) to integrate climate impact into their existing products and services so it becomes a part of their customer experience. According to them, brand-conscious companies use their API and platform to calculate emissions, create climate action through vetted carbon offsetting, and future-proof business growth.
AA	A Carbon Management Software, B2B company focussing on software developers. This company offers the first carbon diagnosis and decisioning platform for software developers, they want to make software as climate conscious as possible, as today software runs the digital lives and businesses. The problem is that we use a lot of energy to build software and also need hardware, data centres and networks to make it operate, and all of this consumes even more energy. The company is trying to change the culture

Company	Customer and Environmental value proposition (descriptions provided by the interviewees)
	of software engineering and in particular make software product more environmentally aware and sustainable in their build. With this aim they have built a platform that calculates the carbon emissions for a software product in the full product life cycle stages; it is something that they believe has not been done before ("there is not such a product in the market").

Appendix 8: Example of rich text data from NVivo 20 – Code climate change KPI



Below are the answers provided by the interviewees when asked about the use of KPIs related to Climate Change. After the NVivo 20 data processing, it can be seen that 15 companies made some reference to this.

<u>Files\\Interview 12- Company Y</u>

2 references coded, 6.05% coverage

Reference 1: 2.49% coverage

Yeah, yeah, yeah, we have this kind of KPI, for example, yeah, we've been developing it with several universities around the world. So today we have different carbon KPIs, we have …. forested them, we have economy generated in the community, we have hours of training done in the communities, we have number of families supported, and those are all subjective KPIs, not as objective as we wish. So that's it's a challenge for us, and we are now trying to figure out a solution at this point

Reference 2: 3.56% coverage

We have the goal, not in terms of carbon, because carbon is one, It's just one parameter, we're trying to build something more complex than just a CO2 offsetting, and trying to do this for us, until now the KPI is how many trees we've been able to plant, because for us, trees mean community support, mean food, mean ecosystem, mean a lot of different variables. In 2,025 we are going to reach more than 1 million trees planted in the last 3 years. So for us is one of the first big milestones of our company, and from here, in 5 years, so let's say 2,027, I would like to be able to plant more than 5 million trees, which is something reachable in terms of numbers. Let's see if we are going to be able to do this.

<u>Files\\Interview 13- Company W</u>

4 references coded, 7.12% coverage

Reference 1: 4.14% coverage

So 2,025 we want to remove a 1 million tons of CO2 from the atmosphere, and early twenty-thirty, maybe even 2,030, we'd like to be removing 1 billion tons of CO2 from the atmosphere, a Gigaton, kick it and scale impact. You see, is what we want to achieve. There are a range of other things that we've been nice to have. I'd like to bundle our technology in a way that makes it accessible. Particularly to small farmers in southern hemisphere farmers, where we can have a meaningful impact on climate justice as well and empower some of the communities that are being left being most affected by climate change, but also are being left out of the solutions because of the technology requirements to participate in this new marketplace.

Reference 2: 0.83% coverage

So impact is our number one metric, which is not necessarily a measurable event, but the proxy for that is number of tons of carbon dioxide removed,

Reference 3: 0.71% coverage

We want to have as much scale impact as possible, as many tons as possible removed from the atmosphere as quickly as possible.

Reference 4: 1.43% coverage

And how scalable is your technology. Somewhere between 4 and 10 billion tons of removal per year is the potential Per year. Wow. So when you talk about this, this goal of being able to sequester 1 billion by 2,030, you're talking about again per year? Yes

Files\\Interview 15 – Company O

1 reference coded, 2.07% coverage

Reference 1: 2.07% coverage

So not directly. we We are part of multiple accelerators in the Net 0 space. but we we take it. We take actions to reduce our impact on the environment? So in terms of the packaging, we use and in terms of working in coworking spaces where they are very good to green policies in place, but we don´t take direct actions to Well, we don't we? Don't have policies to to kind of mandate that other forms of greenhouse gas emission reduction text space.

Files\\Interview 16 - Company V

1 reference coded, 1.71% coverage

Reference 1: 1.71% coverage

Well, it's kind of difficult if I don't have any sales yet. But but in in big terms I I would say the performance will be measured in the amounts of of ton of Co2 surrender, compared to the amount of of of ton of Co2 equivalent that we're tokenizing, I think that would be one of the main kpis, and we expect this to be at least over 5% probably to 10.

Files\\Interview 17 – Company R

1 reference coded, 2.37% coverage

Reference 1: 2.37% coverage

We use the data from Wrap, you know “wrap”? the waste of resources, Government program, they basically make it really easy to figure out how to track your climate impact. And there's really there's industry standards with regard to like how much carbon one kilo of food waste is the equivalent and saving. so it's all very transparent, everyone uses the same measurement. W. R. A. P., Waste and resources action program, I think, but W.R.A.P.

Files\\Interview 18 – Company P

1 reference coded, 3.33% coverage

Reference 1: 3.33% coverage

That's a very good question; because we are a platform company we are not directly using or manufacturing the algae that captures CO2. That's is something you measure directly. Further down the line we would like to capture more information on algae and give recommendations to our customers that will help them to make the processes more sustainable. One thing that we've found, is that … customers are always willing to share in a business if they if the data that they provide will help them to improve their production or will help them to reduce their cost, then they are happy to do so. But if the data could also show that your process may not be sustainable, they're more reluctant to share data.

