Enabling Digital Sustainability:
A Socio-Technical Systems Design Perspective

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"Rivers know this: There is no hurry. We shall get there some day"

Winnie the Pooh

Acknowledgments

At certain points in life, we find ourselves needing to make decisions, whether to stay on our path, or to change direction and commit to the unknown. Starting this doctorate was one of those decisions. It meant leaving my prior path to develop my skills, my thinking, and myself, and to contribute to something beyond what I had previously known. Continuing this journey was not only a matter of discipline, focus, and tenacity (and the constant feeling I had forgotten something); above all, it was a matter of humanity: kindness, curiosity, and the willingness to look beyond the surface and keep digging deeper. This dissertation, however technical it may appear, is the result of a transformative journey that would not have been possible without the steady support of the people around me.

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Abstract

Climate change and related sustainability crises are one of the most pressing challenges of our time. Environmental degradation increasingly translates into economic losses and social disruptions, rendering sustainability an interdependent environmental, social, and economic concern. In this context, digital technologies are widely regarded as key enablers of sustainability transformations. Yet their contributions to long-term value creation remain uneven. While digital technologies can optimize existing processes and incrementally reduce greenhouse gas emissions, they increasingly shape physical, economic, and social realities by steering energy systems, governing supply chains, and enabling new forms of economic coordination. Despite these transformative potentials, many sustainability-oriented digital initiatives - such as decarbonization strategies, circular economy solutions, or digitally enabled ecosystems - struggle to scale or persist. This indicates that sustainability at scale does not arise from digital technologies in isolation, but from the alignment of infrastructures, governance, participation, and organizational integration.

Against this backdrop, this cumulative dissertation adopts digital sustainability as an overarching conceptual frame, defined as the development and deployment of digital resources and artifacts toward improving environmental sustainability, social well-being, and economic welfare. It responds to calls for more integrative and mechanism-based accounts by arguing that digital sustainability emerges from the interplay of three mutually reinforcing mechanisms. First, trustworthy digital infrastructures ensure the availability and verifiability of sustainability-relevant data. Second, sovereignty and governance mechanisms shape control, participation, and legitimacy in data-driven systems. Third, digital resources and dynamic capabilities enable economically viable digital strategic initiatives that translate sustainability objectives into scalable value creation, viable business models, and long-term economic welfare. The IS research domain is progressing slowly in investigating their interplays and underlying mechanisms. Accordingly, the overarching research objective of this dissertation is to examine how digital technologies enable environmental, social, and economic sustainability by addressing information asymmetries, governance challenges, and incentive misalignments in socio-technical systems relying on verifiable data sharing between organizations and individuals.

To address the research objective, this dissertation comprises eight interrelated essays examining digital sustainability from complementary perspectives and levels of analysis. The essays investigate digital infrastructures, data management arrangements, and the capabilities required for implementing, scaling, and sustaining sustainability-oriented organizational initiatives.

Taken together, this dissertation advances a mechanism-based and multi-perspective understanding of how digital technologies are configured and combined to foster digital sustainability. Thereby, if offers descriptive, explanatory, and prescriptive insights into the mechanisms and boundary conditions shaping environmental, social, and economic outcomes.

Keywords: Digital sustainability; Data management; Circular economy; DPP; Digital infrastructures; web3

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Copyright Statement

The following chapters are partly comprised of content taken from the research articles in this dissertation. To improve the readability of the text, I have omitted the standard labeling of these citations.

1 Introduction

1.1 Motivation

Sustainability, defined as "*Meeting the needs of the present without compromising the ability of future generations to meet their own needs*" (United Nations, 1987), has emerged as one of the defining grand challenges of the 21st century. Accordingly, global initiatives such as the United Nations' Sustainable Development Goals (SDGs) recognize that sustainable development extends beyond environmental protection and requires the simultaneous consideration of environmental integrity, social well-being, and economic welfare (Norman & MacDonald, 2015; UNDP, 2025; United Nations, 2015). Climate change, biodiversity loss, and resource depletion not only threaten ecological systems but also entail profound economic risks and social consequences. Climate-induced damages reduce economic output, undermine long-term prosperity, and exacerbate social inequalities (Dang et al., 2025; Waidelich et al., 2024). These impacts illustrate that environmental, economic, and social sustainability are tightly intertwined and cannot be addressed in isolation (Kotlarsky et al., 2023; Owsiany & Brohman, 2024; Watson et al., 2021).

In this context, digital technologies are taking on an increasingly central role in addressing sustainability challenges across these three dimensions of sustainability (Ketter et al., 2020; Kotlarsky et al., 2023; Pan & Zhang, 2020). Digital infrastructures (Pan et al., 2022), data-driven systems (Püchel et al., 2024), and algorithmic decision-making (Ghanbari & Nissinen, 2025) are widely used to measure environmental impacts, assess climate-related risks, optimize resource allocation, and coordinate complex socio-technical systems (Schoormann et al., 2025). Importantly, digital technologies no longer merely represent the physical world but increasingly actively shape it (Kotlarsky et al., 2023), for example by steering energy systems (Gholamzadehmir et al., 2020), governing supply chains (Heeß et al., 2024), or enabling new forms of economic coordination (Medaglia & Damsgaard, 2020). As a result, sustainable outcomes are becoming deeply intertwined with the design, governance, and use of digital resources and artifacts (Kotlarsky et al., 2023; Owsiany & Brohman, 2024).

