

Digital Technology for Decarbonisation: Sectoral and Location Significance for the Net Zero Transition

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Abstract

Building on an ongoing empirical study that explores the links between sustainability and digital technologies, the paper reports on the significance of industry sector and locality in understanding these links. Although the adoption of digital technologies is driving economic, social and environmental changes worldwide, concerns have been raised that the digital transformation risks further environmental damage. The paper presents the results of a systematic literature review exploring the current state of knowledge about the use of digital technologies for decarbonisation by sector and region. The analysis confirms uneven utilisation of digital technologies for the Net Zero transition, linked to the maturity of the political, economic, social and regulatory factors for Net Zero. This analysis will inform the next phase of the study via a Delphi methodology. The study will elaborate on the ways in which the digital transformation can enable positive engagement with the Net Zero transition.

Key words: digital transformation, digitalisation, decarbonisation, Net Zero, Net Zero transition, systematic literature review

Introduction

A Net Zero policy initiative is a key area of policy in response to climate change. The UK government has maintained its commitment to Net Zero over the last few rounds of the national industrial strategy. In 'The UK Industrial Strategy: Building a Britain fit for the future' (BEIS, 2017), the government maintained previous climate change commitments and established clean growth as one of the Grand Challenges, while pledging support to 'maximise the advantages for UK industry from the global shift to clean growth' (BEIS, 2017:34). The strategy emphasised the importance of digital technologies as foundations of productivity and economic growth with the potential to create prosperous communities across the UK.

A recently released green paper on UK industrial strategy (DBT, 2024) states that growth is the number one mission of the present government. Clean energy industries and digital technologies have been identified in the sectors that are strongest at driving growth. It is argued that optimism about Net Zero is justified by the UK's world-leading track record of decarbonisation, underpinned by the Climate Change Act. The UK was the first major economy to halve its emissions, cutting them by 50% between 1990 and 2022, while also growing the economy by 79% (DESNZ, 2024). The UK is also world-leading in making one in three products vital to the Net Zero transition (IPPR, 2024). There is a clear appetite for diversification of the clean technology specialisms across the UK (Financial Times, 2024) and growing ambitions to enable the UK to achieve clean power by 2030 and accelerate the Net Zero transition across the economy.

Throughout national and local policy documents, Net Zero, decarbonisation and digital technologies go hand-in-hand. Yet it is recognised that the Net Zero transition presents significant challenges as well as opportunities for businesses to lead the industrial transformation towards a sustainable future (McKinsey, 2022a). The way businesses operate and contribute to sustainable development is currently argued to be insufficient; experts continue to encourage businesses to accelerate the scale and pace of such a transformation.¹ The role of digital practices in the Net Zero transition and a broader sustainable development agenda is yet to be fully understood (e.g. Dwivedi et al., 2022).

In this study, we explore the potential of digital technologies to enable successful engagement with the Net Zero transition. The study aims to address the following research questions:

- *How can the digital transformation enable successful engagement with the Net Zero transition?*
- *What assumptions are currently being made about the role of digital technologies in the Net Zero transition?*

The paper proceeds with a review of the literature on the digital transformation and the Net Zero transition and the impacts of digital technologies for decarbonisation and Net Zero. It moves onto

¹ <https://forwardfaster.unglobalcompact.org/>

outlining the study design and methods and reporting the early results of the systematic literature review phase of the study.

Initial Literature Review Phase

The Digital Transition and the Net Zero Transition

The literature on the role of the *digital transformation* in supporting the *Net Zero transition* is growing. Okorie et al. (2023) identify 21 digital technology-based core competencies as forms of competitive advantage that may be possible for manufacturing firms pursuing Net Zero emissions. The digital technology adoption scenarios are proposed depending on radical versus incremental change pathways. Cao et al. (2023) articulate the key digital technology innovations necessary for the digitalization of the energy system transition and concerns in terms of data privacy and security.