Files\\Interview 20 - Company T

2 references coded, 5.18% coverage

Reference 1: 2.13% coverage

So one of our objectives is to get to the point where we are removing from the process 1.5 tons of carbon CO2e per Ha per farmer; and that's not necessarily sequestering, that is, removing from the process of farm production, looking to the reduction of Haber–Bosch nitrogen application, reduction of nitrous oxide conversion and emission, decarbonisation of the fleet

Reference 2: 3.05% coverage

So when get to the point of planting, being able to monitor them, and sequester the carbon from avoiding any form of soil disturbance and Also the sequestered carbon from the use of cover crops and lagoons, to be able to increase stored carbon as a whole. But that's the second phase for us, because we are nervous around soil sampling capabilities as they stand at the moment. And we think that we've got a much clearer it's much clearer to have KPIs around the removal of carbon from the process to start with and then use onto that nature.

__**Files\\Interview 22 – Company X**__

2 references coded, 1.61% coverage

Reference 1: 0.41% coverage

I mean I mean, I don't think we think about it. Yeah, I don't think we think about it as an internal KPI.

Reference 2: 1.21% coverage

So climate change is fundamental to our projections and predictions and our risk analysis and all of that. So it's, you know, it's completely that's what it is. The question is asking how climate change features as a KPI? The in different places? I I don't think it's particularly relevant for us.

__**Files\\Interview Company F**__

2 references coded, 5.52% coverage

Reference 1: 4.63% coverage

Our our ambition is to to mitigate and compensate a gigaton of CO_2 by 2027 so we are well, that's what we're tracking. So we're tracking kind of the amount of of emissions that we are able to reduce with our customers, and the the amount of tons of CO_2 that we are either avoiding or capturing through our climate projects and all our activities are supporting that goal. So kind of the within the gigaton there is a part of that that is driven by digital climate solutions. And then kind of to get from that ambition to a more mandate, so monetary valuation, you're looking at kind of what do we think that that reducing a ton of CO_2 cost or kind of brings us and then we kind of calculate that back to number of companies that we need to do that and the kind of revenue that we will be driving through that.

Reference 2: 0.89% coverage

So everything has to kind of convert into tons of CO_2 reduced or avoided or captured. CO_2 equivalent of course, because we don't [not clear] on methane.

Files\\Interview Company G

1 reference coded, 11.55% coverage

Reference 1: 11.55% coverage

Considering some assumptions like, considering an average of 12,000 kilometres per year, the consumption of 7 litres per 100 kilometres, considering 35% adhesion rate, we make some calculations, and we calculated that considering the total fuel life cycle, because there are 2 parts. When you look at Co2 emissions from the car, you have 2 parts. The CO_2 emissions from the origin to the tank, and you have the CO_2 emissions produced in the fuel burning in the car. Okay concerning just the CO_2 burned about, and all these considerations, you will save these amounts. Okay? Good. I can send this this to you in order to You can look at it. Do you as a Company have an annual goal in terms of how much savings in terms of CO_2 you are planning to achieve. Yes, we have, it's easy to calculate. This is the European potential. We are talking about a European scenario. Our target is to achieve within 5 years to have 3 million connected vehicles, and from that bases, you can easily calculate the CO_2 savings. It's not a full or impossible target. Not at all. This is 50% of that's the Octo Telematics hast today. Yes, absolutely possible within 5 days. And we will have another offer That is more more technical, difficult to understand, and commercial difficult got to understand. Maybe I can explain it to you. this technology can be applied to any, any fleet management provider that collects the data from cars that we need. Okay, we can put our algorithms calculating the scores as we do. If they collect the data we tell them to collect, and we know that it's it's easy to collect that. So let's say we can why? extend these goals of 3 million cars, to 20 millions. Because then we will charge just 1 or 2 Euros per month, using your data, and with this you will be able to offer to your customers access to public incentives. Of course they will also have to certificate the date bases, the data loggers, but that is not a huge problem. There's a last point I'd like to mention to you. It concerns the last CO_2

regulation limits for cars and vans for European Union. These regulations came out last July. This is mainly about CO2 emissions for the next 10 years, and trying to prohibit IC cars for 2,030 or 35. But 20% of this regulation focus on a critical point. That is what you call the gap. This gap they are talking about is the gap between your homologated values from car manufacturers for CO2 emissions and the Real World CO2 emissions production. This gap has been increasing from the last 50 years. It started on 10-15% and nowadays, for example for hybrid cars, this gap sometimes reaches 70%. 70% the difference between what is a homologated and what is the real world CO2 emissions, 70% of more. They can today (car manufacturers) homologate for hybrid a consumption of 1. 8 litres per 100 kilometres. 1.8 it's not true, it's not true but the regulations are made in a way that they can do it. But in real world, in real life, it it will not be for sure what happens. This is the famous gap.

Files\\Transcript Company M

1 reference coded, 4.17% coverage

Reference 1: 4.17% coverage

Okay, and based on that, could you have a way to quantify the expected climate change outcomes from your clients, because, in a way, you will be part of that improvement, as well. Yes, we see, like, you know, how the carbon emissions drop or rise. So once we see that our clients use our platform, and the emissions go down, it's of course not all of the difference because of us but we see how they are taking steps to work at zero, so that’s the way. But also we are now currently taking part in measuring positive impact, and there's like the idea to try to catch one of the universities in Poland, they want to catch the positive impact of companies, and we are taking the part as a company to come up with the way it could be assessed, but this is made by one of the universities in Warsaw, and we are helping them with that.

Files\\Transcript from Company C

2 references coded, 9.08% coverage

Reference 1: 2.56% coverage

And then also, and this is slightly harder to measure so in the short term, because even the long term is yeah, people's actual carbon reduction. So if people come in and use our app and just look at their carbon impact and don't do anything about it, then you know, we're missing out what we're trying to achieve. But if people come in and change their behaviours, or change their purchasing patterns, or you know, become vegan for a week, you know, all these kind of things we can see that we are actually changing people's behaviours and spending patterns, and as a result reduce their Net carbon impact.