Within the Information systems (IS) community, sustainability-related research has traditionally been conducted through the lens of Green IT (e.g., Molla, 2013; Murugesan, 2008) and Green IS (e.g., Leidner et al., 2022; Loeser et al., 2017). This discourse has early on already recognized the interplay of the three dimensions of sustainability (e.g., Seidel et al., 2013). However, while this body of work has generated important insights, the IS research domain is progressing slowly in investigating their interplay and underlying mechanisms (Kotlarsky et al., 2023; Owsiany & Brohman, 2024; Watson et al., 2010, 2021). More recent work has therefore argued for a broader conceptualization of the interplay of digital technologies and sustainability that reflects the multifaceted nature of sustainability challenges and the expanding role of digital technologies (Haugjord & Aanestad, 2023; Kotlarsky et al., 2023; Owsiany & Brohman, 2024). The emerging notion of digital sustainability captures this shift by conceptualizing digital sustainability as the "*development and deployment of digital resources and artifacts toward improving the environment, society, and economic welfare*" (Kotlarsky et al., 2023, p. 938). This perspective aligns digital technologies with all three dimensions of sustainability, acknowledges their constitutive role in shaping socio-economic and ecological realities, and thereby supports the ongoing efforts of practitioners to improve sustainability in a multifaceted way (Kotlarsky et al., 2023; United Nations, 2015).

To conceptualize how digital technologies support the three dimensions of sustainability, Dedrick (2010) distinguishes three levels of impact: first-order effects arising from the production, use, and disposal of IT infrastructure, second-order effects resulting from the use of information and information and communication technology (ICT) to optimize processes such as energy systems, logistics, or supply chains, and third-order effects that emerge from broader socio-economic transformations enabled by the widespread diffusion of digital technologies. Importantly, while first-order effects often emphasize the environmental costs of IT, second- and third-order effects highlight the potential of IS to enable more sustainable practices and structural change. In particular, these higher-order effects require common digital infrastructures that enable the collection, verification, and interoperability of heterogeneous data sources, as well as the coordination of multiple actors involved in sustainability-relevant decision-making (Babel et al., 2025a; Ketter et al., 2020; Körner et al., 2024a).

Against this background, it becomes evident that digital technologies can only generate sustainable impacts beyond isolated use cases when they enable higher-order effects in the sense of Dedrick (2010). This rationale is in line with Owsiany et al. (2024) and Weber & Rohracher (2012) who argue that examining whether technology and innovation legitimately contribute to sustainability outcomes will only be possible through an intertwined lens on sustainability and digital technologies.

As Watson et al. (2021) further emphasize, second- and third-order sustainability effects critically depend on the availability, verification, and governance of data across organizational and institutional boundaries. Put differently, sustainability-oriented digital technologies require more than deployment; their impact hinges on how data are generated, governed, and embedded into organizational decision-making. At the input level, particularly with regard to data, complex interdependencies emerge between digital infrastructures, governance arrangements, and organizational initiatives. Prominent examples include Digital Product Passports (DPPs), which rely on verifiable lifecycle and emission data, stakeholder participation in data provision, and organizational capabilities to translate collected data into action. Addressing these interdependencies is essential to ensure that digital sustainability initiatives scale, endure and achieve legitimacy among their users (Babel et al., 2025a). Accordingly, three interrelated elements are of particular importance.

First, sustainability-oriented IS require trustworthy digital infrastructures that provide reliable, granular, and verifiable data to render environmental impacts measurable and actionable (Cichy et al., 2021; Körner et al., 2024a, 2025). Research shows that without verifiable data flows, such as emission-based energy data (Babel et al., 2022; Körner et al., 2024a) or product lifecycle information (Babel et al., 2025a; Heeß et al., 2024), digital systems may fall short in steering sustainable behavior and supporting decision-making.

Second, stakeholders of these systems include both organizations and individuals, thereby depending on appropriate forms of data sovereignty and management that balance transparency, control, and participation (Babel et al., 2025a; Lefebvre et al., 2025). This is particularly critical where sustainability outcomes hinge on the voluntary provision of data (e.g., Berg et al., 2022; Heeß et al., 2024; Körner et al., 2024a) and insufficient governance and privacy mechanisms can undermine adoption and cooperation (Li et al., 2024).

Third, digital sustainability initiatives must be embedded in organizational value logics and decision-making structures (Ixmeier et al., 2024; Lopes & Barata, 2024). Beyond compliance or transparency, digital infrastructures need to be interpretable, actionable, and economically viable for organizations that are required to implement and operate them (Loeser et al., 2017). IS research shows that sustainability-oriented technologies, such as DPPs (Berger et al., 2023; Zhang & Seuring, 2024) or web3-based tokenization (Schaaf et al., 2025), face the risk of initially being perceived as overly complex digital initiatives if their value implications remain opaque or disconnected from organizational practices and initiatives. Accordingly, digital sustainability initiatives require mechanisms that make potential value contributions explicit, comparable, and situationally assessable, thereby enabling organizations to align sustainability-related digital technologies with ongoing digital strategic decision making processes and operational priorities (Corbett, 2010; Gholami et al., 2016; Ixmeier et al., 2024).

Crucially, these three elements do not operate independently. Shortcomings in any one dimension, data infrastructures, data management and governance arrangements, or organizational value integration, can constrain or distort the sustainability effects of the others. As a result, sustainable outcomes depend on how these elements are jointly configured and aligned rather than on isolated technological features or individual initiatives.

However, both organizational practice and IS research continue to approach digital sustainability in a fragmented manner, often focusing on individual technologies, governance mechanisms, or organizational practices in isolation (Kotlarsky et al., 2023; Kranz et al., 2024; Owsiany & Brohman, 2024). Thus, we have lacked an integrative understanding of how digital technologies can contribute to environmental, social, and economic sustainability through the interplay of information infrastructures, data management arrangements, and stakeholder involvement.

Against this backdrop, this cumulative dissertation adopts digital sustainability as an overarching conceptual frame and aims *to investigate how data-driven digital technologies can be designed, governed, and implemented to support environmental, social, and economic sustainability in socio-technical systems*.

1.2 Structure of the dissertation and embedding of the essays

This dissertation is cumulative and consists of eight essays that collectively contribute to the maturing body of research on digital sustainability and the role of digital technologies in sustainability transformations. Building on the conceptualization of digital sustainability as the development and deployment of digital resources and artifacts toward improving environmental sustainability, social well-being, and economic welfare, the dissertation is structured around these three pillars of digital sustainability.

Rather than treating environmental, social, and economic sustainability as separate domains, the dissertation conceptualizes them as mutually reinforcing and jointly enabled through data-driven digital technologies. Across all three pillars, a joint underlying logic connects the contributions: sustainability-oriented digital technologies can only generate enduring impact when verifiable data, legitimate governance arrangements, and organizational value integration are aligned.

