Projects as Vectors of Change: A Transition Toward Net-Zero Sociotechnical Systems

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Abstract

As vectors of change, projects are essential for the Net-zero transition. Yet, the project studies literature largely ignores the Net-zero transition and Net-zero projects, i.e. projects which are vectors of change enabling the transition toward Net-zero sociotechnical systems. Leveraging a systematic literature review, we identify four types of Net-zero projects: New Assets, Upgrade Assets, Behavioural Intervention, and Research, Development and Demonstration (RDD). We present how Net-zero projects can enable the transition of sociotechnical systems toward Net-zero: reducing emission intensity or quantity. Finally, we underline the heterogeneity of Net-zero projects in terms of complexity, barriers, benefits realisation timespan and complementarities.

Keywords: Net-zero projects; Sustainability transition; Decarbonisation; Grand Challenges; Projects as vectors of change

Introduction

In the last decades, project studies have increasingly paid attention to the sustainability aspects of projects (Sabini, Muzio, & Alderman, 2019; Silvius & Schipper, 2014). The field of sustainable project management has made significant contributions in various areas, such as challenges associated with the adoption of sustainable practices within projects (Kivilä, Martinsuo, & Vuorinen, 2017), examining the motivations of project managers in implementing sustainable practices (Silvius & Schipper, 2020), and investigating the impacts of sustainable practices on project success (Carvalho & Rabechini, 2017).

When considering the dichotomy between "sustainability by" and "sustainability of" the projects (Huemann & Silvius, 2017), the majority of existing contributions in the field of sustainable project management primarily focus on the dimensions of "sustainability of" the project. As pointed out by Winch (2022), there is a gap in the exploration of the dimensions of "sustainability by" projects, particularly in understanding how projects can contribute to systemic transitions, also referred to as sociotechnical transitions (Köhler et al., 2019). This gap calls for new theories within the field of project studies and to foster cross-fertilisation between project studies and transition studies (Davies, Manning, & Söderlund, 2018; Winch, 2022).

Only three studies explicitly examined projects in the context of sociotechnical transition. Papachristos et al. (2024) and Papadonikolaki et al. (2023) conceptualised projects as niches or mechanisms for the adoption and diffusion of digital technologies in the construction industry. Their papers theoretically contribute to the analysis of sociotechnical transition by presenting a novel typology of sociotechnical transition where new technologies or practices are spread from the core organisation to peripheral organisations. Similar kinds of sociotechnical transitions, where usually peripheral organisation challenges the incumbent, were overlooked in transition studies. Lenfle & Söderlund (2022) contribute to the pressing issue of agency identification in sociotechnical transitions as highlighted by (Geels, 2011). They highlight how projects, as a collective effort, enable transitions and, therefore, hold agency in the transition process. Their study suggests identifying the "reverse salience" (i.e. actors or components hindering sociotechnical transitions) and establishing projects with them to overcome established lock-in. Considered all this background is surprising the lack of studies investigating the role of Projects for Net-zero transition. Project scholars seem not interested in the topic of Net-zero; indeed, none of the leading journals (PMJ, IJPM, IJMPB, and PLAS) ever published on the topics of Net-zero and Net-zero transitions.

The sustainability-related literature counts hundreds of articles addressing the Net-zero transition by focusing on specific sociotechnical systems and specific technologies. Yet, this sustainability-related literature, is not explicitly interested in projects as a unit of analysis, if not anecdotally. For instance, the energy community focuses on projects related to grid expansion (Zarazua de Rubens & Noel, 2019) and the transport community focuses on projects related to the hydrogen refuelling infrastructure (Rose & Neumann, 2020). Yet, this analysis of projects does not take a project studies perspective but is often technology specific.

This lack of focus on projects in the context of Net-zero may stem from an insufficient emphasis on the relationship between projects and their institutional context or, more simply, from the often retrospective nature of project studies as opposed to the prospective approach commonly used in the vast majority of Net-zero literature. Since the empirical nature of projects transforms the built environment, along with organisations and actors' behaviours, it is meaningful to investigate the Net-zero transition from the project studies perspective. What is needed is, therefore, a systematic literature review (SLR) (Tranfield, Denyer, & Smart, 2003) across different epistemological communities to consolidate knowledge about projects for the Net-zero transition.

To effectively sense-make this literature we draw on a combination of project studies theories and sustainable transition theories. In particular, we elaborate on the concept of "project as agent of change" (Huemann & Silvius, 2017) and the Multi-Level Perspective (MLP)(Geels, 2002). The MLP is a key theory adopted in sustainability transition studies (Sovacool & Hess, 2017), to investigate various forms of sociotechnical transitions (Geels, 2010). Based on the MLP and the concept of "project as agent of change" (i.e., projects to projecting better futures), we embrace the perspective of projects as "vectors of change" between sociotechnical systems. We developed this formulation because projects as temporary organisations do not have agency. This is because they are entirely dependent on other permanent organisations (project owners, project-based firms, etc.) for resources such as financial, human, and technological resources (Winch, Maytorena, & Sergeeva, 2022). Projects can, however, "carry" the change intended by project owners, thereby acting as vectors. This conceptualisation recognises that projects are capable of transitioning sociotechnical systems from a current and fossil fuel-based sociotechnical system to a Net-zero sociotechnical system, as represented in Figure 1. Therefore, *Net-zero transition projects* (for brevity *Net-zero projects*) are those projects aimed at transitioning sociotechnical systems towards Net-zero. The term "Net-zero projects" does not imply that these projects are inherently carbon neutral since they require inputs (e.g., material, labour, energy, etc.) with a carbon intensity, usually known as "embodied carbon". This article aims to investigate Net-zero projects by addressing the following research questions:

- RQ1: *Which are the main types of Net-zero projects?*
- RQ2: *How do Net-zero projects transform sociotechnical systems toward Net-zero?*