Reference 2: 6.52% coverage

It can do. Yes, so the idea would be. I would say, .. if I wanted to… I could say I'm going to offset all my carbon spend, in which case we would every month we would calculate your carbon impact, and then buy, plant enough trees or whatever to offset all of it. You could put a cap, and say i'm going to spend up to £5 a month on offsetting. Some people can actually choose to be net carbon positive, which means, for every ton of carbon dioxide I create I'm gonna offset 1.2 for example. I compensate more than what I produce. So that obviously not everybody's gonna do that. But that's what we're trying to steer people to do is to offset some of their spend. And equally there'll be the opportunity to do ad hoc offsetting. So you know, maybe I go on a on a foreign holiday, and I take a flight. I might say right, I'm going to offset that flight, that one single transaction. So are climate change objectives part of of your kpis. Well, yes, clearly, I mean, as I said, we have to be a commercially viable company, but that commercial viability is there to help us to deliver our climate change objectives. Or do you have a way to actually quantify this expected climate change outcomes? Yeah, I mean that's one of the things that we will have within our data. We will, we will know how many tons of CO2 our customers have offset. We will know if people's net carbon impact is rising or falling within our database, by looking at our customer data. So yes, we we will have much data that we can use to assess our performance in meeting our sustainability goals.

Files\\Transcript Company Z

1 reference coded, 5.63% coverage

Reference 1: 5.63% coverage

So I think you know, the long-term long term it goes back to a mission about making every product that service, climate positive. In the short term success is measured by you know the number of successful customers that we onboard, how much they're using our products, how many tons of carbon we've you know removed from the atmosphere. Yeah. And how much revenue we generate as a company. How are climate change objectives part f your KPIs? Like carbon removal as you just mentioned. Yeah, yeah, I'd say that that's the main one now, then, also beyond that, something that isn't part of our KPIs, but you know, carbon offset projects also have many other benefits in terms of improve biodiversity, and to improve employment in local communities in the global South, improve education, and so on and so forth. So those are things that we don't measure yet but hopefully there will be methodologies to measure those benefits as well in the future. But today carbon is the main thing we can track.

Files\\Transcription Company L

2 references coded, 13.16% coverage

Reference 1: 7.78% coverage

That's an area we're still working on if I'm honest, because it will be…. you have to understand everything we're doing now has never been done before. Pieces of it here and there, but has never been done before. So there are a number of areas we can measure. So from a forest elephant perspective, we can look simply by adding numbers. How many elephants there is within the area, has the population decreased, increased or is stable. Look at that. There is, of course, the behaviours of the elephants themselves, has it changed, are they stressed? they don't like having names. For example. So there's a measurement of the elephants, there's the measurement of the forest from the biodiversity standpoint, like I was telling you, with the eDNA perspective. And then there's the manager measurement the local communities. You know, and some of it can be measured by polls. You know. What is your attitude towards the forest elephants? and do you see them as source of income, as a welfare for your family, or do you see them as a threat. There is a human wildlife conflict, for example in Gabon, elephants because they go hungry, they will destroy farms to eat, and farmers sometimes get killed. So you get back in a lot of public pressure on the Government to call the elephants, so we can do some polls. You know. What is your relationship to elephants? Equally though we can look at how has that local communities health KPIs improved, you know, is there less miscarriages, for example or do people tend to live longer, let's look at the education level, you know, has literacy rate increase, has unemployment decreased, park rangers are they now being paid regularly. For example, you can just go in Twitter, you will see how very often Park rangers are sometimes not paid for 2 to 3 months at a time. And they never get the money. And yet the data shows that once salary the park ranger supports 20 members of a local community. So these are roughly our KPIs measured at the Keystone specie level, and ecosystem level, and a local community level. For us as a corporation is, of course, is, how fast are we able to put new keystone species onto our platform, because the vision, you ask me what is the big vision, and then told you about the natural capital, but the kind of the inter vision is that we want to be able to launch Rebalance in a number of countries, and up to 3 to 5 different species. So forest elephants, savanna elephants, orangutans, maybe the rhinoceros, because we want to show how flexible and modular our scientific model is, so that if we can do it, then it's modular enough and flexible enough and get robust, then you suddenly have a system where countries can upload their own species under our platform as long as they follow our scientific model.

Reference 2: 5.38% coverage

So that's that's kind of the vision and that will be one of the KPIs, how many species can we put on our platform as fast as possible? Perfect. The other 2 questions about KPIs, I think, are all your business model. The first one was, how is climate change part of KPIs? You have explained that, and the third one was, Do you have a way to quantify the expected climate change outcome. Yeah. I mean one of the ways we can do it is to say, by 2030, and this is just, you know, finger in the air, can we remove one Gigaton of carbon, you know, from the from the atmosphere. Here I'm not able to say we've increased biodiversity by one gigaton of something, you know. So I i'm not quite sure about the biodiversity element yet. But yeah, these gonna be some of the other kind of KPIs. At a very high level. So we will have one KPI specifically in terms of GHG reduction.

We still have to use carbon as a metric, no matter how much I don't particularly like it. Because that's what the market today is. Biodiversity credits, biodiversity, you know, increase is, is kind of at the same stage that the Kioto protocol was in the early 1990s, when they launched the carbon markets. Right now, we are in the equivalent of 1990s for the biodiversity. So it's still very early days. I mean, Verra, you know, who does the carbon standard, it's got a biodiversity one called the CCB (Climate, Community and Biodiversity Standard). And You've got an alternative standard agency called "Pandivo" [name not clear], that also launched a biodiversity much more sophisticated standard, called I think it's called the biodiversity…. or I can`t remember its exact name. But here it's a bit more intelligent because what they do is that they use a basket of binary species indicators to see, you know, if you're increasing or decreasing biodiversity in ecosystem. So there's lots of interesting stuff people are doing. But, it's still early days.