Methodologically, the dissertation applies multiple theoretical lenses, including data governance, the resource-based view, game-theoretic reasoning, and capability-based perspectives, and combines diverse research designs such as Design Science Research (DSR), literature reviews, case studies, and analytical modeling. The empirical contexts span multiple levels of analysis, ranging from individuals and organizations to inter-organizational ecosystems. Figure 1.1 illustrates the positioning of the essays around the digital sustainability paradigm.

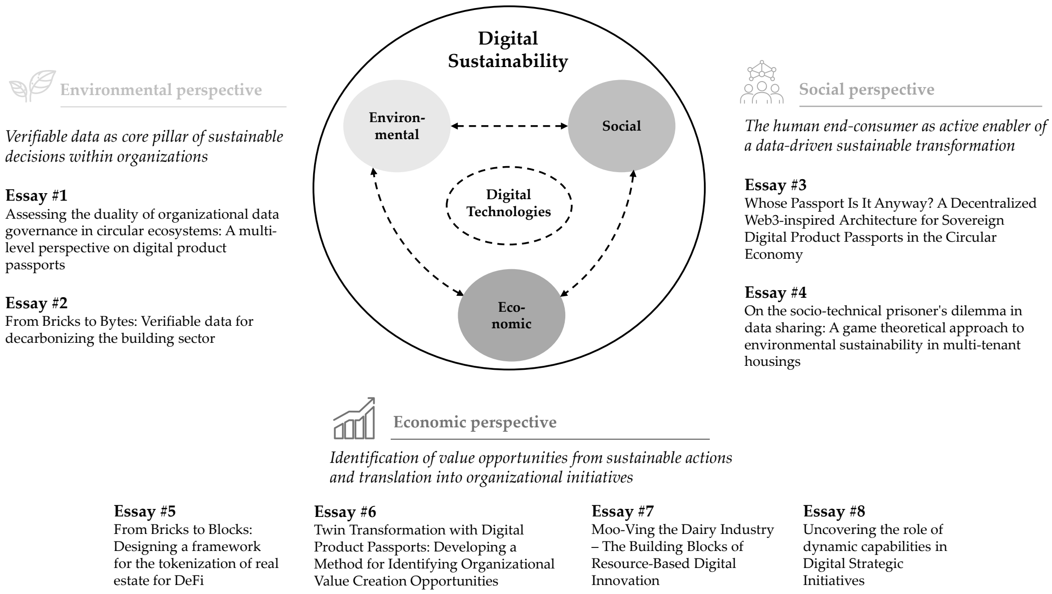

Figure 1.1: Interplay of the three dimensions of Digital Sustainability at the intersection of Digital Technologies

First, from an **environmental perspective**, this dissertation examines how digital technologies enable sustainability by supporting decarbonization efforts and Circular Economy (CE) practices. Central to this pillar is the role of verifiable sustainability data, particularly emission- and product lifecycle-related data, as a critical digital resource for making environmental impacts measurable, comparable, and actionable.

Essay 1 and 2 provide a foundational understanding of how data-driven digital infrastructures enable environmental sustainability. They demonstrate that digital technologies generate ecological value only when underlying data, such as emission intensities, energy consumption, or product lifecycle information, is reliable, granular, interoperable, and verifiable across organizational boundaries. Without such data inputs, digital systems remain limited to symbolic transparency and lack the capacity to steer sustainable behavior, inform decision-making, or support regulatory and managerial interventions.

This pillar thus establishes verifiable data infrastructures as the environmental foundation of digital sustainability, while highlighting that technological potential alone is insufficient in the absence of robust data governance mechanisms that ensure sharing of verifiable data.

Second, taking a **social perspective**, this dissertation builds on the environmental foundation by examining how digital sustainability systems depend on individual human actors. This pillar emphasizes that digital technologies for sustainability enablement and their underlying data infrastructures rely on appropriate forms of data sovereignty and governance to ensure participation, trust, and legitimacy.

Essay 3 and 4 analyze how human-centric digital technologies need to be designed in terms of sovereignty, privacy, and governance mechanisms and how their adoption depends on individuals' willingness to engage with digital sustainability systems to voluntarily provide data. Accordingly, this pillar highlights, that environmental and economic sustainability outcomes hinge on social acceptance, especially when data provision is decentralized and benefits are indirect or long-term. Thus, verifiable data infrastructures must be paired with governance arrangements that balance transparency, control, and participation, making social legitimacy the key link between environmental data availability and the diffusion and effectiveness of digital sustainability initiatives.

Third, from an **economic perspective**, this dissertation investigates how digital sustainability initiatives can be translated into sustained economic welfare by embedding them into organizational value logic and decision-making structures. This pillar builds on the premise that verifiable data and legitimate governance are necessary but not sufficient conditions for impact unless organizations can integrate sustainability-related digital technologies into strategic capabilities, business models, and operational priorities.

Essay 5, 6, 7, and 8 adopt an integrative view on digital sustainability. They demonstrate how organizations leverage data infrastructures and governance mechanisms to comply with sustainability-related regulation, develop new digital markets, and create novel value streams. At the same time, the findings show that sustainability-oriented digital technologies may be perceived as regulatory burdens if their value implications remain opaque or disconnected from organizational practice. This pillar conceptualizes digital sustainability as a strategic-economic phenomenon in which environmental objectives and social legitimacy translate into organizational capabilities and long-term value creation through deliberate alignment with digital strategies. Table 1.1 provides and overview of the eight essays and their assignment to the pillars of digital sustainability.