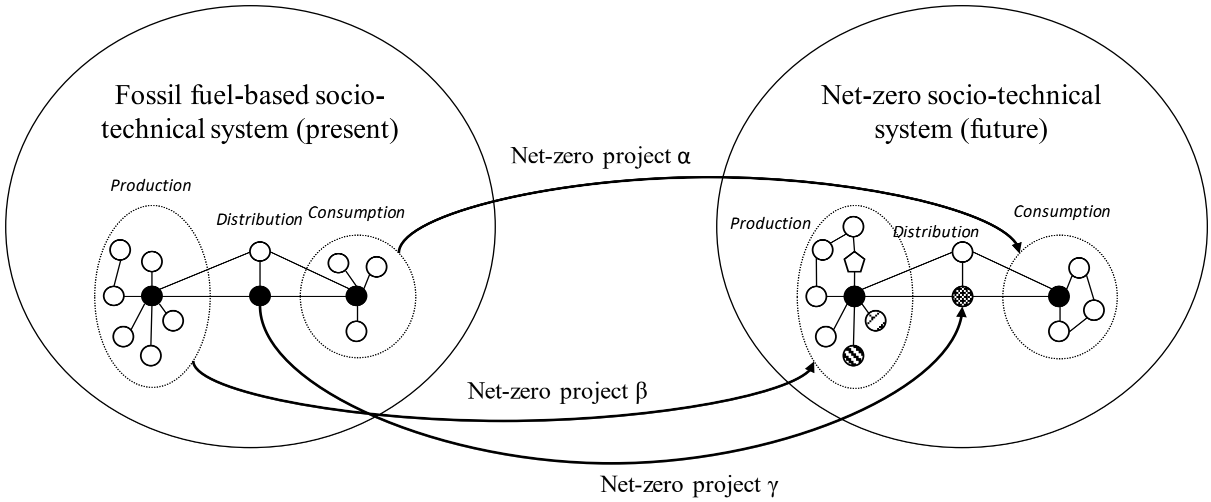

Figure 1. Projects as vectors of change toward Net-zero sociotechnical system

This article is structured as follows: in the methodology section, we outline the rationale behind the SLR. Next, in the findings section, we present the key themes derived from the SLR and organise them accordingly. Subsequently, we delve into a discussion of our findings, focusing on the main limitations observed in the literature and highlighting the potential for project scholars to contribute to addressing these limitations. Following the discussion, we propose a research agenda that outlines potential areas for project scholars to investigate regarding the net-zero transition. Finally, we summarise the main points covered in the article and issue a call for further research on the topic of the net-zero transition.

Methodology

We started our research by reviewing the key project management journals (PMJ, IJPM, IJMPB, and PLAS) using the keywords: "decarboni*" or "Net-zero" or "Netzero". Surprisingly, this effort did not return any articles. Consequently, we were motivated to redirect our research efforts towards a broader epistemological community to collect data about Net-zero projects from other disciplines. To collect relevant and scientifically sound articles, we selected the "sectorial studies" journal list from the Chartered Association of Business Schools academic journal guide (53 journals). We selected this list since it includes high-quality journals related to sustainability and relevant sociotechnical systems for the Net-zero transition (e.g., transportation and energy). Therefore, we conducted an SLR, as presented in Table 1.

Query in SCOPUS	• TITLE-ABS-KEY ((("Net-zero" OR "Netzero") W/3 ("carbon" OR "ghg" OR "greenhouse gas*" OR "emission*")) OR "decarboni*") AND ISSN (sectorial studies CABS journals)
Number of articles	• 868 (31/12/2022)
Years of publication	• 2022 (231) • 2021 (154) • 2020 (111) • 2019 (89) • 2018 (59) • 2017 (51) • Before 2017 (173)
Most frequent Journals	• Energy Policy (369) • Journal Of Cleaner Production (331) • Transportation Research Part D Transport and Environment (55) • Building Research and Information (21) • Transport Policy (20) • Other (72)
Most frequent Subjects	• Environmental Science (625) • Energy (576) • Engineering (309) • Business, Management and Accounting (250) • Social Sciences (117)

Table 1. Systematic literature review query and bibliometric findings

The search query, performed on 31/12/2022, returned 868 articles. Using the PRISMA methodology (Moher, Liberati, Tetzlaff, & Altman, 2009), we assessed the articles based on their relevance to our aim and research questions. First, we selected the articles based on their title and abstract, applying the following inclusion and exclusion criteria:

- Inclusion criteria: articles that provide insights into the Net-zero transition as introduced and described in the article's introduction.
- Exclusion criteria: articles that do not address the Net-zero transition or do not focus on its implementation (e.g., articles discussing the consequences of the Net-zero transitions).

In this phase, 411 articles were excluded since they were out of scope. Of the remaining 457 articles, 455 were downloaded and full text analysed, and 2 were excluded because unavailable. Of the 455 articles, 253 were relevant, while 202 were excluded because they were irrelevant. The 253 relevant articles directly focus on Net-zero projects, such as Alcalde et al.(2019) and Dolter et al.(2022), discuss issues relevant to the implementation of Net-zero projects, such as Susskind et al.(2022), or compare different low-carbon technologies and the benefit delivered by the Net-zero projects implementing those technologies, such as Connolly et al. (2014). Figure 2 shows the process and the number of excluded articles.

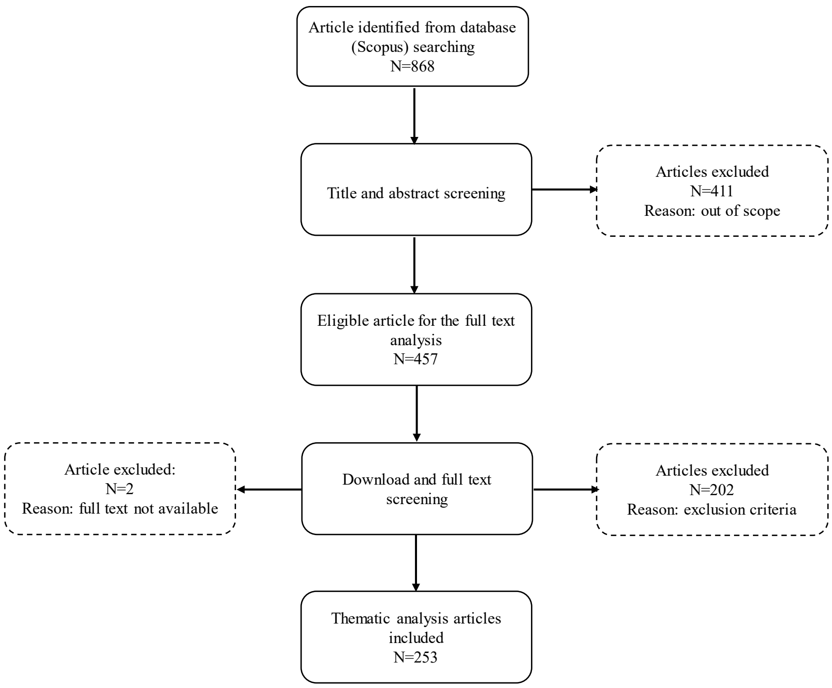

Figure 2. PRISMA flow chart

After screening the papers, we conducted a thematic analysis (Braun & Clarke, 2006). The first step consists of familiarisation with the data (in this case, the 253 papers), where the authors iteratively analysed them to have a general idea of how to generate the coding. In this phase, we realised that most of the articles discussed Net-zero projects even if they did not conceptualise them as such. For instance, Brémond, Bertrandias, Steyer, Bernet, & Carrere, (2021) present the potential of biogas as technology in decarbonising the energy sociotechnical system and its economic viability (i.e. the economic viability of different biogas plant projects) without adopting projects as the unit of analysis. Taking this information into account, we proceeded into the coding phase, which was manually performed. In the coding phase, we isolated quotes from the text and gave these quotes specific keywords. We coded all semantic (i.e., explicit and surface meanings) and latent (i.e. underling ideas and assumptions) information about the net-zero project (e.g., the financial barrier of the project, improving energy efficiency, etc).

At the end of the coding process, we reviewed the codes by merging or eliminating some codes to ensure the consistency of the coding process. In the third phase, we shifted the analysis to a broader level of themes. This involved sorting the different codes abductively into potential themes and collecting all the relevant coded data extracts within the identified themes. This process was iterated several times to precisely identify the most meaningful themes for the research question and their relation to the codes. The relationship between codes and themes is that the codes represent subcategories of the themes due to the exploratory nature of our research questions. Table 2 lists the themes and elements that emerged from the thematic analysis.