Files\\Transcription Company N

2 references coded, 2.32% coverage

Reference 1: 0.91% coverage

Yeah, because I think ESG is literally inherently in what we do. I just haven't had time to roll out specific to the ESG metrics

Reference 2: 1.41% coverage

Because like we're building sustainable houses on a scale, is so inherited to the nature of the business that it was not needed to quantify it. But 100%, and then, when I have the resources 100%.

Appendix 9: Example of Interviews' results - Company M

Interview Company M

NB: In bold the text related to the questions from the interviewer.

Hello! Excellent, so I will go through the questions. As requested, I sent them to you half an hour ago. I don't think you had the time to have a look in advance, but I will go through them or try to cover all of them during this 45 minute conversation. Would that be all right?

Yes.

Perfect. So yes, just a couple of short questions, so how many people work with you and when was the company founded?

So, currently there are 15 people in the company, and the company was founded in 2020, however, the product which is connected to the environmental change climate issues was established one year ago [2021].

Perfect. So why is your company in business? So in other words, what specific market needs are you tackling or addressing?

So, we have a carbon footprint platform and… do you hear me well?
Perfectly.
Okay, so we have a carbon footprint plaform and we have companies to calculate, monitor and reduce carbon footprint. It is based on the international standards and we help companies so we are B2B business and also… yeah, we help both small and medium sized companies, and also the larger one. The solution is on one hand related to environmental issues to reduce carbon footprint to meet the Paris agreement goals, and the EU goals as well, but on the other hand, it's the answer for regulation regarding carbon reporting so the biggest companies already have to report carbon emission in EU from 2024 at the companies over 250 employees, and it is said that from 2026 most of the companies, also small and medium entrepreneurships will have to calculate carbon footprints as well.

Thank you for that, so you don't have any specific sector you work with, it's basically agnostic to the industry as I understand?

Yes, that's right, currently we are agnostic for that but maybe in the future we will turn into one industry. Currently, we are trying to to accommodate all industries, since we want to see where we have the biggest advantage and once we catch, like the the industry which are the most interesting in our solution, we probably will switch to one or two industries.

Okay, and who would you say are your ideal customers at this point?

I would say the medium companies over, a little bit, somewhere between 200 to 300 employees, so they are not that small, but they are still not big, and those companies usually are schooling up that we are working with one person so this one person uses our products, our platform, and we usually contact one person and we don't need to do much personalization for that, because for bigger companies in our platform, in our platform we do some personalization, because companies need some additional features, some additional questions and stuff like that, and when it comes to this medium clients, this is a client who is usually not too big to have personalization, but big enough to understand the problem regarding environmental change and the need to calculate carbon footprint.

And would you say you focus on mitigation or adaptation when it comes to climate change?

Mitigating, definitely, and carbon management, because as we said, our platform is a carbon management software, and it helps to firstly calculate, understand, and then reduce carbon footprint, so I would say mitigation.

Would you classify your company as a software company, then?

Yes, yes.

Okay, and is it open or closed system?

Um, I don’t get what closed system means.

Is it like an open source, the software you provide?

Oh okay, yes, it’s closed. I mean you can login from the website but you need to pay to enter.

Okay, and at what stage is the company? Is it on development, in the market, scaling, mature?

In the market. We've started helping the first clients.

Wonderful, so that's the first part of the questionnaire about the strategy. The second part is about the value proposition of your service, or product in this case. So how would you describe your company's value proposition? And, maybe you already answered this, but I don't know if there is anything else you would like to add.

So well, we say that we leverage the value of the company and develop the strategy towards sustainable future all in one solution, so we not only, like, we try to show companies that there is much more than only carbon management in our platform, and because once carbon management is done the company can see other processes that might be not so efficient, and our employees who work in a way that sends quite a lot of carbon emissions, so it's not only about the harm on the environment but also to show other strategies and solutions to help companies in all of the aspects like the carbon calculation on the first step, and based on that the company, can see how how they can… in which aspects they can do better. So, for example, they see that they have a lot of spending on electricity, and then they can reduce it going to renewable energy or something like that so on one hand, it's good for the planet, on the other hand, it mitigates risks related to electricity, currently quite big, I think, in our region. And, third of all, in the medium-term it has a return on investment. So, we want to show not only the green part, but also the economic part of the decision.

Okay, so the way it works is that clients have to type in some information you request from them, and then the software makes the calculations for the footprint, is that how it works?

Yes, so there is a list of questions companies have to fill and then the platform does the calculations, giving recommendations regarding reducing CO2, helps to track it over time. But, yeah, the company needs to put the information in the platform.

Okay, so there are no like, devices on the field like you collect data automatically to as an input to the system?

Well, we can put API, connect to our clients, or they can send to the platform Excel, a spreadsheet, and that's how the information is collected.

Okay, perfect. So what would you say is the main innovation of the business model?

That there is everything in one solution. Because currently, specifically in Poland and in Central European markets, Central-Eastern European markets, that the companies still are not so aware about the carbon footprint and what they can do with that, and the knowledge, there's a lack of knowledge, and there isn't a places where you have all knowledge, all factors and ways how to reduce carbon footprint in one tool, so we have something like that, and we offer it from the competitive price when it comes to the other solutions.

And how does the company capture value, the revenue model you have, in general terms? How does it work?

Um, what do you mean with capture value?

What's the revenue model you have?

Oh, okay. So, we are facing two models. The first one is the monthly subscription. So the company pays for monthly access to the platform, and the second one is like the one called calculations, and in this way the company pays once to have the calculation, and they only have, like the information about what is the carbon footprint, they don't have recommendations, they cannot track over time the carbon footprint.

Is it a mix, then, between the software and also consultancy, because you say you provide recommendations, so I guess that's a consultancy model?

