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

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Abstract

This research contributes to the debate at the intersection between Climate Change, BMfS and Digital Technologies (DT). Using a qualitative methodology, it provides an insight on how DT are enabling new value propositions that incorporate the objective of tackling climate change as part of their business models. It is expected that the theoretical framework that will emerge from this case-based research will advance and stimulate new approaches to inspire entrepreneurs and institutions to make further progress in Digital Climate Solutions (DCS), and that it will also support them in understanding how the business model and its value proposition can benefit the natural environment.

Keywords: Business Models for Sustainability, Digital Climate Solutions, System Dynamics.

Introduction

Addressing climate change (CC) through business-based solutions is a well-recognised necessity, as has been highlighted in the recent IPCC Report (2022), stressing the need to move from science to solutions and to implementation. Thus, there has been a growing effort to understand the role and the need to engage businesses to tackle CC, as businesses have a significant potential to finance projects, develop technologies and innovations, and deploy these solutions on the field at a global scale, thus enhancing the reach and effectiveness of CC measures (Averchenkova *et al.*, 2015).

The rapid development of digital technologies (DT) in the last few years has empowered new business solutions with the potential to significantly contribute to this challenge. We define DT as 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. Similarly, Digital Climate Solutions

(DCS) are solutions that use DT as a core element of their value offering and that have been developed with the purpose of tackling climate change.

This paper addresses the gap of knowledge and opportunity at the intersection and synergies between new Business Models (BM) addressing climate change and digital technologies for sustainability.

The research question addressed in this paper is: *How are new business models based on Digital Climate Solutions (DCS) supporting climate change actions?*

The remainder of this paper is organised as follows. The next section covers the literature review. This it is followed by the methodology section on qualitative methods. Next, some key preliminary results are presented. After that, the discussion of findings in the context of the literature are presented. Finally, conclusions including summary, limitations and future research opportunities are provided.

Literature Review

The concept of BM for Sustainability (BMfS) was first mentioned in the academic circle by Stubbs (2008, p.103). She defined BMfS as *"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). In fact, BMfS are defined as BMs incorporating concepts, principles, or goals that aim at sustainability, or integrating sustainability into their value proposition, value creation and delivery activities, and/or value capture mechanisms (Cosenz *et al.*, 2019, Minatogawa *et al.* 2022).

According to Gregori and Holzman (2020), DT contribute to the development of new value propositions that combine environmental, social and economic value. Digitalization is also seen as a 'problem solver' for CC (Lenz, 2021) and can contribute to the development of smart solutions to many environmental problems related to CC in sectors, such as: health, farming, food security, manufacturing, among others (Eteris, 2020). Falk and Gaffney (2020) concluded that DT could help reduce global carbon emissions by up to 15%, which is also one-third of the 50% reduction required by 2030. This could be achieved through DT solutions in sectors such as energy, manufacturing, agriculture and land use, buildings, services, transportation and traffic management. It is also true that DT may have several unintended consequences, as it is high energy consumption, the dominance of large technology companies centralising power in few hands, data privacy issues, among others, in what may be called destruction of sustainable value (Bocken et al., 2013, in Bohnsack *et al.*, 2022), although this research is focussing on the intended positive outcomes of DCS.

According to George *et al.* (2019), entrepreneurs are already employing DT to address key sustainability challenges, not only through technology innovations, but also through the development of business models (BM) that provide a new purpose to the innovations. In fact, the investigation of innovative BM, a key component of enterprises, has just started to receive attention from sustainability management research, and has been identified as one of the main avenues for future research (Schaltegger *et al.*, 2016). Finally, it has also been stressed that research on BMfS has not only to be practical (the dominant tendency), but there needs to be a clear foundation in organization theory as well (Pinkse, 2020).

Methodology

The topic of this research is well suited for a qualitative methodology, as it is about understanding the aspect of interconnections. In addition, 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 a topic (Bican and Brem, 2020). In the same sense, applying a qualitative research design enables an adequate study and description of the complex relationships of various business model components, their exemplification, and the materialization of multiple institutional logics (Gregori and Holzman, 2020). Furthermore, through qualitative methodology we can better understand how things work in the particular context under study. In words of Mason (2012, p.1), it allows us to *"engage with things that matter, in ways that matter"*.