Theme	Elements
Type of Net-zero project	○ New asset (e.g., building new power plants) ○ Upgrade asset (e.g., retrofitting a building or a large ship) ○ Behavioural intervention (avoid/change the use of assets, e.g., awareness campaign) ○ Research, development and demonstration (RDD)(e.g., develop a new fusion reactor or consultancy)
Key deliverable of Net-zero projects	○ Technology ○ Practice ○ Enabling condition ○ Behavioural change ○ New Knowledge
Sociotechnical system	○ Energy ○ Buildings ○ Transports ○ Manufacturing ○ Food ○ Landfills and waste
Timespan for the Net-zero projects GHG benefit realisation	○ "short" delivery up to 10 years ○ "medium" from 10 to 20 years ○ "long" more than 20 years
Barriers to Net-zero projects	○ Financial & economical ○ Technical uncertainty ○ Technical limitation ○ Technology lock-in ○ Other barriers
Net-zero projects' complementarities	○ Intra-system ○ Multi-system
Decarbonisation modality of Net-zero projects	○ Quantity ○ Intensity

Table 2. Themes and elements

Findings

Types of Net-zero projects

The literature includes four types of Net-zero projects: new assets, upgrade assets, behavioural intervention, and research, development, and demonstration (RDD). This exhaustive typology allows us to classify Net-zero projects discussed in the literature and to identify the type of interventions that Net-zero projects can undertake to transform sociotechnical systems.

New asset projects decarbonise sociotechnical systems by adding new or replacing existing physical assets, e.g., replacing a coal plant with a wind farm, which reduces the average carbon intensity of electrical sociotechnical systems. New assets Net-zero projects are extensively discussed in the decarbonisation of the energy sociotechnical system (Kim & Bae, 2022; Marchi, Niccolucci, Pulselli, & Marchettini, 2018; Murele, Zulkafli, Kopanos, Hart, & Hanak, 2020; Oshiro, Kainuma, & Masui, 2017; Zarazua de Rubens & Noel, 2019) and the transport sociotechnical system (B. Li et al., 2021; Mckinnon, 2016; Rose & Neumann, 2020; Zhang & Zhang, 2021).

Upgrade asset projects decarbonise sociotechnical systems through upgrading/improving existing physical assets, e.g., retrofitting a building to increase insulation and reduce gas and electricity consumption. The literature presents several cases study which empirically evaluates upgrade assets Net-zero projects in decarbonising housing sociotechnical system (Banfill & Peacock, 2007; Chaudry, Abeysekera, Hosseini, Jenkins, & Wu, 2015; Flower, Hawker, & Bell, 2020; Paardekooper et al., 2020; Thomaßen, Kavvadias, & Jiménez Navarro, 2021; Watson, Lomas, & Buswell, 2019) and manufacturing sociotechnical system (Bataille et al., 2018; Gerres, Chaves Ávila, Llamas, & San Román, 2019; Gilbert, Alexander, Thornley, & Brammer, 2014; Obrist, Kannan, Schmidt, & Kober, 2021; Sgobba & Meskell, 2021; Worrell & Boyd, 2022).

Behavioural intervention projects are intended to shape individuals' consumption behaviours. Behavioural intervention can reduce GHG emissions in two ways: changing intensity (e.g., Net-zero projects to convince people to use a less carbon-intensive means of transport, i.e., trains instead of cars) and quantity (e.g., Net-zero projects to reduce the number of miles travelled, e.g., using videoconferencing instead of attending in person) (see section "decarbonisation modality"). Behavioural intervention Net-zero projects are seldom discussed, with few exceptions being in transport (Liimatainen et al., 2014; Marsden, Mullen, Bache, Bartle, & Flinders, 2014) and food consumption (Gadema & Oglethorpe, 2011; Garvey, Norman, Owen, & Barrett, 2021).

Research, development and demonstration projects are projects aiming at creating new knowledge for a specific technology that could potentially decarbonise a sociotechnical system or project aiming at demonstrating the technical and financial viability of a technology (Nemet, Zipperer, & Kraus, 2018) around a specific low-carbon technology. RDD Net-zero projects include not only research and development-intensive initiatives focused on elevating the technology readiness level of low-carbon technologies but also embrace demonstration and pilot projects dedicated to enhancing our understanding of the economic aspects of low-carbon technologies and their viability at a utility-scale level (Nemet et al., 2018; Wang, Jiang, Wang, & Roskilly, 2020). RDD Net-zero projects are rarely mentioned, exceptions being (Abrantes, Ferreira, Silva, & Costa, 2021; Bosetti & Longden, 2013; Nemet et al., 2018; Poortinga, Spence, Demski, & Pidgeon, 2012).

Net-zero projects deliverables

As presented in the introduction, Net-zero projects have the fundamental characteristics of delivering sustainable capital goods aiming at transitioning sociotechnical systems Net-zero project deliverables is a central theme since projects, as temporary organisations, cannot decarbonise sociotechnical systems. Instead, it is through the benefit realisation of project deliverables that the existing sociotechnical system can be effectively transitioned towards net-zero. Additionally, Net-zero project deliverables highlight that Net-zero projects can transform both the tangible and intangible elements of sociotechnical systems. We identify five key types of deliverables of Net-zero projects: technology, practice, enabling conditions, behavioural change, and new knowledge.

Technology refers to planning and delivering a technological artefact (often based on proven technologies). For instance, substituting gas boilers with heat pumps decarbonising the housing sociotechnical system (Banfill & Peacock, 2007) or installing carbon capture and sequestration (CCS) systems in cement production plants (J. Li, Tharakan, Macdonald, & Liang, 2013).

Practice refers to planning and delivering Net-zero projects aiming to transform organisations' practices. For instance, Net-zero projects aim to establish guidelines to optimise shipping routes and speed according to the weather forecast (to decarbonise the sociotechnical systems of goods transport (Bouman, Lindstad, Rialland, & Strømman, 2017)) or to establish design guidelines for dematerialised goods (Garvey, Norman, & Barrett, 2022).

Enabling condition refers to planning and delivering Net-zero projects which shape the context in which artefacts are operated. For instance, constructing a highway to substitute secondary roads enables road hauliers to travel at a constant speed, reducing GHG emissions (Liimatainen et al., 2014) or upgrading the local public transport enables to reduce the volume of traffic related to private vehicles (Böhringer et al., 2020).

Behavioural changes are delivered by behavioural intervention Net-zero projects. For instance, a project to incentivise people to use bikes instead of cars to decarbonise the transport sociotechnical systems through behavioural change (Philips, Anable, & Chatterton, 2022).

New knowledge is mainly delivered by RDD Net-zero projects. For instance, Abrantes et al., (2021) describe research projects for developing sustainable aviation fuel, which potentially decarbonise the air travel. Additionally, new knowledge can be delivered by research projects aiming at understanding individuals' behaviours. For instance, Poortinga et al. (2012) describe a live experiment set up to understand individual behaviours regarding shared commuting vehicles.