Table 1.1: Overview of the 8 essays investigating the three pillars of digital sustainability

Title	Publication outlet	VHB Rating 2024	Publication status
1. Environmental sustainability			
Essay 1:			
Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports	Blinded due to peer review process	A	Under Review
Essay 2:			
From Bricks to Bytes: Verifiable data for decarbonizing the building sector	Energy Informatics	C	Published as Körner et al. (2024)
2. Social sustainability			
Essay 3:			
Whose Passport Is It Anyway? A Decentralized Web3-inspired Architecture for Sovereign Digital Product Passports in the Circular Economy	Blinded due to peer review process	B	Under review after minor revision
Essay 4:			
On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings	Blinded due to peer review process	B	Prepared for submission
3. Economic sustainability			
Essay 5:			
From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi	IEEE Access	B	Published as Kranz et al. (2025)
Essay 6:			
Twin Transformation with Digital Product Passports: Developing a Method for Identifying Organizational Value Creation Opportunities	Blinded due to peer review process	B	Under review after major revision
Essay 7:			
Moo-Ving the Dairy Industry - The Building Blocks of Resource-Based Digital Innovation	Proceedings of the European Conference on Information Systems 2024	A	Published as Kranz et al. (2024)
Essay 8:			
Uncovering the role of dynamic capabilities in Digital Strategic Initiatives	Blinded due to peer review process	B	Under review after major revision

By structuring the essays around the three interdependent pillars of digital sustainability, this dissertation aims to provide an integrative understanding of how data-driven digital technologies enable environmental sustainability, social well-being, and economic welfare across organizational and societal domains.

The dissertation concludes with a summary and discusses limitations as well as avenues for future research in Chapter 5. Chapter 6 contains the references. The Appendix (A) provides (1) additional information on the essays included in this dissertation (A.1), (2) further research work (A.2), (3) my individual contributions to the essays (A.3), and (4) the essays' abstracts.

2 Environmental Sustainability

Environmental sustainability represents the most established and extensively examined dimension of sustainability in IS research (Melville, 2010). Early work in the Green IS stream primarily focused on reducing organizations' environmental footprint, for instance by decreasing energy consumption, lowering greenhouse gas emissions, and improving resource efficiency (Gholami et al., 2016; Jenkin et al., 2011; Melville, 2010). Within this stream, IS were largely conceptualized as instruments for monitoring, reporting, and optimizing resource use, thereby supporting environmentally responsible behavior at the operational level.

However, prior research has long emphasized that more transformative sustainability effects extend beyond such first-order impacts. In particular, second- and third-order effects, such as the optimization of energy systems, supply chains, or broader socio-technical transformations, critically depend on the systematic collection, integration, and analysis of sustainability-relevant data (Dedrick, 2010; Watson et al., 2021). As Watson et al. (2021) further argue, realizing these higher-order effects requires ISs that integrate heterogeneous data sources and enable coordination and collaboration across organizational and institutional boundaries.

Building on this foundation, more recent research has advanced a data-centric perspective on environmental sustainability, conceptualizing data not merely as an output of digital systems, but as a foundational input and strategic resource for sustainability initiatives. In this regard, Krasikov & Legner (2023) demonstrate how organizations develop dedicated data sourcing practices to reliably measure environmental impacts, comply with sustainability regulation, and avoid greenwashing. Their findings show that environmental sustainability initiatives increasingly hinge on organizations' ability to source, reconcile, and govern high-quality environmental data, particularly emission- and product-related data, across complex value chains. This perspective shifts attention from isolated system functionalities toward the underlying data infrastructures and practices that render environmental impacts visible, comparable, and auditable.

Complementing this view, recent work further emphasizes the importance of data quality and availability for enabling environmental sustainability in practice. For example, Ixmeier et al. (2024) show that emission data becomes actionable for decarbonization only when it is sufficiently granular, temporally resolved, and reliable at the level of operational processes. Without these data characteristics, digital systems risk remaining decoupled from environmental performance, thereby limiting their ability to support informed decision-making and effective sustainability interventions.

Taken together, this stream of research conceptualizes environmental sustainability in an increasingly active and interventionist sense. Rather than treating digital technologies merely as tools for representing environmental impacts, contemporary perspectives emphasize their role in shaping and steering environmentally sustainable transformations by enabling organizations to actively intervene in physical processes, supply chains, and production systems (Watson et al., 2021).

Central to these transformations is the availability of reliable, granular, and verifiable environmental data, particularly Greenhouse Gas (GHG) emission data and product lifecycle information, which forms the basis for operational decarbonization, CE practices, and crossorganizational coordination.

Against this background, environmental sustainability in the context of digital sustainability is closely tied to the design of digital infrastructures and governance mechanisms that enable trustworthy data collection, sharing, and use. Accordingly, this chapter addresses environmental sustainability through two complementary essays. While the first essay focuses on the intra-organizational data management of product-related data to enable CE practices, the second essay examines how verifiable emission data can support operational decarbonization in a highly emission-intensive sector. Table 2.1 provides an overview of the research designs of the presented studies.

Table 2.1: Research designs of Essay 1 and 2

Title	Research design
Verifiable data as core pillar of sustainable decisions within organizations	
Essay 1:	
Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports	**Multivocal literature review and interview study** • Screening 1006 academic (AL) and 58 gray literature (GL) items (Garousi et al., 2019) • Derivation of a final set of 37 papers (27 AL, 10 GL) • Qualitative coding of the literature (Gioia et al., 2013) • Derivation of design requirements for intra-organizational data management • Evaluation of design requirements by means of 20 semi-structured expert interviews (Schultze & Avital, 2011) • Derivation of five design principles and framework for interplay of design requirements and supporting mechanisms for intra-organizational data management
Essay 2:	
From bricks to bytes: Verifiable data for decarbonizing the building sector	**Design science** • Identification of current problems and existing approaches in literature and practice • Structured literature review of 97 articles yielding a final set of 25 articles relevant to the scope of the study (vom Brocke et al., 2015) • Derivation of design challenges and meta-requirements for a BEEMS (Peffers et al., 2007; Walls et al., 1992) • Development of six design principles for BEEMS (Gregor et al., 2020) • Conduction of twelve semi-structured expert interviews to evaluate initial set of design principles (Sonnenberg & vom Brocke, 2012) • Qualitative content analysis of the expert's input (Mayring, 2000) • Development of an high-level architecture of a BEEMS