This method offers the opportunity of a holistic view of a process (Gummesson 1991, in Patton and Appelbaum, 2003), and also allows an investigation to retain the holistic and meaningful characteristics of real-life events (Ying 1984, in Patton and Appelbaum, 2003). 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". The justification for cases studies also rests on the phenomenon´s importance and the lack of visible theory and empirical evidence (phenomenon-driven research questions).

This study is based on multiple case studies. It started with a desk-based analysis of the UK Net Zero Tech Nation Program companies (https://technation.io/) and was later complemented by the inclusion of other leading DT companies. The objective was to obtain a wide understanding of business opportunities being tackled and value propositions being developed in relation to digital technologies and climate change. Tech Nation Program was selected to provide a coherent sample of highly innovative tech companies that are working towards climate change.

A pilot phase of interviews was performed in order to test and refine the questionnaire. Four UK companies were selected using the criteria: Business Models (BM) based on digital sustainability, companies with BM oriented or related to tackle CC, provision of services to others (B2B or B2C), innovative performance, and growth potential. For the full data collection, the scope was expanded to companies in the rest of Europe.

In terms of data analysis, this was preliminary organised, creating systematic indexing categories. It has to be considered that the data obtained is predominantly text-based, which according to Mason (2012) supports the rationale for cross-sectional indexing. The initial objective of this systematic overview of the data was to establish whether and how well the data addresses the research questions. The indexing categories were produced based on interpretative and reflexive reading (instead of more literal reading). Similarly, 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 obtained from the interviews was not expected to be concrete and tidy labelled variables, but instead loose and flexible groupings of unfinished resources, primarily developed 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 on the basis of ongoing interpretation of data.

Finally, a final phase of semi-structured interviews was used as the primary sources of data. Interviews were guided by a questionnaire on strategy, KPIs and BM design. Ten CEOs and founders of companies were interviewed online for 45 minutes approximately via video conference. Questions included: specific market needs being addressed, main innovation being proposed, customer value proposition, environmental value proposition, value capture and value creation mechanisms, CC objectives and KPIs, and description of the digital technologies and climate strategies. Companies were mainly start-ups from the UK and Europe, and were selected based on recommendations and referral by related

official programs (e.g. Net Zero program, EIT Climate-KIC) and other sources (e.g. Tech Nation program, web searches, experts on the field). Secondary data was collected from publicly available reports, websites, newspaper, and journal articles. ***Figure 1*** shows the general framework for analysis and the type of information sought from the interviews.