Targeted sociotechnical system

Sociotechnical system is a fundamental ontological object in sustainable transition studies. Sociotechnical systems are large systems including artefacts (e.g. infrastructure), organisations (e.g., project-based organisation building infrastructure, infrastructure owners, etc.), policies and regulations (e.g., energy markets, technical norms, etc.), end-users (e.g. households) and meta-structures (e.g. consumption patterns, institutionalised meanings, shared engineering practice, etc.)(Geels, 2004). As Geels (2004) explains, the fulfilment of societal function (e.g., the need of electricity) is central to sociotechnical system. This assumption allows to include within sociotechnical system all the sub-system involved in the production, distribution, and consumption of a specific service or good. In the context of Net-zero transition, analysing the sociotechnical system ontological object allows to identify the GHG emission reduction outcomes of a project at the system level, overcoming some of the barriers posed by the characterisation by sectors. Indeed, the characterisation by sectors does not include the consumption side and does not account for technology complementarities (see section "Net-zero project complementarities"). For instance, the chemical sector is secondary in terms of GHG emissions, but Net-zero projects aimed at developing novel chemical compounds have enormous potential to reduce GHG in other sectors (e.g., low-carbon fuel for transport). The literature discusses seven key sociotechnical systems: Electricity mainly focused on power generation (Denholm, King, Kutcher, & Wilson, 2012; Kavouridis & Koukouzas, 2008), Transport such as cars, airplanes, ships, trains (Arioli, Fulton, & Lah, 2020; Irena, Ernst, &

Alexandros, 2021), Housing including heating and cooling (Herring, 2009; Opher et al., 2021), Manufacturing such as chemicals and metals production (Bataille et al., 2018; Grottera et al., 2022; Irena et al., 2021), Food (Gadema & Oglethorpe, 2011; Garvey et al., 2021), Waste management, including management of municipal and industrial waste, and wastewater (Nakkasunchi, Hewitt, Zoppi, & Brandoni, 2021; Theotokatos, Rentizelas, Guan, & Ancic, 2020).

Timespan for the Net-zero projects GHG benefit realisation

Net-zero projects have different timespans in GHG reduction also because of the different Technology Readiness Levels (TRL) of the involved technologies. For instance, low TRL Net-zero projects aimed to plan and deliver fusion power plants are implemented today, but the benefit in terms of GHG reduction will be materialised in decades if and when fusion plants will be commercially available. Conversely, high TRL Net-zero projects (e.g., a project to promote remote working to avoid commuting) can reduce GHG within a few days/weeks.

The timespan for the Net-zero project GHG benefits realisations is often implicit but can be deduced, as in the examples above. The Net-zero projects mentioned in the data collection are often based on high TRL, commercial-ready technologies (e.g., building retrofitting, renewable energy, heat pumps), which can be implemented in months and deliver GHG reduction within a year. Nicholas et al. (2021), being an exception, discuss the future possibility of fusion energy in the decarbonisation of power plants. In addition, Nicholas et al. (2021) highlight the risk of developing such technologies with long-term decarbonisation outcomes. For instance, when fusion energy might be commercially ready, maybe at the end of this century, renewable energy power plants could be sufficient to satisfy the electric power energy demand. Obviously, fusion power plant proponents have a different perspective (Bednyagin & Gnansounou, 2011).

Barriers to Net-zero projects

Many articles in the literature do not adopt projects as the unit of analysis but instead focus on the broader context in which Net-zero projects are conceived, planned, and implemented. Such articles recognise that low-carbon innovations are less competitive than well-established and institutionalised fossil fuel-based technologies and practices, proposing policies or context-specific interventions to facilitate the investment in Net-zero projects. Drawing on the MLP, the "barrier to Net-zero projects" theme reflects the challenges that low-carbon innovation and related Net-zero projects face in challenging the incumbent sociotechnical regime. We identified four key barriers: Financial & economical, Technological uncertainty, Technological limitations, Technology lock-in and other barriers.

Financial & economical barriers are a central element when discussing Net-zero projects. Indeed, the low-carbon innovations implemented by Net-zero projects are competing with fossil fuel-based technology and practice at the financial and economic level since organisations and individuals are mainly driven by economic rationality (e.g. efficiency, effectiveness and profitability maximisation) (Oliver, 1997). Articles frequently discuss the financial viability of Net-zero projects throughout the asset lifecycle. For instance, Irena et al. (2021) discuss the marginal abatement cost curve (MACC) of different low-carbon technologies to decarbonise vessels, highlighting that only a few retrofitting projects are profitable for project owners. Also, Brémond et al. (2021) argue that even if the bio-gas plants can be built with low risks and acceptable capital costs, the final product's cost of bio-gas is still higher than natural, posing a risk to the profitability of the asset. Moreover, certain articles discuss the difference balance between capital expenditures and operational expenditures, which hinder investments in Net-zero projects. For instance, Burgess and Biswas (2021) argue that the higher capital cost of renewable energy projects compared to fossil fuel energy projects (which present a higher operational expenditure) creates barriers to investments in Net-zero projects.

Technological uncertainty refers to the lack of knowledge about a specific low-carbon technology, increasing the risk of Net-projects. Gilbert et al. (2014) argue that non-conventional ammonia production plant projects potentially have lower capital and operational costs than traditional ones. However, the capabilities of the technologies adopted in non-conventional ammonia production plants have not yet been demonstrated commercially. Therefore, during the capital budgeting appraisal, this type of plant becomes less financially attractive for investors. Moreover, we include under "technology uncertainty" articles addressing individuals' lack of knowledge, which often results in reluctance towards certain types of Net-zero projects. For instance, Ho, Xiong, & Chuah (2021) present how the lack of knowledge on nuclear technologies hinders public support for the construction of a nuclear research facility in Singapore.

Technological limitations. This barrier encompasses the technical constraints, performance limitations, and decarbonisation limits associated with the implementation of Net-zero projects. For instance, implementing an electric truck fleet will reduce the overall payload capacity of the fleet due to the increased weight of electric trucks compared to traditional trucks and the legal road weight limit (Hanesch, Schöpp, Göllner-Völker, & Schebek, 2022). Also, Lilliestam, Bielicki, & Patt, (2012), while presenting coal with carbon capture and sequestration (CCS) as a possible solution to decarbonise the electricity grid baseload, highlighted that CCS systems could be implemented only in retrofitting-ready coal power plants and CCS implementation is limited by the availability of geological storage.

Technology lock-in occurs when new technology emerges and cannot (at least short term) compete with existing technologies, e.g., lower performance, social norms, lack of network supporting the emerging technology, etc. For instance, in the housing sociotechnical system, a lock-in barrier occurs when the electric heating system aims to replace fossil fuel-based heating systems in new buildings. Organisations providing equipment for heating systems prefer to push into the market fossil fuel-based solutions to increase profits from sunk costs (e.g., RDD activities) related to fossil fuel-based solutions (Böhringer et al., 2020). Lock-in barriers can also occur because fossil fuel-based heating systems have been socially acceptable for decades. Therefore, households may be reluctant to switch to "less trusted" electric heating systems (Broad, Hawker, & Dodds, 2020).

Other barriers. The analysed articles also discuss a range of other less recurrent barriers. Such minor barriers range from social dimensions (e.g., acceptability of nuclear infrastructure and job loss related to Net-zero transition) (Abdulla, Vaishnav, Sergi, & Victor, 2019; Ostfeld & Reiner, 2020), to supply chain (e.g., availability of input materials)(Garvey et al., 2022), to negative end-user experience (e.g., buildings comfort loss) (Wrapson, Henshaw, & Guy, 2014).