The latest MIT technical report on the role of digital in the Net Zero transition (MIT, 2023) argues that digitalization is the backbone that will support clean energy transition. Digital enables decarbonisation due to an ability to process more data more effectively, identify problems faster, and test solutions virtually. Energy-intensive systems can achieve efficiency gains from digital and Web3 technologies such as cloud and edge computing, internet of things (IoT), artificial intelligence (AI), machine learning (ML) and blockchain technology (MIT, 2023). Empirical data is emerging on the impact of digital technologies on greenhouse gas (GHG) emissions. PwC (2023) calculates that AI alone can reduce global GHG emissions by 4% by 2030. The World Economic Forum (WEF,2022) and Accenture (2023) state digital technologies can help the energy, materials, and mobility industries reduce emissions by between 4% and 10% by 2030.

Despite experts being positive about the role of digital in the Net Zero transition, some approach this issue with caution. According to Professor Adrian Friday, Professor of Computing and Sustainability at the University of Lancaster, ‘Digital technology lets us do things differently and it has huge potential to help achieve Net Zero – if used responsibly. That means thinking much more carefully about how the entire system impacts on the planet and society. It’s more than the energy efficiency of a video call, or the emissions to build the digital infrastructure that keeps the internet running and growing. It’s how these technologies change our society and habits’ (MIT, 2023).

Throughout the academic literature, a range of positives and challenges are identified in relation to the digital transition for Net Zero (see summary in Table 1).

[insert Table 1 here]

The importance of geographical location and energy sector performance for energy transition is getting attention in both the professional and academic literature. A report on energy transition (McKinsey, 2022b) suggests that countries fall into five main archetypes with respect to their opportunities and priorities for an orderly energy transition: (1) affluent, energy-secure countries (Australia, Saudia Arabia, US); (2) affluent, energy-exposed countries (Germany, Italy, Japan); (3)

large, emissions-intensive economies (China, India, South Africa); (4) developing, naturally endowed economies (Brazil, Indonesia, Mexico) and (5) developing, at-risk economies (Africa, South Asia). This categorisation of countries reveals that the burdens of the energy transition, and each region's ability to meet the challenges of adaptation and mitigation, will not be evenly distributed. Global cooperation and coordinated collective action across multiple stakeholders beyond current levels will be needed. The report highlights the importance of geopolitics and financial flows in acceleration energy transition across these archetypes:

“The pathway to mobilizing global financial flows from more affluent to more at-risk countries is still unknown, but our analysis indicates that developing countries can benefit from readily available solutions such as abatement and avoidance of coal expansion or methane emissions, which increased financing flows can catalyze. Similarly, affluent countries would benefit from greater availability of critical natural resources from developing countries, which would require investment in the sustainable extraction and processing of these resources” (McKinsey, 2022b).

Digital technology is set to play a pivotal role in addressing these tensions by removing so-called physical blocks and economic and social blocks of energy transition. This includes modernizing and repurposing legacy infrastructure and creating new assets to accelerate the integration of renewables and cleantech into the energy system and managing economic dislocations to promote energy affordability and create fair opportunities for affected and at-risk communities (McKinsey, 2022b).

Methodology: Problematisation, Systematic Literature Review, Delphi Study

This study adopts a problematisation approach (Alvesson and Sandberg, 2011), which aims “to come up with novel research questions through a dialectical interrogation of the domain of literature targeted for assumption challenging, instead of spotting gaps within a literature domain” (p. 252). Based on Alvesson and Sandberg (2011) and Dieste et al. (2023), the study follows a set of six methodological principles (see Table 2) regarding how assumptions in existing theory can be problematised and used to generate new research propositions.

[insert Table 2 here]

A preliminary literature review (reported above) was used to initiate the study, providing an initial approach to the first three stages set out in Table 2 (identifying literature domain; identifying, articulating and evaluating assumptions). A systematic literature review was then undertaken to develop an alternative set of assumptions (moving into the fourth stage, as explained in Table 2). In the fifth and sixth stages, a Delphi study will be designed and conducted, and findings elaborated.