2.1 Strategic data sharing to support the circular economy

Building on prior IS research, environmental sustainability is increasingly conceptualized in an active and interventionist sense, emphasizing the role of digital technologies in shaping and steering physical processes, supply chains, and production systems toward less environmentally harmful outcomes (Kotlarsky et al., 2023). In this context, data has emerged as a central enabler of sustainability transformations. In particular, the transition toward a CE depends on organizations' ability to share product-related data across value chains, enabling practices such as reuse, refurbishment, and recycling (Jäger-Roschko & Petersen, 2022; Zeiss et al., 2021). Prior research highlights that data in these settings serves not merely an informational purpose for compliance or reporting, but a transformational one by enabling organizational learning, decision-making, and innovation (Côrte-Real et al., 2017; Krasikov & Legner, 2023; Püchel et al., 2024). Responding to these developments, regulatory initiatives such as the Ecodesign for Sustainable Products Regulation introduce DPPs as a key instrument for structuring and sharing product lifecycle data across organizational boundaries. Thereby, existing research conceptualizes DPPs as digital infrastructures that span organizational and temporal boundaries, including the need for persistent data availability across lifecycle stages (Jensen et al., 2023, 2024). Their effectiveness therefore hinges on organizations' ability to reliably prepare, manage, and provide product-related data in forms that are usable, interoperable, and verifiable for multiple stakeholders in circular ecosystems (Chaudhuri et al., 2024; Gieß & Möller, 2025; Püchel et al., 2024).

However, while debates in research and policy predominantly focus on inter-organizational solutions such as shared data spaces, standards, and federated identity infrastructures, these approaches presuppose substantial intra-organizational readiness to generate trustworthy data inputs and to govern access, accountability, and lifecycle updates (Jarvenpaa & Essén, 2023; Zeiss et al., 2021). Traditional data governance frameworks have primarily been designed to ensure internal control, compliance, and risk mitigation (Abraham et al., 2019; Otto, 2011), reflecting a defense-oriented data strategy (DalleMule & Davenport, 2017). In DPPs contexts, this orientation becomes increasingly insufficient, as organizations are simultaneously expected to protect sensitive information while enabling controlled data sharing that supports circular value creation and sustainability innovation (Bodendorf & Bayr, 2025).

Against this background, it remains unclear how organizations must structure intra-organizational data governance and management to enable the introduction of DPPs and the controlled, verifiable sharing of product-related data required for CE transitions. Addressing this gap, Essay 1 asks: *How can intra-organizational data management be structured to enable the introduction of DPPs and the sharing of product-related data that advances the transition toward the circular economy?*

To address this research question, Essay 1 follows a design-oriented research logic that is informed by established IS research on design science (Hevner et al., 2004; Peffers et al., 2007). Empirically, the essay draws on a multivocal literature review, a researcher workshop, and 20 semi-structured expert interviews. Rather than treating DPPs success as a purely technical interoperability issue, the study focuses on the organizational "data work" through which product-related sustainability data are sourced, curated, updated, and made shareable over time.

The results are presented in two steps and structured across three analytical levels. At the macro level, the essay derives six requirements that specify what DPP-oriented sustainability data sharing must accomplish from an inter-organizational and regulatory perspective (e.g., data availability and quality, interoperability, and verifiability). At the micro level, these requirements are translated into five intra-organizational design principles that operationalize external demands into internal roles, processes, and controls. At the meso-level, the principles are complemented by three organizational mechanisms that stabilize implementation by embedding DPP-relevant data governance in strategy, CE roadmaps, and cross-functional coordination. Figure 2.1 depicts the interplay between the derived requirements and principles within intra-organizational data management.