Net-zero project complementarities

The concept of complementarities describes positive interactions between two technologies or components belonging to the same sociotechnical systems, and "*Complementarities arise if the value of a combination of specific elements or assets is greater than the sum of the value of each individual element*" (Markard and Hoffmann, 2016, p.63). Net-zero project complementarities theme underscores the inherent need for complementary technologies when implementing specific low-carbon innovations. For instance, fostering the adoption of electric vehicles requires a Net-zero project to expand the electric vehicle recharge infrastructure. At the same time, electric vehicles can provide storage capacity for the electricity grid, enabling a Net-zero project aiming at building renewable energy power plants. We identify two key types of complementarities: intra-systems complementarities in a single sociotechnical system, such as electricity (Zarazua de Rubens & Noel, 2019) and multi-system complementarities across at least two sociotechnical systems, such as energy and transport (Szinai, Sheppard, Abhyankar, & Gopal, 2020).

Decarbonisation modality

We identify two modalities in which Net-zero projects can transition sociotechnical systems toward Net-zero: Intensity reduction and quantity reduction. Figure 3 presents these two decarbonisation modalities referring to a generic sociotechnical system as a reference. The circle represents the current GHG emissions of a sociotechnical system, characterised by its Quantity and Intensity. The product of these two characteristics returns the overall amount of GHG emitted by a sociotechnical system. The two decarbonisation modalities are represented by the arrows.

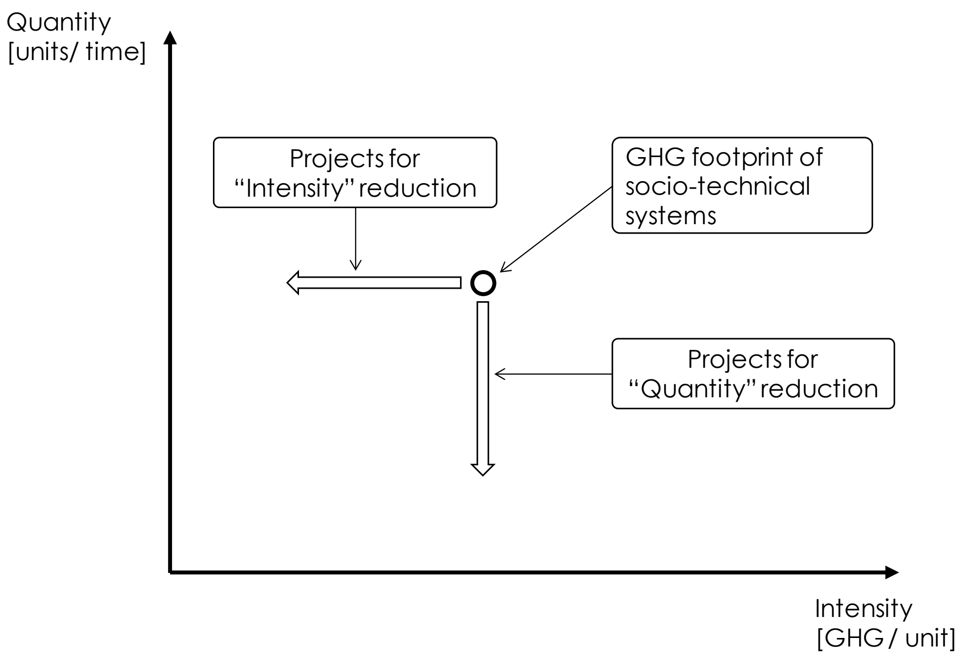

Figure 3. Net-zero projects decarbonisation modality

"Intensity" refers to the intensity of GHG emissions per unit produced or consumed (e.g., GHG produced per kilometre flight or GHG produced per unit of electric energy). Examples of Net-zero projects related to "intensity" reduction include developing more efficient aeroplane engines or replacing coal-fired power plants with wind farms. "Intensity" related Net-zero projects usually exploit technical solutions implemented where the GHG emissions are emitted or the services/goods are transformed/created (e.g., smelting plants, cement production plants) (Cloete, Giuffrida, Romano, & Zaabout, 2019; Di Maria et al., 2022).

"Quantity" refers to a specific sociotechnical system' "intended consumption" over a certain time (e.g., a year). Examples of "quantity" are, for air transport sociotechnical system, millions of kilometres of flights in a year, or for electricity sociotechnical system, the TWh of electricity produced and consumed over a year. Net-zero projects in the "Quantity" perspective include Net-zero projects aimed at behavioural changes. For instance, teleworking instead of commuting by car (Grottera et al., 2022) or assuming proteins through low-carbon options like legumes instead of high-carbon options like meat (Garvey et al., 2021).

A framework linking Net-zero projects to sociotechnical systems

Figure 4 presents a framework conceptualising Net-zero projects and their links with sociotechnical systems. This framework systematised the discussions concerning Net-zero projects for Net-zero transition and was generated by adding the links and the objects as they emerged from the thematic analysis until we achieved theoretical saturation (Saunders et al., 2018).

This framework connects the Net-zero projects to the targeted sociotechnical systems. For instance, Katris & Turner (2021) investigate how different types of funding can influence homeowners' investments in house retrofitting. Homeowners implementing upgraded assets Net-zero projects (i.e., home retrofitting) contribute to decarbonising the housing sociotechnical system by reducing the energy consumption for building heating (i.e., quantity reduction).

This framework includes four sections: Net-zero project owners, Net-zero project types (see section "types of Net-zero projects"), decarbonisation modalities (see section " decarbonisation modality") and sociotechnical systems (see section "sociotechnical system").

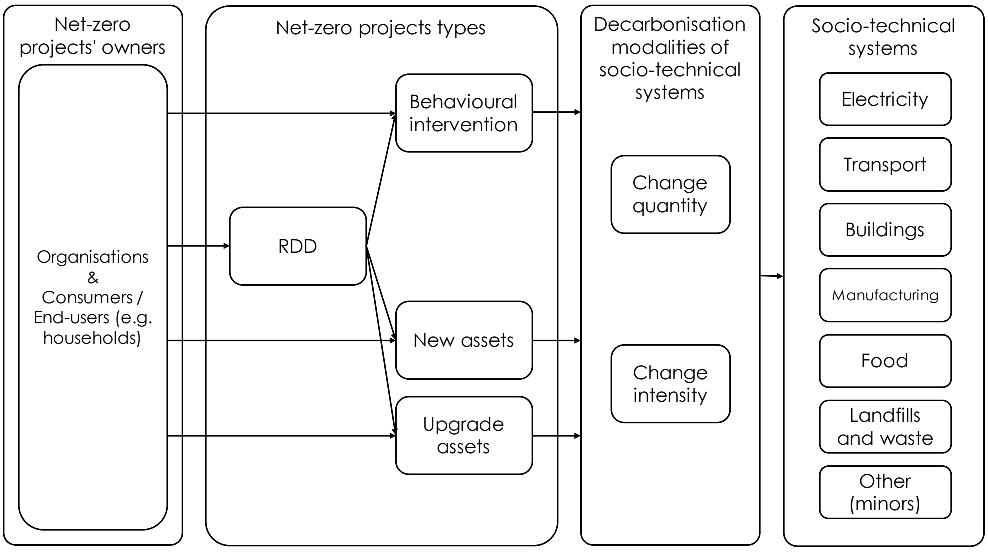

Figure 4. Net-zero projects framework

The owners (Winch & Leiringer, 2016) of Net-zero projects include public, private and third-sector organisations and individuals, particularly households. Organisations and individuals can take different roles in Net-zero projects, including owners, financiers or champions. There are four types of Net-zero projects. While organisations can own all types of Net-zero projects, households can own "New assets" and "Upgrade assets". "New assets", "Upgrade assets", and "behavioural intervention" Net-zero projects can directly decarbonise sociotechnical systems, changing their intensity and quality. "RDD" Net-zero projects cannot directly decarbonise sociotechnical systems but create potential emission reduction in future Net-zero projects.