This paper focuses on the systematic literature review. The papers were identified through a Scopus search for the terms “decarbon* OR “net zero” AND digital*”. This returned 1,950 results from 2006 to the end of 2024. After the removal of duplicates, introductions to conference proceedings, erratum, non-English papers and announcements the papers for review numbered 1,942.

As the scope of the results was very broad, the research team began by seeking an initial understanding of where current research into digitalisation and decarbonisation was focused. A spreadsheet of all articles was produced from Scopus and uploaded to NVivo, where abstracts were coded in preparation for review. The coding concentrated on three areas: the sector the article focused on, the technologies discussed, and whether there was a country or regional focus.

The UN's International Labour Organisation² was consulted to obtain a definitive list of industries/sectors; this was used as a guide for sector coding. The technology coding was divided into two areas: technologies that have been identified as key to decarbonisation, such as carbon capture and storage, renewable energy generation, hydrogen, and biomass (Nurdiawati and Urban, 2021); and those associated with digitalisation and Industry 4.0, such as Digital Twins, Big Data, AI, Internet of Things (IoT), etc. (Liu et al., 2022; Ghobakhloo, 2020). These terms were searched for alongside abbreviations and any associated terms, e.g., "Advanced Manufacturing" is an umbrella term for 3D printing and additive manufacturing. Additional terms were identified from the abstracts as they were being coded. Countries and regions were identified while reading the abstracts. In the case of the UK, the nations were searched for individually and included, as well as Great Britain. Each time a paper was associated with a code, the full abstract was coded to ensure minimal repetition of the articles and to allow for cross referencing of the codes in the creation of the data matrix visualisations.

Findings

The preliminary results of the systematic literature review indicate an uneven utilisation of digital technologies for the Net Zero transition, perhaps linked to the maturity of the political, economic, social and regulatory factors for Net Zero. For instance:

[insert Tables 3 to 5 here]

- Country/regional focus: the majority of existing studies focus on Europe/EU, UK and China (Table 3)
- Industry focus: the majority of studies focus on petrochemicals, built environment and construction, energy and electric vehicles (Table 4)
- Focus on decarbonization technologies: the majority of studies focus on renewable energy, hydrogen and carbon capture (Table 5)
- Focus on digitalization technologies: the majority of studies focus on digital twin, AI, IoT and blockchain (Table 5).

[insert Tables 6 to 8 here]

² <https://www.ilo.org/industries-and-sectors>

An analysis that maps sector by region indicates likely differences; for example, while studies based in Europe/EU and UK lean towards the built environment & construction and oil & gas, studies in China lean towards energy and coal (Table 6).

Table 7 shows the five most discussed technologies for decarbonization. Across Europe/EU, UK and China, the most studied topic is renewable energy, followed by carbon capture and hydrogen.

Finally, Table 8 suggests some differences in technology utilization by sector. While studies in the oil & gas sector focus on carbon capture, hydrogen and renewables, most studies on AI are focused on the built environment and construction or the energy sector more generally.

These preliminary findings of the systematic literature review are currently the focus of further analysis, to complete the fourth stage of the problematization approach (developing alternative assumptions, see Table 2) and to inform the fifth and sixth stages where the above points will be explored further.

Next steps

The authors are currently synthesising the outcomes of the systematic literature review to develop a conceptual framework for a Delphi Study. The study is scheduled to be deployed July-September 2025 with preliminary results from the first round of Delphi being available for presentation at the BAM Conference (September 2025).