Yes and no, because we have a few experts working with us in different industries, and the platform asks the user what the industry is, and once they put the industry, the algorithm matches the right recommendation to the right industry. So, it's kind of like the person, experts that made their recommendation, but it's not dedicated to this central company, but for the sector.
Okay, so it's not case by case, but it's more to this sector.

And what would you say was the rational and the motivation behind the development of your company? What was the inspiration?

Yeah, so there are actually two inspirations. The first one was regarding sustainability and the environment, that there's not much about ways how to calculate carbon, how to calculate companies input and companies influence and impact on the environment. It seems like one year ago there was not much talk about carbon footprint. And the second one was the regulations that are coming regarding that the companies need to calculate carbon footprints, so that was the additional rational behind the idea.

Okay, perfect. And what would you say is the vision of the company for the next 5 or 10 years?

So we are now very much focused on advancing the platform to not only carbon reporting but ESG reporting, so environmental, social and governance, to have it in one solution. So this will be for the next, I wouldn't say 10 years, but definitely for the next two years. And, the second thing, we are still figuring out which industry will be our target clients, because now we are operating in many industries, we'll see if we are going to focus on the one industry or not.

Okay, perfect. And how relevant is science for your offering? And how do you involve science in what you do?

So, first of all is this carbon calculation, carbon footprint calculation. There's emission factors which said for example, I don't know, what is one kilometre by car, how much does it emit to the environment? So this is like, we read a lot of papers and different views on that so we collect data from those papers, and to prepare the right information. And, the second aspect is that we work with experts from the field who are preparing for us recommendations regarding how to reduce CO2, so this is the second way we implement science in our solution.

Okay, perfect. So now we now move to KPIs and performance. So, the first one is, how do you measure performance in your company? What are the criteria for your success?

Yes, so we have like two types of targets. One type is like numerical targets that we want to actually, for example, I don't know, x number of clients this year, or have the traction on our website and stuff like that. But we also have some qualitative measurements so we assess how the platform looks like, if the pace of the development of the platform is right, so this is regarding the product and the numbers were regarding sales and marketing, and we also ask our employers how they are feeling about the platform, and about our product and also it's more qualitative than quantitative.

Okay, thank you. And in terms of climate change, is climate change part of, in some way, part of your KPIs and how?

I wouldn't say that it's our KPIs because we have climate change in our DNA. I would say, since we help companies to reduce the negative impact on climate change. So on that side we don't aim to do something about climate change, but we help companies to do something in a climate change field. But, we also, of course, measure our carbon footprint, and going paperless, and stuff like that. But it's like not the big thing when we compare our company to, for example, our clients, which have much, much bigger CO2 emissions and have much more to say about climate, about the impact on climate change.

Okay, and based on that, could you have a way to quantify the expected climate change outcomes from your clients, because, in a way, you will be part of that improvement, as well.

Yes, we see, like, you know, how the carbon emissions drop or rise. So once we see that our clients use our platform, and the emissions go down, it's of course not all of the difference because of us but we see how they are taking steps to work to net zero, so that’s the way. But also we are now currently taking part in measuring positive impact, and there's like the idea to try to catch, from one of the universities in Poland, they want to catch the positive impact of companies, and we are taking the part as a company to come up with the way it could be assessed, but this is made by one of the universities in Warsaw, and we are helping them with that.

Perfect, thank you. And when you do the calculation of the carbon footprint, I guess you base your calculations on standard databases in terms of how much is the footprint of a given activity? Or how does it work?

Yes, it's like a mix of this standard database which can be found online but from some questions, some industries we go much more deeper and we need to make some estimations regarding that. So it's kind of both, I would say, a mix of both.

And, can you think of an example of a carbon footprint production that one of your clients has achieved by using your technology?

So, like, the smallest thing currently, one of our clients is going paperless, and this is a small company, and they have quite a big usage of paper, so we can now see that really is a difference. But most of our clients are starting to use the platform, and they are bigger, so it's not that easy to see already the change, it needs to be at least half a year to see that the trend is really going down. So yeah, currently I could only say about this, like, little examples from smaller companies.

Okay, thank you. Now, moving to.. we are like halfway already, moving to technology and the barriers. So, the first one, in terms of the digital component of your value proposition, could you list the main technologies that are being used, in case you're using, beyond the software, I don't know, artificial intelligence or IOT or blockchain, or this kind of solution?

Yeah, we use IOT and machine learning.

Do you think there may be unintended consequence by using your technology? Is there a potential, you know, rebound effect by the use of your solution?

To be honest, I don't know. I didn't think much about that yet and I'm not the technical person in our company. What we've now seen is that sometimes it might be misleading that, for example, our users put the data, for example, they want to put, I don't know, 10 litres, but they put 10 tons, or they want to put 2 litres, but they mistype and put, I don't know, 200 litres or something like that and this has an impact on the carbon footprint, definitely, and currently we haven't captured this problem, this issue. So, it might no be related to the technology like machine learning or stuff like that, but it's things that we are now thinking about fixing.

How do you prove your technology? How do you get credibility at the outset of the solution? Like how do you demonstrate that you have potential clients, that this is going to work, and the information of the advice you're providing sounds, you know, scientifically based?

So currently we are, the technology, the platform under certification process. So the auditor outside of our company like third-party auditor, he's checking the platform and based on that, I hope we will say that we are, like, checked solution and the technology is working.

And is that something you tell your clients, I mean how do they rely? Because they're going to rely on the results that are coming out of the software isn't it? So I was just wondering if you have to run like a pilot test before? At the beginning? So you can actually show some examples to them?

Yes, we also show them, like, the pilot's version of the platform where they can, like, use it and see if they like it or not. It's usually for one or two months just for them to see if they like the way it is structured and once they've said yes, then we set up the platform for them, and they can use it for how much time they want.

And what would you say are the main barriers for the success of your business, your company?