Discussion

In this section, we will outline the primary limitations of the Net-zero literature and propose ways in which project scholars can address these limitations.

Lack of theoretical approach

The literature regarding Net-zero projects is often atheoretical, with only seven articles (Batalla-Bejerano, Trujillo-Baute, & Villa-Arrieta, 2020, p.; Boute & Zhikharev, 2019; Grottera et al., 2022; Mercure et al., 2014; Poortinga et al., 2012; Szolgayová, Golub, & Fuss, 2014; Timmons et al., 2019) mentioning a theoretical lens, even if the actual application varies. The only article with a robust theoretical approach is (Sopjani, Stier, Hesselgren, & Ritzén, 2020), which applies Social Practice Theory as a theoretical lens to explain the behaviour change of individuals involved in an experiment.

Theories generally have three basic elements: What, How, and Why (Müller & Klein, 2018). However, most of the articles analysed have a future-oriented or a hard technical perspective, which does not give room to the third element of theories (Why). Exploring Net-zero projects from a project management perspective can bring relevant theoretical insights and contributions. Following the call of Müller & Klein (2018) for more theoretically rich articles in project studies, we suggest that project scholars adopt a range of theories (Sovacool & Hess, 2017) and approaches (Markard, Raven, & Truffer, 2012) developed in the sustainable transition research to investigate Net-zero transition projects. In particular, further research on Net-zero projects could adopt a multi-level perspective (MLP) on sustainability transitions (Geels, 2002; Geels & Turnheim, 2022) to make sense of the institutional context in which the Net-zero project is planned and delivered. The MLP explains how and why transitions occur through the interactions of three nested levels: the niche, the regime, and the landscape (Geels, 2002). Niches are protected space from market pressure (Schot, 1998), where radical innovations can be improved through learning processes (Kemp, Schot, & Hoogma, 1998). The regime refers to incumbent sociotechnical systems stabilised by a semi-coherent set of rules shared by different social groups (e.g., end-users, scientists, suppliers, policymakers, etc.) (Geels, 2004; Sovacool & Hess, 2017). As explained by Geels (2002), sociotechnical regimes account for the dynamic stability of the sociotechnical configuration, allowing incremental innovation. Finally, the landscape accounts for the technology external factors, including economic crises, wars, political changes and environmental problems such as climate change (Geels, 2002). Change in the landscape can put pressure on the regime, creating windows of opportunity for niche innovation to challenge incumbent sociotechnical regimes. Considering the MLP, there are three different types of projects for sociotechnical transition in general and the Net-zero transition in particular: niche projects (i.e., projects fostered in niches helping to develop and discover radical technology, such as projects to develop fusion energy), transition projects (i.e., project aided by landscape pressure to reconfigure incumbent sociotechnical systems, such as constructing a wind farm) and regime project (i.e., project fostering incremental innovation in regime, such as project to develop more efficient internal combustion engine).

Work has already started in trying to develop a multi-level perspective on project studies more aligned with the MLP (Daniel, 2022; Daniel & Daniel, 2023) drawing on complex adaptive systems theory. However, we suggest that a more intensive effort is required to align the project studies and sustainable transition literature. We conceptualise Net-zero projects, defined in the standard ways (Winch et al., 2022) as a vector for an element of sociotechnical systems changes, while a portfolio, again defined in the standard way (Winch et al., 2022) of Net-zero projects consists of multiple vectors for change. However, a project portfolio is, by definition, the group of projects owned by a single organisational entity such as an electricity utility (e.g., EDF or RWE) as they rebalance their generation assets from fossil fuels to renewables and nuclear. Yet sociotechnical transitions require investment by multiple owners to both realise change (e.g., all generators in the electricity system) and realise complementarities (e.g., generators and owners of transmission grids). We suggest, therefore, that the concept of "mission" (Mazzucato, 2021) is an appropriate addition to the conceptual framework of multi-level project studies.

Neglect of an execution perspective

Most of the articles focus on policies to foster technology adoption (Brémond et al., 2021; Gerres, Chaves Ávila, Martín Martínez, et al., 2019; Gilbert & Bows, 2012) and technology feasibility at the sociotechnical system (Ampah, Yusuf, Afrane, Jin, & Liu, 2021; Bouman et al., 2017; Furszyfer Del Rio, Sovacool, Bergman, & Makuch, 2020; Nakkasunchi et al., 2021). This perspective is deeply concentrated on the possible outcomes of adopting and diffusing future low-carbon technologies. As per Winch et al. (2023), we identify a vast neglected area of investigation related to the delivery of Net-zero transition. For instance, we still do not know how Net-zero programmes are rolled out and how we can enhance the benefit realisation of such programmes. Additionally, we still do not know how projects are organised within niches (Raven & Verbong, 2009) and how eventually they succeed in transforming sociotechnical systems or not.

Overlooking the Relevance of Stakeholders and Value

There is a lack of studies regarding stakeholders' involvement in Net-zero projects. Classic project study topics such as governance, stakeholders' management, value creation, etc., are seldom mentioned. Wade et al. (2020) is an exemption discussing linked ecologies of *"middle actors"* (local authorities and delivery partners, such as private contractors and commercial consultants) in delivering national-scale building retrofitting programmes.

Some articles discuss the negative impact of Net-zero projects on local communities. As per the section "barrier to Net-zero projects", one of the most recurrent barriers analysed is the context barriers, such as job loss (Ostfeld & Reiner, 2020), increased household energy cost (Gao & Ashina, 2022), etc. However, the literature has a narrow perspective on stakeholders. From a project studies perspective, several stakeholders are not accounted for (e.g., the organisation planning and delivering Net-zero projects), the interaction and influence among key stakeholders are not considered (e.g., the bi-directional influence of Government and organisation planning and delivering Net-zero projects), and the value created and destroyed by Net-zero projects is not addressed. As highlighted by (Perlaviciute, Steg, & Sovacool, 2021), the Net-zero transition is primarily a socio-economic challenge. Socio-economic barriers are present in large infrastructure projects but also in constellations of small projects financed by individuals or households. Despite the relevance of individuals or households in enacting small projects, there is a lack of discussion about their agency (Raven et al., 2021). Project scholars should contribute to this limitation by looking at value creation, distribution, and capture of value from Net-zero projects. Given the normative nature of such research, theoretical lenses such as "New stakeholder theories" are a reasonable choice (Gil, 2023; McGahan, 2021).