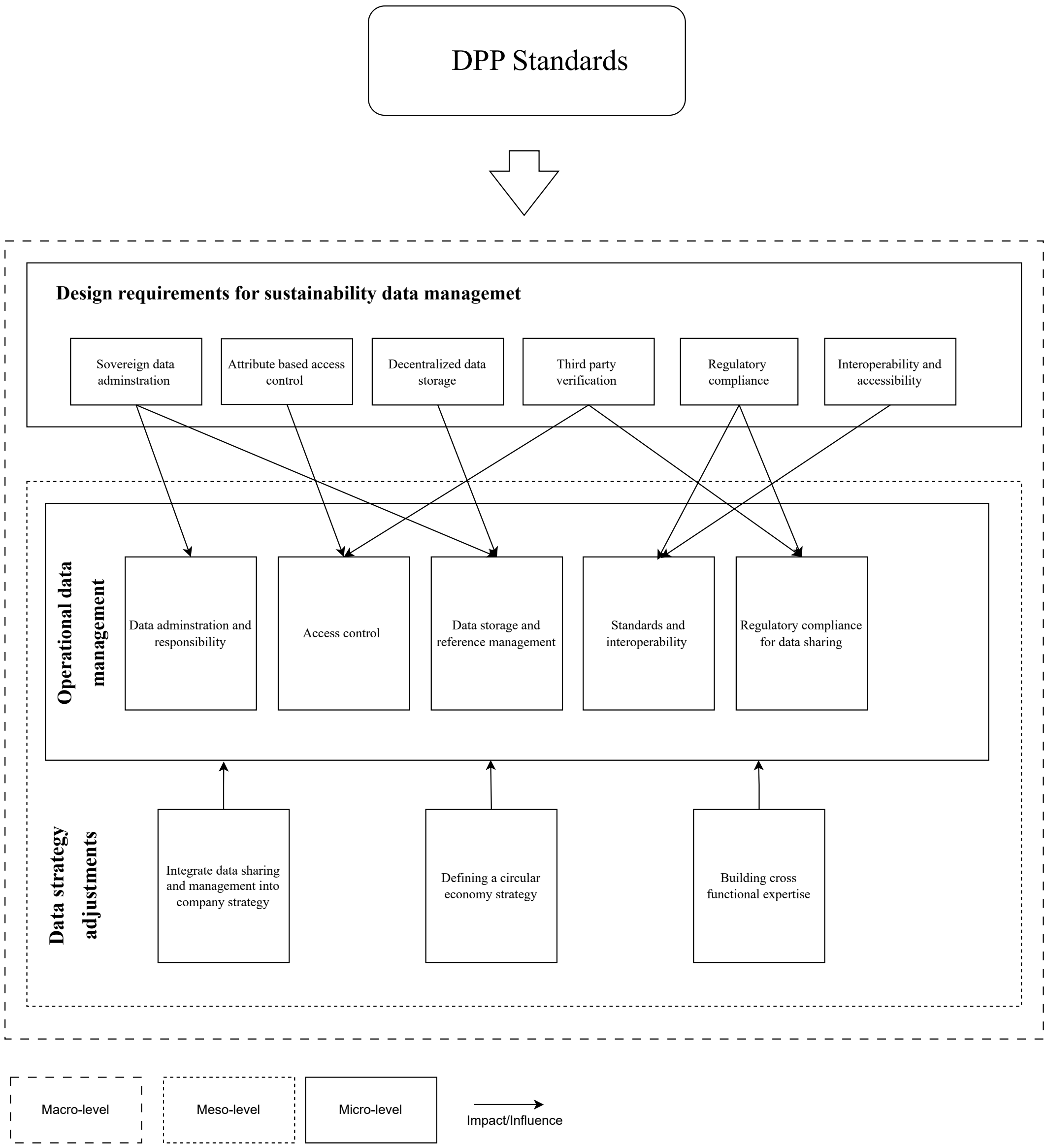

Figure 2.1: Embedding of the design principles and mechanisms into the macro-meso-micro logic of inter-organizational data management (Essay 1)

First, the macro-level requirements clarify that the usefulness of DPP data depends on an organization's ability to collect, process, and share product-related information beyond its boundaries while ensuring accuracy, security, and regulatory compliance (Lefebvre et al., 2025; Reich et al., 2025). Together, the requirements reflect that DPPs ecosystems require not only "more data," but permissioned and interoperable data flows that remain reliable over time and across multi-actor value chains (Berg et al., 2022; Heeß et al., 2024; Jansen et al., 2023; Piétron et al., 2023; Plociennik et al., 2022). At the same time, they highlight the organizational tension between enabling transparency and protecting sensitive information, making data governance a prerequisite for DPP implementation rather than a secondary compliance task (Ducuing & Reich, 2023; Steinwender et al., 2024).

Second, the micro-level design principles translate these requirements into intra-organizational guidance. The five principles specify how organizations should (1) establish clear data administration and responsibility structures that coordinate centralized governance with decentralized business units; (2) implement fine-grained access control aligned with role- and attribute-based models; (3) ensure sovereignty-preserving storage and persistent reference management that enables lifecycle-long access; (4) harmonize data standards and interoperability to avoid fragmentation and enable scalable integration; and (5) institutionalize regulatory compliance and auditability so that DPP data can function as a verifiable basis for data sharing under evolving requirements (Heeß et al., 2024; Langley et al., 2023; Otto, 2011). In doing so, the principles respond to the shift from defense-oriented governance aimed at internal control toward governance that must simultaneously enable externally accountable, value-generating data sharing in circular ecosystems (DalleMule & Davenport, 2017; Zeiss et al., 2021).

In sum, Essay 1 demonstrates that implementing DPPs cannot be achieved through inter-organizational infrastructures alone. Rather, it requires a reconfiguration of intra-organizational data governance and management so that product-related sustainability data becomes continuously usable, controlled, and reusable across organizational boundaries and product life cycles. By conceptualizing intra-organizational data governance and management as a meso-level organizational capability, the essay highlights its pivotal role in enabling organizations to operate effectively within regulated, evolving inter-organizational ecosystems. In this sense, DPPs do not merely function as technical or regulatory instruments, but as digital infrastructures that link internal data practices with crossorganizational collaboration and circular value creation.

The derived requirements and principles provide a transferable blueprint for aligning intra-organizational readiness with ecosystem-oriented data sharing arrangements. By embedding role-based access, sovereignty-preserving reference management, interoperability alignment, and compliance-oriented auditability into coherent organizational structures, firms can support trustworthy product data sharing and thereby strengthen the conditions for circular economy practices and environmental sustainability.

Accordingly, Essay 1 contributes to this dissertation by showing that sustainability-oriented digital infrastructures unfold their potential only when supported by adapted intra-organizational data governance and management structures.

2.2 Verifiable GHG emission data to leverage effective decarbonization measures

While Essay 1 addresses environmental sustainability through the management of product-related data for CE practices, Essay 2 focuses on operational decarbonization and examines how verifiable GHG emission data can enable emission-based decision-making in energy-intensive systems. The essay is situated in the context of the building sector, which represents one of the largest contributors to global GHG emissions and remains significantly behind required decarbonization trajectories despite advances in energy efficiency and renewable energy integration (IEA, 2023; IPCC, 2021; United Nations, 2022a).

Prior research in Green IS and Energy Informatics has demonstrated that digital technologies can support energy efficiency, demand-side management, and the integration of renewable energy sources (Fridgen et al., 2021; Goebel et al., 2014; Watson et al., 2010). However, much of this work relies on average or static emission factors, which limits the effectiveness of emission-based actions and undermines trust in the resulting information (Reichelstein, 2023; Sjödin & Grönkvist, 2004; Sullivan & Gouldson, 2012). As recent literature on digital decarbonization emphasizes, meaningful emission reductions require granular, traceable, and verifiable data that links energy consumption to its actual emission footprint along the entire energy flow (Babel et al., 2022; Körner et al., 2023a; Müller et al., 2023).

Importantly, this highlights a broader role of sustainability-relevant data that complements the governance perspective developed in Essay 1. While inter-organizational data sharing and governance are necessary to enable transparency, accountability, and coordination across value chains, they are only one aspect of achieving decarbonization outcomes in practice (Körner et al., 2025; Krasikov & Legner, 2023). Data must not only be collected and managed across organizational boundaries, but also translated into concrete actions within organizations' existing business models. Environmental sustainability thus depends on a dual role of data: enabling coordination and trust at the inter-organizational level, while simultaneously steering operational processes at the organizational level (Ixmeier et al., 2024; Ketter et al., 2020).