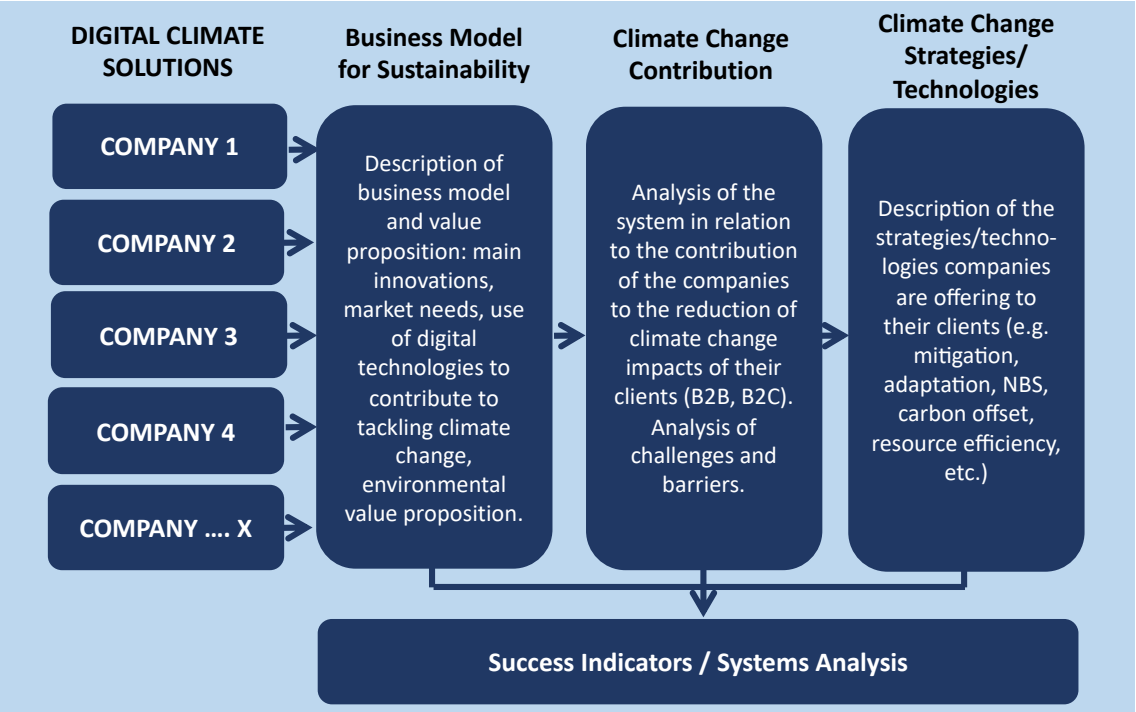

Figure 1 *- General framework for data analysis*

Table 1 summarises the three stages of the research.

Table 1*: Main stages considered for the research*

Stage	Description	Objective
Desk-based analysis	Revision of general information related to 60 companies that are part of Tech Nation Net Zero Program and other companies of interest. Particular attention to value proposition, focus on mitigation vs adaptation, and sectors being targeted.	Contribute to an initial understanding of the needs and sectors being targeted by emerging companies addressing climate change in the UK; understand what type of climate solutions are being offered and the relevance of digital technologies within this offering. Have a preliminary description of some BMfS.
Pilot phase interviews	Selecting and interviewing CEOs or high-level executives of four companies related to climate change and digital technologies.	Testing of the research questions initially defined, as well as the methodology and criteria for selection. Identification of climate change opportunities for DT.
Final phase interviews	Selecting and interviewing CEOs or high-level executives of ten companies offering Digital Climate Solutions.	Understand their customer value proposition, environmental value proposition, value capture and value creation; and its connection with climate change impacts. Apply the systems thinking approach and propose a general framework for analysis.

Preliminary Results

Desk-based Analysis

Based on the desk-based analysis of the companies that are part of the UK Tech Nation Net Zero Program, two types of value propositions were found: mitigation and adaptation value propositions. From the group of 60 climate tech companies that are part of this program, around 90% of the companies focussed on mitigation value propositions.

Mitigation value propositions include services to identify and invest in sound carbon offset projects, with the visualisation of the impact of their investments, and monitoring it along time. Adaptation value propositions include services to identify, prevent, anticipate, and mitigate the impacts of CC on companies´ assets.

75% of these companies are CC natives (i.e. were created with the aim of tackling CC), and 70% of them have DT as part of their value proposition. The most commonly mentioned sectors are: transport, energy, construction and food, although very often these companies declare to be agnostic to sectors (implying that their value proposition is wide reaching).

DT include: AI, ML, IoT, blockchain, satellite images, among others, and business models usually consider a combination of these technologies. Some of these companies improve the CC decision-making process for their clients (e.g. deciding on a portfolio for carbon offsetting), others deal with CC risks (insurance, smart contracts, climate intelligence) while others attempt to directly contribute to carbon sequestration through the restoration of ecosystems or the promotion of tree planting.

As part of this desk-based analysis phase, BM of selected companies were also studied in order to get preliminary insights. ***Table 2*** shows some of the main characteristics of Ecosia´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 also highlighted by the company.

Table 2*: General description of value proposition of the company Ecosia*

Company Description	
Ecosia 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 Ecosia´s website).	
Value Proposition (customer & environmental value proposition)	Value for the Planet (final impact on climate change mitigation)
▪ Internet search engine. ▪ Search ads generate income for Ecosia. ▪ Ecosia uses this income to plant trees. ▪ They don´t sell the data to advertisers and has no third party trackers. ▪ 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 compay will replace it at no additional charge. ▪ Ecosia is powered by 200% renewable energy. Their solar panels produce twice the	▪ They plant native species where they are needed most; monitor the trees for at least 3 years; share 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.

amount of energy needed to power all searches with renewables. ▪ They are transparent about everything they do, publishing detailed financial reports and frequent updates from their tree planting projects. ▪ They publish monthly financial reports and tree planting receipts. This way they can be holded accountable in their "journey to a reforested world". ▪ Planting, monitoring and protecting one Ecosia tree costs €1.	▪ Fight desertification.