Insufficient focus on product and service innovation

Innovation is an important part of the Net-zero transition. From the literature, is it possible to distinguish two different levels of innovation: "*products and services innovation*" (e.g., a new type of sustainable jet fuel)(Dangelico, 2016) and "*system innovation*" (e.g., wind farm, which transforms the electric power system of provision)(Geels, 2005). Both types of innovation are implemented by Net-zero projects: the first by RDD projects aiming to develop and demonstrate technologies; the second by New assets and Upgrade assets, which transform the existing system of provision of goods and services. While the literature presents different articles on "*system innovation*" (Jacobsson & Karltorp, 2013; Schmidt, Schneider, & Hoffmann, 2012), there is a lack of studies on "*products and service innovations*". Some exceptions are studies discussing free-riding phenomena related to RDD projects (Dodd & Yengin, 2021) and public support for RDD projects (Nemet et al., 2018). "*Product and service innovations*" are highly relevant since the average TRL of Net-zero projects is generally lower than the counterpart (e.g., gas-fired power plant TRL is higher than floating solar plant TRL, both from a technology and a management of project perspective). Therefore, such technologies need to be "protected" and developed within niches until they can interact with the regime. Project scholars could contribute to this discussion by investigating the characteristics of projects which escape the niche and start to interact with the regime. This discussion can be fostered into contemporary project studies' narratives, such as project success and benefits realisation in fostering innovation (Atkinson, 1999; L.A. Ika & Pinto, 2022; Lavagnon A. Ika, 2009).

Lack of attention to system complementarities

The literature addresses the topics related to complementarities even if the discussion still be limited to the technological level. The concept of complementarities is broader and includes other forms of complementarities, such as vertical complementarities (e.g., PV solar farm complementarities are solar PV panel factories, Polysilicon refinery plants, silicon mines, etc.) or institutional complementarities (e.g., PV solar farm complementarities are technology-specific support programmes, regulations, technology standards)(Markard & Hoffmann, 2016). Also, new forms of complex projects are emerging from this transition, such as industrial clusters (within which different technologies strengthen complementarities) (Sovacool, Geels, & Iskandarova, 2022), which require the integration of several organisations with different capabilities and roles within the cluster (Geels, Sovacool, & Iskandarova, 2023). Such systems-of-systems complementarities enhance the technological and management complexity of the Net-zero transition. For instance, complementarities are one of the key factors in the success of national decarbonisation programmes (Sturm, 2020). Therefore, it is essential to investigate new forms of technology and expertise integration within a project and also rethink the project outcome success, investigating how a specific Net-zero project complements other Net-zero projects in achieving the decarbonisation of a sociotechnical system. Investigating complementarities provides project management scholars with a fertile ground for enhancing the understanding regarding the Net-zero project's success in complex and diffused engineering systems, the dynamics intercurrent between organisations involved in the development and construction of such systems and, from a national programmes perspective, the inherent complexity of programmes. Addressing this topic may provide practical insight into how to design, organise and implement national decarbonisation programmes. Project scholars could use (Markard & Hoffmann, 2016)'s theoretical framework to investigate project complementarities.

Lack of discussion of behavioural interventions

The literature highlights the importance of pursuing behavioural and lifestyle change in achieving the Net-zero transition goal (Dwivedi et al., 2022; Newell, Twena, & Daley, 2021; Poortinga et al., 2012). For instance, decreasing the average European household temperature by 1° Celsius can save the equivalent of Denmark's 2020 CO2 emissions (European Environment Agency, 2023; International Energy Agency, 2021). However, the Net-zero transition literature lacks discussion on how to implement such interventions. Moreover, the effectiveness of such intervention is still under debate (Geels, 2023). Indeed, projects can change the provision of goods and services, but as we have explained in the findings section, they can also be interventions to change behavioural patterns. Yet, behavioural intervention projects, in general and for the Net-zero transition, are still an under-investigated topic in the project management literature. Investigating the success of behavioural interventions and how they are planned and delivered can provide practical implication to strengthen the effectiveness of this important type of Net-zero projects.

Research agenda

Due to the novelty of the Net-zero transition topic for the research project, the research agenda is based on the framework presented in Figure 5.

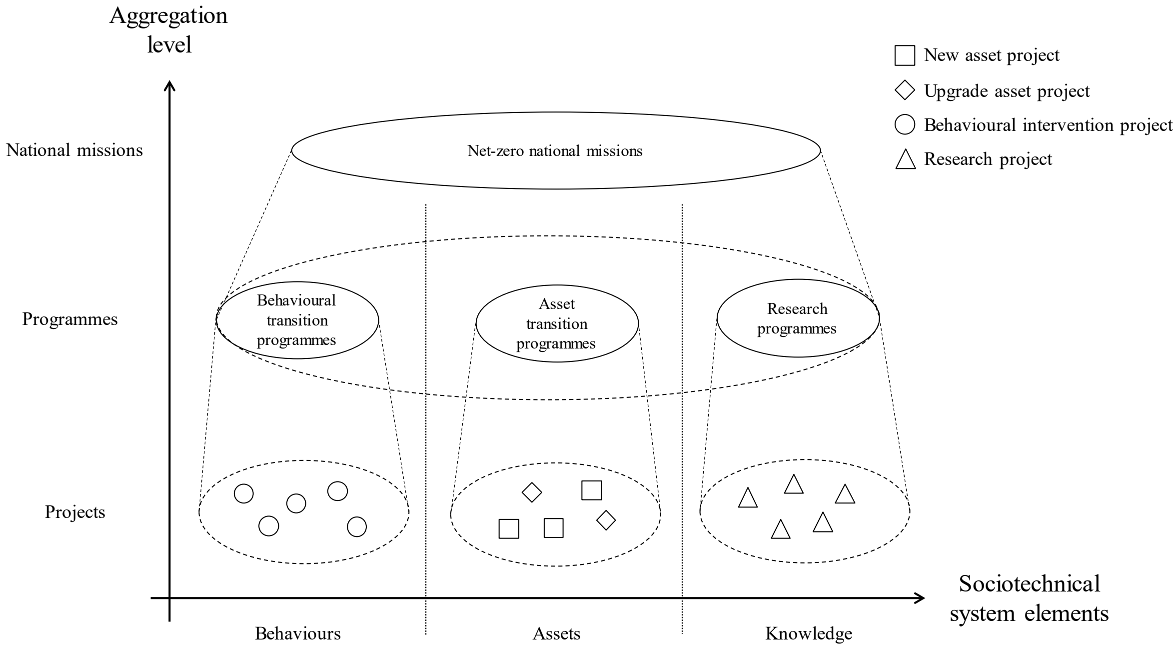

Figure 5. Net-zero research agenda.

The framework presents three nested levels similar to the MLP (Geels, 2002). We suggest project scholars investigate all three nested levels and the interrelations among them. In this section, we will provide some possible areas of investigation, which are not intended to be exhaustive, for exploring the topic of the Net-zero transition from the project studies perspective.