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Table 1: Identifying positives and challenges of the digital transition for Net Zero
(Source: Authors)

Positives of digital for Net Zero	Challenges of digital for Net Zero
Enabling decision-making and effective governance of Net Zero	Data heterogeneity, data privacy and data security (Cao et al., 2023)
Decarbonisation initiatives supported by digital technologies	Lack of resources for digital in SMEs (Sonar et al., 2023)
New technologies such as the IoT, sensors and big data analytics can reduce the resource and energy consumption of manufacturing activities through detection and data analysis (Bai et al., 2020)	Lack of business support for digital (Sonar et al., 2023)
Better working conditions due to more ergonomic and safer tasks as a result of adoption of human-machine interaction technologies (Muller and Voigt, 2018).	Shortages of green skills and digital skills (Skidmore, 2023)

**Table 2: Proposed research process, adopting a problematisation approach
(Based on Dieste et al. (2023) and Alvesson and Sandberg (2011))**

Principles for identifying and challenging assumptions	Description
1. Identifying a literature domain: what main bodies of literature and key texts make up the broader domain?	Preliminary review of key texts on the digital transition and sustainability
2. Identifying and articulating assumptions: what major assumptions underlie the literature within the identified domain?	Identification of assumptions to be challenged regarding the digital transition and sustainability
3. Evaluating articulated assumptions: are the identified assumptions worthy of challenge?	Identification of preliminary evidence regarding impacts of the digital transition on sustainability
4. Developing alternative assumptions: what alternative assumptions can be developed?	Literature review on the sustainability impacts of the digital transition, to identify and develop alternative assumptions
5. Relating assumptions to audience: what major audiences hold the challenged assumptions?	Selection of an expert panel and development of a Delphi study
6. Evaluating alternative assumptions: are the alternative assumptions likely to generate a theory that will be regarded as interesting and useful by the targeted audiences?	Discussion of the results of the Delphi study

Table 3: Top 10 countries/regions by paper focus

Europe & EU	233
UK	138
China	110
Germany	62
Russia	35
Italy	33
India	32
Canada	29
Australia	26
Japan	25

Table 4: Top 10 industries identified by paper focus

Petrochemicals	165
Built Environment & Construction	150
Energy sector	133
Electric vehicles	107
Transport and Logistics	53
Steel	48
Chemical	47
Minerals	45
Mining	43
Business	37

Table 5: Technologies by paper focus

Decarbonisation Technology	Papers
Renewable Energy	382
Hydrogen	202
Carbon capture	168
Solar Energy	134
Wind Energy	77
Biomass	41
Nuclear Energy	29
Tidal Energy	4

Digitalisation Technology	Papers
Digital twin	150
AI	139
IoT	90
Blockchain	85
Industry 4.0	55
Big data	47
Cloud computing	17
Advanced manufacturing	15
VR	10
AR	9
Quantum computing	4

Table 6: Top 5 sectors in the top 10 countries/regions

Place/Sector	Built Environment & Construction	Electric vehicles	Energy sector	Coal	Oil and gas
Europe & EU	15	9	12	10	14
China	8	3	11	10	6
UK	13	12	5	2	9
Russia	0	1	5	3	3
Germany	3	3	5	1	2
India	1	3	1	4	3
Australia	4	1	1	3	1
Canada	1	1	1	1	7
Ukraine	0	0	3	1	1
USA	1	1	2	2	2

Table 7: The five most discussed technologies for decarbonisation by country/region (top 10)

Place/Tech	Carbon capture	Hydrogen	Digital twin	Renewable energy	Solar
Europe & EU	23	24	10	41	17
UK	12	15	12	17	4
China	13	5	4	18	3
Germany	2	7	1	11	5
Italy	1	6	3	9	5
Japan	2	6	0	6	3
Canada	5	4	2	4	4
Australia	4	4	0	5	5
Russia	1	3	1	6	0
India	1	4	2	5	1

Table 8: Which top 10 sectors are looking at which top 5 technologies?

Sector/Tech	Carbon capture	Hydrogen	AI	Digital twin	Renewable energy
Oil and gas	39	31	8	5	24
Energy sector	12	13	15	3	31
Built Environment & Construction	5	3	14	25	10
Electric vehicles	2	9	8	6	28
Transport and Logistics	4	6	5	7	5
Chemical industry	12	9	3	3	7
Steel	8	11	2	1	7
Mining	3	7	2	2	8
Minerals	9	4	2	0	6
Manufacturing	0	0	5	3	2