This dual role becomes particularly critical in sectors with high CO_2 intensity, where sustainability outcomes are shaped less by isolated strategic commitments and more by the cumulative effects of daily operational decisions. In such contexts, organizations must be able to align ongoing processes, such as energy consumption, load shifting, or asset operation, with the carbon intensity of the underlying energy sources. Doing so requires data that is not only shared across heterogeneous actors and infrastructures, but also verifiable, timely, and actionable, allowing organizations to steer current operations based on actual emission impacts (Körner et al., 2023b; Müller et al., 2023).

Against this background, Essay 2 addresses a central limitation of existing Building Energy Management System (BEMS). While BEMSs are widely deployed to optimize energy consumption and costs, they primarily prioritize economic efficiency and neglect emissions as a core steering variable (Cavalheiro & Carreira, 2016; Fiorini & Aiello, 2018; Jradi et al., 2021). Further, current systems lack mechanisms for ensuring the verifiability, traceability, and integrity of emission data across decentralized and heterogeneous energy infrastructures. As buildings increasingly operate within complex energy ecosystems involving multiple producers, distributors, prosumers, and regulatory stakeholders (Bjørndal et al., 2023; Fridgen et al., 2022), this gap limits the ability to translate sustainability goals into reliable, emission-based operational decisions.

To address this challenge, Essay 2 poses the following research question: *How to design a Building Energy Management System to enable verifiable GHG-emission based actions?*

Following a DSR approach (Hevner et al., 2004; Peffers et al., 2007), the essay develops actionable design knowledge for advancing BEMSs toward emission-centric decision support systems. Building on a systematic literature review in Energy Informatics and Green IS, the study identifies ten recurring challenges related to data quality, interoperability, automation, trust, privacy, and usability in emission-based energy management (Melville & Whisnant, 2014; Zampou et al., 2022). These challenges are consolidated into three meta-requirements that capture the core demands of verifiable emission management: robust data processing, integrated automation and analytics, and secure, trustworthy data handling.

Based on these meta-requirements, the study derives six design principles for a BEEMSs, addressing end-to-end data collection, interoperability, scalable automation, data sovereignty, verifiability, and stakeholder-oriented usability. In contrast to purely technical system proposals, these principles explicitly integrate organizational, regulatory, and socio-technical considerations, reflecting the multi-stakeholder nature of building energy systems (Goebel et al., 2014; Kranz et al., 2021; Zampou et al., 2022). The design principles are iteratively evaluated through expert an workshop and semi-structured interviews with stakeholders from energy provision, building management, and sustainability reporting, thereby grounding the results in both research and practice. The original artifact and full design specification are reported in the published paper (cf. Körner et al., 2024a). For the purpose of this dissertation, I summarize the validated design principles and their theoretical grounding in table 2.2.

Table 2.2: Design principles for a BEEMS (Körner et al., 2024b)

Design Principle	Aim	Key Literature
DP1: End-to-end energy and emission data collection	The BEEMS should collect, receive, and pre-process production and energy consumption-related data at a sufficient level of granularity for stakeholders' use cases and enrich these data to establish a solid foundation for comprehensive analysis and decision-making.	Cavalheiro and Carreira, 2016; Gräuler et al., 2013; Hilpert et al., 2013; Melville and Whisnant, 2014; Zampou et al., 2022
DP2: Interoperability and flexibility	The BEEMS should be able to integrate and run in parallel with external work- and data flows from existing or future energy IS and market requirements (e.g., regulations). Also, it should demonstrate adaptability to effectively address both current and evolving requirements and objectives.	Gräuler et al., 2013; Hoang et al., 2017; Melville and Whisnant, 2014; Zampou et al., 2022
DP3: Scalable and efficient data processing	The BEEMS, along with all its components, should autonomously manage (i.e., collect, store, and process) energy data and corresponding actions to reduce reliance on human-operated tasks and enhance overall efficiency.	Arnesano et al., 2018; Hilpert et al., 2013; Hoang et al., 2017; Sangeeth LR et al., 2020; Wehkamp et al., 2020; Zampou et al., 2014
DP4: Data sovereignty and zero-trust policy	The BEEMS should follow a data sovereignty approach and ensure the confidentiality, integrity, authenticity, verifiability, and availability of processed data in line with jurisdictional frameworks. Additionally, the system should also be enriched by a continuous verification (zero-trust) concept to prevent unauthorized data access.	Goebel et al., 2014; Zampou et al., 2022
DP5: Data verifiability and information reliability	The BEEMS should enable traceability, validity checks, and verifiability of energy and emission data as well as processing workflows and data flows to enhance trust in the data and the derived information.	Hilpert et al., 2013; Kranz et al., 2021; Melville and Whisnant, 2014; Zampou et al., 2022
DP6: Usability for all stakeholders	The BEEMS should provide sufficient usability to foster system acceptance by ensuring alignment with stakeholders' specific application purposes and different asset types.	Ali et al., 2020; Gimpel et al., 2020; Kranz et al., 2021; Melville and Whisnant, 2014; Zampou et al., 2022

In addition, Essay 2 develops a conceptual architecture for a BEEMS that integrates energy management, building management, and emission management modules with a workflow engine and role-based access mechanisms (cf. Figure 2.2). This architecture illustrates how verifiable emission data can be operationalized across the full energy flow, from production and distribution to consumption, while preserving data sovereignty and enabling auditability. By doing so, the essay demonstrates how digital technologies can move beyond representing environmental impacts toward actively steering decarbonization processes in physical systems, in line with the digital sustainability perspective (Kotlarsky et al., 2023; Schoormann et al., 2025).