National Net-zero missions

Governments are key actors in achieving the Net-zero transition. They ratify international agreements and develop policies to foster the development of certain technologies (e.g., electric car subsidies) while hampering others (e.g., restricting diesel car circulation). The attention of governments is often at the mission level, defining budgets and policies to drive the development and adoption of low-carbon technology (Geels & Turnheim, 2022; Mazzucato, 2021). For instance, in the housing sociotechnical system, the government actions are not focused on retrofitting the single building level (e.g., the individual building) but on promoting thousands of individual Net-zero projects with multiple different owners, which includes the retrofitting Net-zero projects of a certain class of buildings in the country (e.g., those buildings with energy efficiency below a certain level), RDD Net-zero projects fostering the development of new low-carbon technology (e.g., advanced insulation material or advanced heating systems), and new assets Net-zero projects fostering the transition of specific industries (e.g., incentivise the construction of new heating systems factories). Therefore, Net-zero missions are characterised by a high degree of complexity. Indeed, Net-zero missions have high heterogeneity, multiple inter- and intra-system complementarities, and complex multi-level governance. Many governments already promote missions of Net-zero projects (e.g., European Green Deal ('European Green Deal', 2023)) to comply with international agreements. However, despite the multi-billion invested (International Energy Agency, 2022), the outcomes of Net-zero missions are controversial. For instance, see the discussion about the German energy transition mission (Kamlage, Drewing, Reinermann, de Vries, & Flores, 2020; Leiren & Reimer, 2018; Milder, Grundinger, & Unnerstall, 2020; Pegels & Lütkenhorst, 2014; Sturm, 2020). Following Denicol et al. (2021) framework, public institutions can be owners, champions or financiers of Net-zero projects belonging to missions. Further research should be devoted to studying governance mechanisms for such diverse (and massive) missions. Another area of investigation would be understating how such missions are organised to achieve the overarching goal of Net-zero, how their performance and success are measured, and understanding how policies shape projects.

Net-zero programmes

Net-zero transition programmes range from the construction programme of a fleet of nuclear reactors to internationally funded innovation programmes (See, e.g., NER300 EU innovation programme). Net-zero programmes have specific peculiarities that differentiate them from traditional programmes managed by organisations. More research is needed to investigate the value creation, distribution and capture of programmes for Net-zero transition and their governance, particularly considering that such programmes are spread across organisations and countries.

Among all the programmes, future research should aim at exploring research programmes sponsored by public institutions. Several national governments and international organisations (e.g., the EU) sponsor innovation programmes for developing low-carbon technology. International innovation programmes create a protected space (i.e. niches) where private organisations can foster innovation-oriented RDD Net-zero projects (Mazzucato, 2016, 2018). Such protected space is necessary to protect innovations from market pressure (Schot & Geels, 2008). The ultimate goal of such innovation programmes is to make a technology competitive and enter the sociotechnical regime, as explained by sustainable transition literature (Geels, 2002). Therefore, a possible area of investigation could be understating the knowledge diffusion mechanism within Net-zero programmes, the characteristics of Net-zero programmes, and, drawing on the MLP, how Net-zero programmes successfully push low-carbon innovation in challenging the regimes. Investigating RDD programmes should not be limited only to technology development programmes but also to programmes including projects aimed at building knowledge on the social dimensions of low-carbon technologies and policies to incentives them.

Net-zero projects in global south

The project level is widely discussed in the literature but is heavily biased toward the EU, China and North America. The Middle East is the area with the highest emissions per capita (The World Bank, 2022), and Africa is the continent in the world where the biggest increment of the population (and therefore emissions) could be expected over the next decades (United Nations, 2022). We know very little about projects in these contexts in general (Lavagnon A. Ika, Keeys, Tuuli, Sané, & Ssegawa, 2021) and the Net-zero transition in particular. For instance, it is unclear how such projects are financed, the role of the different stakeholders and international cooperation. Further research is needed, particularly from scholars who are experts in these contexts.

Behavioural intervention Net-zero projects

Another relevant area of investigation is behavioural intervention projects. As introduced in section " Lack of discussion of behavioural interventions", behavioural intervention projects (e.g., those to convince people to reduce home temperature during winter (International Energy Agency, 2021)) are essential to achieve the Net-zero transition goals. However, the Net-zero literature does not explicitly discuss behavioural intervention projects. Moreover, in project studies, behavioural intervention projects are seldom discussed. Very little is known about behavioural and lifestyle change projects outside Net-zero transition (e.g., projects to decrease smoking in a country or convince people to wear seat belts). Therefore, Net-zero behavioural intervention projects provide a valid empirical field to ground studies related to behavioural intervention projects, in general, and contribute to the body of knowledge of project management. This would be a great topic for interdisciplinary research, as prompted by Locatelli et al. (2023), with project scholars co-authoring articles from behavioural studies. Moreover, as proposed by (Daniel, 2022; Daniel & Daniel, 2023), exploring the project dimension and applying the MLP perspective to macro projects studies could be useful in understanding how projects at the micro level produce an impact on public policy at the macro-level or how projects could shape technology trend (Geels & Raven, 2006; Turnheim & Geels, 2019).

Conclusions

Net-zero transition is one, if not the biggest, challenge humanity will face over the next decades. Trillions of dollars have already been invested in Net-zero projects involved in this transition, and even more investments are expected for the next decades. While Net-zero projects are extremely relevant, project studies do not discuss this topic. With our SLR, we brought together the key ideas around Net-zero projects. Indeed, even if project scholars do not discuss this phenomenon, in our SLR, we identify other scholars and journals where Net-zero projects are discussed, even if they are not the unit of analysis. The first conclusion of our research is a "wake-up call" for project scholars: if we truly believe that Net-zero projects are vectors of change for a better future, Net-zero projects need to become a key topic in our research. Therefore, we fully agree with Morris (2016) that project management scholars have the moral duty to help address a big societal issue like climate change and the importance of studying "sustainability by the project". Additionally, our research presents how project scholars can adopt theories from the sustainable transition literature and contribute to this literature in investigating the Net-zero transition.

Our SLR is dominated by Net-zero projects discussed in the context of policies and the deployment of new technologies. Our thematic analysis identified four types of Net-zero projects: New assets, Upgrade assets, RDD and Behavioural intervention. Moreover, we found that Net-zero projects are highly heterogeneous. From a complexity perspective, they can range from developing home appliances to building complex systems such as nuclear power plants.

From a TRL perspective, they range from low-level TRL (e.g., nuclear fusion) to commercially available solutions (e.g., bicycles). Finally, Net-zero projects can decarbonise portfolios of assets in two ways: reducing quantity (e.g., reducing the number of km flight through awareness campaigns) or intensity (e.g., using more efficient aeroplane engines).

Studying Net-zero project represents an incredible opportunity for project scholars to inform practitioners, particularly decision-makers. As we have shown, Net-zero projects aim to implement technological and social innovation. Decision makers drive technological and social innovations by implementing public policies at the national and regional levels and corporate strategies at the firm level. The success of public policies and corporate strategies heavily depends on the success of Net-zero projects.

Despite the empirical and theoretical relevance, at the time of writing, no articles from the four major project studies journals (IJPM, PMJ, IJMPB, PLAS) discuss Net-zero projects. We trust that this article will be a platform for other project scholars to build their research in investigating Net-zero projects for sustainability transition in general and Net-zero in particular.

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