Well, currently it's the lack of knowledge related to the carbon footprint, and that's what companies need to address. And the second thing is that once we start working with that company there's still a lot of questions from them, and we try to address them all (?) they take the external expert, the expert team, it calculates the carbon footprint, then it finishes its job. It costs quite a lot of money, but the company doesn't have to take care about anything, they just invite the expert and have things done. And with our platform it's much, much more cheap but the company has to do something on their own, for example, put the data in, and you'll see that maybe not all companies are willing to do that, some of them want to delegate it to the… external expert.

Yeah, I perfectly understand. And the next question, and maybe you already answered this one, because it's related to the former one, is what the external variables can influence the results you are expecting to get, and I understand one of them is already the one you mentioned that clients may not be willing to actually do the work themselves. But what about policy or regulations? Is there anything else?

Yeah, definitely policy and regulations are important in our solutions. But, we don't see much risk that some unexpected would come because there was, like half a year ago, there was a war, there is still here in Ukraine, and it's quite much influencing what is happening in Poland, and we thought that this will be changing the policy regarding carbon footprints, everyone would care about the military stuff, and how to get the security business. But, actually it wasn't true and there are still lots of regulations coming, and they will be on the scheduled timeline, so we don't see much risk about the regulation changing regarding carbon footprint. There is a tiny percent of probability that that might come, but we didn't expect that and of course it's also because the solutions in Western Europe are much more developed. (?) from France, or from Germany, or from the UK will come to Poland and just take the all markets if they are bigger, faster and have much more marketing budget. So, yeah.

Okay, let's hope it's not the case. So the last 2 questions are about nature based solutions and I'm not sure if these are related to your offering, but these are the questions. The first one is are ecosystem services part of your company's value proposition and in what way? Because I think I read that you, of course, calculated carbon footprint but you also get involved in the offsetting part or not, at some point?

Well, when it comes to offset you mean offset the carbon footprint, yeah?
Yes.
Yeah, we have a partner for that, so we are working together with another company to offset it. I'm not sure I get the question.

It's what you were just saying, like, because I mean one option, of course, is that you help companies to find out how much is their carbon footprint, and that's it, so that's your all involvement. But you can also work with them to offset their emissions. So the question in this case is, if that's the case, are you using the capacity of nature for the offsetting, for example, planting trees, or conserving biodiversity?

Yes, but we do it with our partners, so it's not that it doesn't come from our companies, but for our partner company and they do it through mainly planting trees, but also through photovoltaic panels. Yeah, I think that these two sources are the vast majority of offset they offer.

And, as I understand, you don't get involved in the monitoring of the trees, for example, the growing of the trees?

No, this is our partner, so yeah, we just get to them.

<u>**END OF QUESTIONS**</u>
Well, that was my last question. I don't know if there is any final comment you would like to make, or question, or observation.

No, I think everything was quite clear for me. I’m wondering what type of companies, kind of startups you ask? Is it the startups which are just, like, starting or big ones who already have quite a high revenue, or you have, like, a mix from small and bigger ones?

Appendix 10: Examples of data processing - from first order concepts to second order themes

Example 1:

First order Concept - Customers Demands

Second Order Theme – The Natural Environment as Stakeholder

Files\\Interview 12- Company Y

1 reference coded, 1.96% coverage

Reference 1: 1.96% coverage

Okay, huge market need, which is the CSR; companies today need to be much more responsible, more sustainable, they have to create a communication strategy in order to, you know, to be understood as most sustainable as possible, because the market is requiring it. So we are interested in companies who need to integrate in their business reforestation, CO2 offsetting, and so on.

Files\\Transcript Company Z

1 reference coded, 6.62% coverage

Reference 1: 6.62% coverage

What market needs we tackle is that on the one hand, consumers everywhere want climate-friendly products and services and businesses have started waking up to that. But still for businesses, on the one hand, they see climate impact as a cost center, and they see it as something really challenging to do. It takes lots of time, takes lots of resource, and so on. So for those 2 reasons it's a cost center and it's difficult to do. For those 2 reasons businesses have been slow to act, and what we do at Lune is to make it really easy for them to integrate climate impact into their customer experience, starting with carbon emissions calculations and carbon offsetting, carbon removal. And when it's part of the customer experience the business can increase customer acquisition because they're elevating their brand as a sustainable Brand, they can increase customer engagement and customer loyalty and so on, and hit the their commercial growth metrics while having a positive impact on the planet. So we are shifting the mentality from climate as cost center to climate as a growth driver, and we're making it really easy with our software solution to do that.

Files\\Transcription Company N

1 reference coded, 2.39% coverage

Reference 1: 2.39% coverage

For customers, we so we give them a peaceful house which is sustainable and affordable. For the planet, you know if you don't have a roof on top of your head, you can't do anything right. But then, why why resolving the need should come at the cost of polluting the environment, both for building it as well as you know, operating it.

Example 2:

First order Concept - New Legal Requirements

Second Order Theme – The Natural Environment as Stakeholder

Files\\Interview 19 – Company S

3 references coded, 4.82% coverage

Reference 1: 2.98% coverage

Okay. So we work on in this space. and very specifically in the physical physical climate riks space. So there are 2 parts. Transition and physical risks at TFCD. And we we focus on the physical climate risk. We basically first of all, because there is literally no offer in the space. So for companies there is nothing they can use to. So basically the regulation says all companies in Europe and the Uk need to evaluate the physical climate risk, but the regulators simply forgot how to to explain the companies how they should use it, how they should do it, it's like asking you to file taxes without giving you the platform for filling taxes. So this is a little bit the same story with the physical climate risks. So we are solving this problem for companies. We help them, and at the end it's not only private companies. It's also adaptation funds. It's a basically there is a bunch of applications where you can use this data, and not only for company reporting of risks but also for risk management.