Pilot Phase

The pilot phase took place in July 2021. ***Table 3*** details the four participating companies.

Table 3*: Companies in the pilot study*

Company	Interviewees	Company Description
A	2 people: ▪ Founder & CEO ▪ Chief Climate Risk officer	This is a new highly innovative UK company that provides "On-demand Climate Intelligence". The company seeks to help companies and governments to make informed business decisions to better manage climate risk. Through their platform, they deliver on-demand, personalized and actionable Climate Intelligence, providing access to current, historical and predictive insights on how combined risks such as flooding, droughts, and extreme temperatures will impact the assets owned by their clients.
B	1 person: ▪ Principal Environmental Data Science Consultant	This is a highly specialised business unit dependant from a UK University. They provide consulting services on big data analytics. They also provide training on environmental applications of big data. Their vision is to harness the power of big data using cutting-edge expertise in big data analytics and visualisation to the benefit of clients, providing meaningful and effective communication of data to give commercial value.
C	2 people: ▪ CSR Manager ▪ Corporate Sustainability Project Manager	This is a platform that seeks to democratize access to data and enable enterprises to build their own path to AI in a human-centric way, through data preparation, visualisation, machine learning, data ops and analytic Apps. This is a French company with offices in London and was valued at more than 1 billion USD a few years ago and currently has more than 400 employees.
D	1 person: CEO & Founder	This company seeks to help businesses to invest in the fight against climate change. Their science-backed natural solutions help companies balance their carbon impact – and go beyond, to become climate-positive. All the solutions are recommended by an Independent Scientific Board of Advisors. And through their immersive platform clients can see and share their positive impact.

The primary objective of the pilot was to inform the general methodology (research questions, criteria for selecting companies, strategy for data analysis, questionnaire for interviews). As a result, some improvements were made before going to the final stage, in particular, the research questions were modified, new questions were added to the interview questionnaire while others were eliminated, and the criteria for selecting companies were expanded to include companies beyond the UK. In addition, a decision was made to concentrate on companies offering services based on DT (as opposed to products) and specifically aiming at mitigation (as opposed to adaptation).

Another objective of the pilot phase (together with the desk-based analysis) was to obtain a preliminary view of some of the business opportunities arising from Climate Change where DT can add value. ***Figure 2*** summarises the main opportunities identified from the desk-based analysis and pilot interviews:

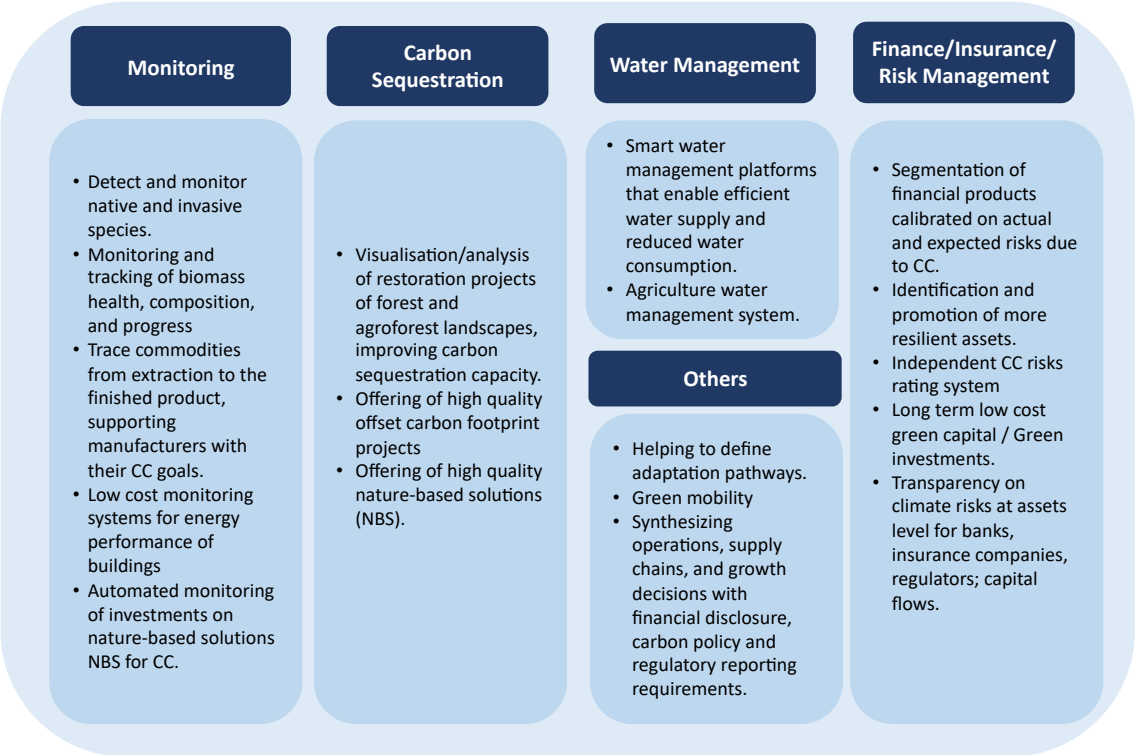

Figure 2 *- Business opportunities identified from the pilot study and desk-based analysis.*

Another relevant aspect was the separation of DCS focussing on mitigation from those focussing on adaptation. 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).

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.

Finally, some of the barriers identified in this stage to further DCS include: the need to build credibility and climate literacy, the ability to collect the best possible data, 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.

Final Phase

The final phase of this research, currently under development, seeks to refine the analysis by interviewing 1ten companies. Based on the model proposed by Abdelkafi and Täuscher (2016), ***Figure 3*** shows a preliminary general logic of a BMfS for the company Alfa (a pseudonym), the first company interviewed in this final phase. Alfa has developed a software to make it easy for companies to integrate climate impact information (measuring and offsetting) into the products they sell, becoming part of their customer experiences.

Thus, the primary clients of Alfa (i.e. retailers) are able to embed a climate impact approach into their products, making it easy for their clients to know the carbon footprint associate with the products they are buying. The software also allows the clients to choose how they want to offset the carbon footprint of their purchases, by choosing from alternative offsetting projects. For this purpose, Alfa has partnered with several high-quality carbon offset project developers.