Reference 2: 0.49% coverage

According to my knowledge. So okay, the climate regulation, the new TFCD Alliance regulation says, companies need to evaluate the forward-looking flood risk.

Reference 3: 1.35% coverage

All companies in the Europe with more than 40 million revenue, Okay, They need to evaluate the climate risks in future, and according to my knowledge, their data just doesn't exist. Right. So basically we are in the development phase to answer the question, because if we we are developing, but we are already operational also. But we continue developing in the forward looking flood risk assessment. It's a matter of several years of development

Files\\Interview Transcript Company H

1 reference coded, 1.62% coverage

Reference 1: 1.62% coverage

The direction of travel here is linked to digital product passport regulation that is being discussed both for batteries and other product streams, as well as moving into the areas of the new Eco design principles which chapter 3 of the sustainable product Initiative incorporates the need for traceability and transparency. So our aim in the next 5 years will be to continue our expansion out of polymers and chemicals into metals.

Files\\Transcript Company M

1 reference coded, 0.91% coverage

Reference 1: 0.91% coverage

And the second one was the regulations that are coming regarding that the companies need to calculate carbon footprints, so that was the additional rational behind the idea.

Example 3:

First order Concept - Mitigation vs Adaptation

Second Order Theme – The Climate Objectives

Files\\Interview 12- Company Y

1 reference coded, 1.96% coverage

Reference 1: 1.96% coverage

Okay, huge market need, which is the CSR; companies today need to be much more responsible, more sustainable, they have to create a communication strategy in order to, you know, to be understood as most sustainable as possible, because the market is requiring it. So we are interested in companies who need to integrate in their business reforestation, CO2 offsetting, and so on.

Files\\Transcript Company Z

1 reference coded, 6.62% coverage

Reference 1: 6.62% coverage

What market needs we tackle is that on the one hand, consumers everywhere want climate-friendly products and services and businesses have started waking up to that. But still for businesses, on the one hand, they see climate impact as a cost center, and they see it as something really challenging to do. It takes lots of time, takes lots of resource, and so on. So for those 2 reasons it's a cost center and it's difficult to do. For those 2 reasons businesses have been slow to act, and what we do at Lune is to make it really easy for them to integrate climate impact into their customer experience, starting with carbon emissions calculations and carbon offsetting, carbon removal. And when it's part of the customer experience the business can increase customer acquisition because they're elevating their brand as a sustainable Brand, they can increase customer engagement and customer loyalty and so on, and hit the their commercial growth metrics while having a positive impact on the planet. So we are shifting the mentality from climate as cost center to climate as a growth driver, and we're making it really easy with our software solution to do that.

Files\\Transcription Company N

1 reference coded, 2.39% coverage

Reference 1: 2.39% coverage

For customers, we so we give them a peaceful house which is sustainable and affordable. For the planet, you know if you don't have a roof on top of your head, you can't do anything right. But then, why why resolving the need should come at the cost of polluting the environment, both for building it as well as you know, operating it.

Appendix 11: Feedback Received from Climate-KIC

On July 2022 a workshop (on-line via Zoom) was organised with three representatives from EIT Climate-KIC (Knowledge and Innovation Community - KIC), the leading organisation in Europe working to accelerate the transition to a zero-carbon, climate-resilient society, by supporting climate start-ups. EIT Climate-KIC is an organisation based in The Netherlands, it is supported by the European Institute of Innovation and Technology, with the aim to identify and support innovation that helps society mitigate and adapt to climate change. In particular they have an Entrepreneurship Programme aimed at measuring and improving the positive climate impact of start-ups.

A one-hour workshop was carried out with three staff members from EIT Climate-KIC. The participants of the meeting were: Christine Roehrer (Entrepreneurship Programme Designer and Manager - Focused on Climate Impact); Emily Amann (Project manager, entrepreneurship), and Lia Montserrat Alvarez (Project manager, climate impact).

These were some of the main comments provided:

- What other sectors need to be included? Food production, agriculture. They will help with IT Food. Also construction (digital passports), textile and fashion industry.
- In relation to the second RQ, what we want to know is: How to start a company that is truly addressing CC? what is needed.
- Regarding a third potential RQ (what tensions exist), I have to be more specific "tensions between who and who".
- I need to improve the way I classify companies, e.g. Lego type or components that are needed. What are the blocks that form the basis for a company that is truly addressing CC in a positive way. All companies may have similar elements but in different combinations, and then do the mix and match. Another way is to categorise where is the money coming from, where is it going to, who is the client, and to which transaction is the positive CC impact allocated; make it a bit more abstract.

- Think on enablers: creators y facilitators, the former create while the later make something more efficient; the former are more independent, while the later depends on others.
- In terms of how to classify BM: Look at product/service and the way they integrate into the ecosystem, how are these companies connected, and do they collaborate. Also, where is the regenerative component, beyond compensating, mitigating, reducing.
- Another way to differentiate the interventions of the companies, is to look at if they focus on energy intensity or carbon intensity.
- Classify: if the solution is enabling others to do something, or direct mitigation. If it is enabling, distinguish between Energy or Carbon intensity at a user level.
- Look at CAIT date base for localised emissions of companies.
- I wonder whether and which of the companies that focus on carbon offsetting use CDM methodologies and tools and if they do not do that, which other methodologies and approaches they use. Maybe this is something to look into?
- Another question is the following: What are the attributes (or elements …) that distinguish a solution that is truly focused on generating a climate adaptation/mitigation impact from a solution that is used for greenwashing?
- Regarding NBS you might find this useful: https://naturebasedcity.climate-kic.org/reports/nature-based-solutions-tools-catalogue/

About the analysis of BM:

- Thesis from Tomás Santa Maria, University of Graz: What is known about business model innovation for the circular economy? How does it happen in the practice? and how can we facilitate its implementation in more firms?

https://unipub.uni-graz.at/obvugrhs/7901946?lang=en

- Experimenting with new business model strategies for the circular economy

https://www.researchgate.net/publication/351455712_Experimenting_with_new_business_model_strategies_for_the_circular_economy

- How do companies measure and forecast environmental impacts when experimenting with circular business models?

https://www.sciencedirect.com/science/article/pii/S235255092100292X#bib0007

- Other examples of BM / digital Startups /technologies of relevant sectors:

Construction – Materials Passport: https://www.metabolic.nl/news/circular-economy-materials-passports/

Fashion: Teemill https://archive.ellenmacarthurfoundation.org/case-studies/an-open-access-circular-supply-chain-for-fashion

Food waste: https://toogoodtogo.com/en-us

Appendix 12: List of conferences where this PhD research was presented

Conference Details	Title of Presentation
8th International Conference on New Business Models, Maastricht, The Netherlands. June 2023.	“Challenges faced by data-driven climate change start-ups”. Extended abstract.
31st Summer Research Academy, EDAMBA, Athens, Greece. July 2022	“Unpacking Digital Climate Solutions: A Sustainable Business Model Perspective”. Extended abstract.
7th International Conference on New Business Models, Rome, Italy. June 2022.	“Business Models Embedding Ecosystem Services to tackle Climate Change: The case of Digital Climate Solutions”. Extended abstract.
20th EUROMA Conference, Berlin, Germany. May 2022.	“Digital Climate Solutions: How emerging enterprises are responding to Climate Change and delivering value to customers and the planet”. Full paper.
Paper Development Workshop (PDW) for PhD students and Early Career Researchers, Birkbeck, University of London, Department of Management, November 2021, on-line	“Digital Climate Solutions: How emerging business enterprises are responding to Climate Change and delivering value to customers and the planet. Developmental Paper Roundtable”.
British Academy of Management, Doctoral Symposium, September 2021. Lancaster University Management School, on-line.	“Digital Technologies and Innovative Business Models for Enhanced Climate Action”.
6th International Conference on New Business Models, Doctoral Workshop, Halmstad University, Sweden, June 2021, on-line.	“Business Model Innovation for Enhanced Climate Action: A Digital Sustainability Approach”.
CEGBI Summer Conference, 2022 and 2023. School of Business and Society, University of York.	Presentation of different components of the PhD research at CEGBI – Centre for Evolution of Global Business and Institutions.

Appendix 13: Feedback received from various conferences (examples)

Some of the recurrent feedback comments were:

- Ensure the rigour of literature review analysis to gaps to research questions are there,
- Improve definition of climate start-ups (as well as other key definitions),
- Better define the phenomenon being study,
- Further develop the theoretical concepts,
- What is specific about DCS compared to the general start-up literature?
- Improve thematic analysis and clearly show the process for grouping, identification of themes, etc.
- Move from a descriptive phase to an explanatory one.
- What type of contributions companies make, whether they are able to live up to their promise of tackling CC; I could have an objective measure of it and a perception of it.

Specific feedback

NBM22:

Type of certification available for companies to demonstrate CC contribution; how to differentiate from green washing, meaning of locked-in services, what is the value to nature vs only from anthropocentric perspective.

EUROMA22:

Are companies solely relying on offsetting? Are the companies I´m studying non-for-profit? Are the BM scalable? How many trees need to be planted in order to be effective? What type of digital solutions are companies offering? Maybe a next step could be to do field work to check on companies 'claims. Maybe use Dynamic Capabilities theory to look at how companies are evolving (e.g. Alpha)

EDAMBA Summer Academy:

Even a small contribution is relevant in this field

I may be trying to achieve too much (why not concentrate on one aspect).

Keep in mind that it may be difficult to publish in a top journal based only on a qualitative research.

Each RQ may produce a different publishable paper.

Is the topic totally new? There may be related research looking at mechanisms 1 and 2 to solve a given problem (although in a different field). Check in literature.

It would be interesting to have access to results of changes in customers behaviour.

It would be convenient to add an agriculture case. I could probably do less cases, but go deeper in some of them.

The independent variable is the V_P (this is the starting point); then mediating variables, and the dependent variable is the impact on tackling CC.

Look at Millennium Ecosystem Assessment (MES) as a possible framework.

To understand value creation we need to understand the outcome. One thing is the intention of the ventures, and something different is the value creation.

Appendix 14: Abstract of a full Paper to be published in 2024

The Competitive Business for Saving the Planet: Unpacking Digital Climate Start-ups

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Abstract

Digitalisation and climate change (CC) are two of the main trends and dominant processes of social change of our time, although the discourses about them have run in parallel to each other and research on their interconnectedness is still scarce with little published on this. Through an empirical investigation, this research offers an early perspective on the topic by looking at the business opportunities emerging from the current climate crisis and the value offering developed by Digital Climate Start-ups (DCS), as there is an extended expectation that digitalisation could make a significant contribution to tackling the global challenge of CC.

This exploration of entrepreneurial firms is based on qualitative research, with the collection of primary and secondary data. It started with a mapping of over 200 European digital start-ups where addressing CC was at the heart of their value offering. Additionally, interviews were carried out with a sub-sample of 25 CEOs and Founders of these climate start-ups; these interviews provided an insight on how Digital Technologies (DT) are enabling new value propositions and what are the main characteristics of the emerging DCS.

The research question that guided this study was: *How do we unpack the value proposition of digital start-ups tackling climate change?* The findings suggest three attributes that should be addressed by DCS in order to have a meaningful value proposition. These attributes constitute their climate credentials.

Keywords: Business models for sustainability, value proposition, climate change, digital climate start-ups, climate credentials.