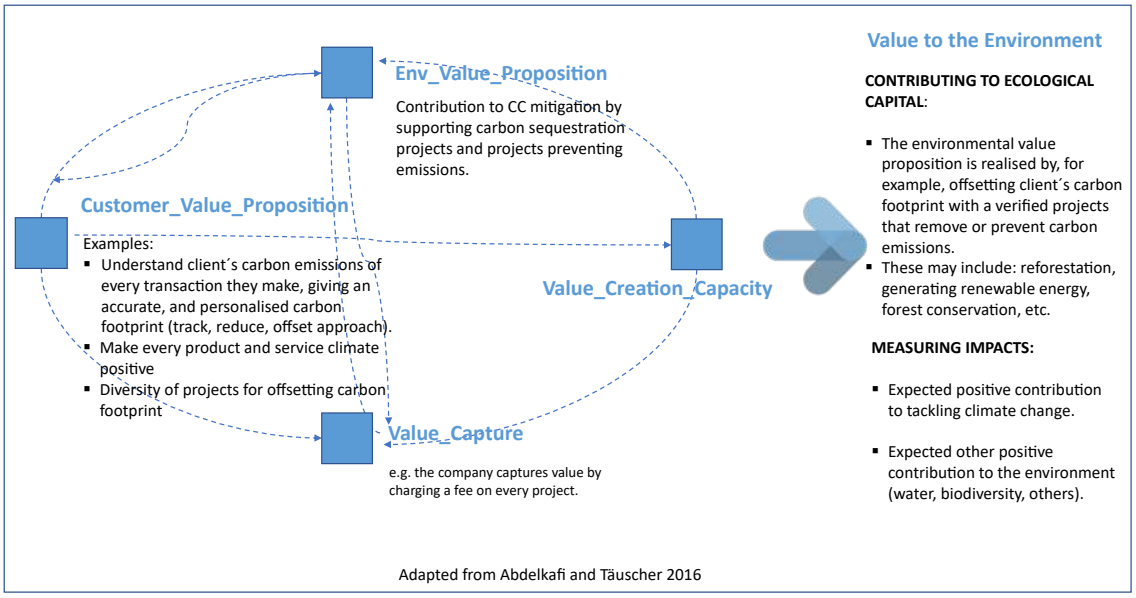

Figure 3 *- Generic Logic of Business Models for Sustainability: the case of DCS.*

Following the findings by Abdelkafi and Täuscher (2016), the above figure represents the intended impact from the firm´s perspective (Alfa and their clients). The arrows in this diagram show a reinforcing feedback loop between, for instance, the customer value proposition and the environmental value proposition, as clients of the retail company are expected to value the information given in relation to the carbon footprint of their purchases (together with the possibility of choosing an offsetting project) and, subsequently, will be more open to keep buying in this store. In turn, the environment will be benefited by the offset projects that the company is sponsoring (on behalf of their clients). In our research, we are also attempting to expand this model and represent the actual impact of the business model on the environment, by identifying the contribution to ecological capital and the mitigation actions which are being proposed. These are expected to be achieved through the value creation capacity indicated in the BM. For this a system thinking approach will be applied.

From the interviews performed so far (including those from the pilot phase), 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 most of the analysed cases were concerned with

mitigating climate change through some type of carbon management offering. One key finding was that most of the interviewed companies looked to support their value proposition based on science by, for example, having a scientific board as part of their organisational structure.

The range of identified solutions ranged from measuring the carbon footprint of products, services, consumers, software designers, to providing options for offsetting the carbon footprint of both individuals and companies. At the same time, many of these solutions promised to evaluate and transparent the "climate credentials" of companies (which in the end may be related to access to capital, access to markets, reputation, legal commitments, attraction of talents, etc.). For all of these they relied on a chain of partners and suppliers. 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 done by nature).

Discussion and Conclusions

The research question addressed in this paper was: *How are new business models based on Digital Climate Solutions (DCS) supporting climate change actions?*

In order to answer this question, empirical research was conducted based on an interpretative approach. The study involved the collection of primary and secondary data. Primary data was obtained from multiple case studies through semi-structured interviews of companies (CEOs, founders or high-level managers) while secondary data was mainly obtained from publicly available information from companies' web sites. The aim of secondary data was to obtain a wide overview of the state of the art in terms of DCS being developed. The analysis of primary data was carried out through thematic/content analysis, as it was predominantly text based, and was organised by creating systematic indexing codes/categories. The companies were selected based on recommendations obtained from various specialists in the field and from technical publications highlighting leading companies on DCS.

This paper provides preliminary illustrative examples of DCS and the design of their BM in real organisations, showing their value propositions to tackling CC and showing CC as an engine of sustainable value creation. It also provides a preliminary taxonomy of DCS and identifies some of the business opportunities related to the challenge of CC.

The main limitation of this research is that it is based on qualitative interviews which can provide rich data but they cannot be used for generalisation of results. In addition, the system dynamics approach has yet to be developed to propose a meaningful framework thus contributing to management theory.

In terms of areas for future research, as other studies on this area of BMfS and system dynamics have suggested (references?), there is a clear need to further look into the interdependencies among key elements of the BM value proposition, particularly looking at how the outputs may contribute to tackling climate change, what key elements are shaping their BMfS and outline the causal interdependencies among them, as well as looking at the extension of the value creation process beyond the limits of a single firm. Based on these it is expected that a system dynamics perspective on the DCS and their BM may provide a strategy design tool to be used on a regular basis.

Future research could also focus on moving from an empirical perspective in the design and the adoption of BMfS in the context of DCS, to a more conceptual development. Furthermore, when it comes to understanding the contribution of these emerging DCS to tackling CC, it is also important to understand first and second order consequences on and across different levels (positive and negative), as has been highlighted by other researchers in the field (e.g. Cosenz *et al*., 2019).

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