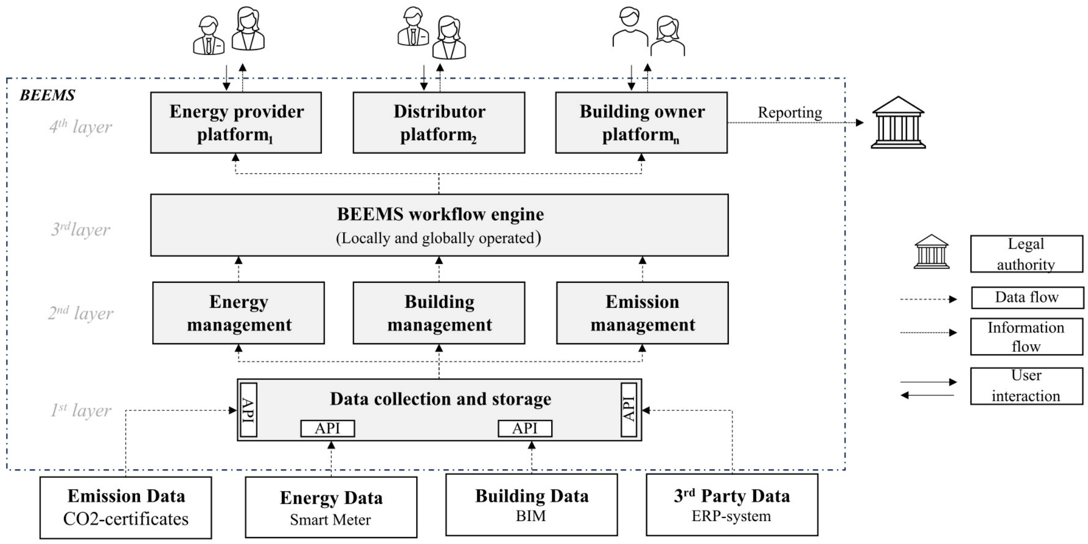

Figure 2.2: High-level architecture of a Building Energy Emission Management System based on the six design principles (Essay 2)

Overall, Essay 2 contributes to environmental sustainability research by showing that operational decarbonization critically depends on the availability of verifiable, trustworthy emission data embedded in digital infrastructures. It extends prior work on Energy Emission Management Systems (EEMSs) by focusing explicitly on the building sector and by conceptualizing verifiability and data sovereignty as core design concerns rather than optional features. In doing so, the essay complements Essay 1 by shifting the focus from circular product data governance to real-time, emission-based operational decision-making, thereby covering two central mechanisms through which digital technologies enable environmental sustainability.

3 Social Sustainability

Social sustainability constitutes a core dimension of sustainability, as it concerns the conditions under which societal needs are met without compromising the well-being, autonomy, and participation of present and future generations (Mckenzie, 2004; Vallance et al., 2011). In contrast to environmental sustainability, which primarily focuses on the preservation of natural resources, social sustainability emphasizes human-centered outcomes such as equity, inclusion, agency, and quality of life. It thus addresses not only the distribution of benefits and burdens within societies but also individuals' ability to participate meaningfully in social, economic, and political processes (Kotlarsky et al., 2023; Mckenzie, 2004).

Within the field of IS research, social sustainability has increasingly been examined through the lens of digital technologies and their societal implications. Prior studies highlight the potential of IS to enhance individuals' quality of life and to mitigate the social consequences of economic activities by improving access to services, enabling participation, and supporting vulnerable groups (Kneissel et al., 2023; Mckenzie, 2004; Mohamed et al., 2020). Recent research in this domain has, for example, investigated how digital technologies facilitate access to healthcare (Barjis et al., 2013) or support entrepreneurship and economic participation in rural and underserved regions through online platforms (Tim et al., 2020). These contributions illustrate how IS can act as enablers of social inclusion and social welfare.

Building on this stream of research, Schoormann and Kutzner (2020) propose a layered conceptualization of social sustainability in IS research, distinguishing between stakeholders, social themes, services, and implementation mechanisms. This perspective highlights that social sustainability is not achieved through isolated technological interventions but emerges from the interaction of digital infrastructures, governance arrangements, and human actors across multiple levels of analysis. Importantly, it positions ISs not only as tools for service provision but also as socio-technical structures that shape access, control, and participation.

In this context, the proliferation of connected devices, sensor technologies, and digital infrastructures, has positioned data as a fundamental driver of innovation, digital services, and sustainability transitions across industries (Beverungen et al., 2022; Duparc et al., 2024; Hillebrand et al., 2023). Accordingly, social sustainability in digital environments is no longer limited to the provision of social services or digital access alone. As organizations adopt sustainability strategies, they require new forms of data on environmental impacts, deeper insights into causal relationships, and mechanisms for sharing knowledge about effective and ineffective practices (Melville, 2010, p. 2). In an increasingly interconnected socio-technical landscape, these requirements extend beyond organizational boundaries and involve multiple stakeholders while these coordinated contributions determine collective outcomes.

Consequently, the provision and sharing of data should be understood as a socio-technical phenomenon rather than a purely technical process. It depends not only on interoperable ISs but also on governance structures, institutional trust, and individuals' willingness to contribute information (Adeyeye, 2024; Cichy et al., 2021; Gimpel et al., 2018; Hammer & Luse, 2025). Building on this foundation, and in line the United Nations, who define social sustainability as the positive and negative impacts of organizations on individuals (United Nations, 2022b), these considerations point toward a human-centric approach in which individuals are not merely data subjects but active participants in sustainability-oriented data ecosystems (Babel et al., 2025a).

This shift is particularly salient in sustainability-oriented and CE contexts, where extending product lifecycles and reducing environmental impacts require continuous data management long after the point of sale. In such settings, data infrastructures increasingly mediate individuals' roles in sustainable value creation by shaping how information is generated, accessed, and governed across a product's lifecycle (Babel et al., 2025a).

A human-centric approach to digital infrastructures emphasizes consumer control over data, traditionally framed in terms of privacy and informed consent (Human et al., 2022). However, prior research highlights that organizations often apply opaque data collection and usage practices, thereby limiting individual agency despite formal regulatory safeguards such as the General Data Protection Regulation (GDPR) of the EU (Human et al., 2022; Li et al., 2024). Extending beyond privacy and consent, the concept of data sovereignty provides a broader lens on social sustainability by emphasizing self-determination over data use. Defined as the capability of a natural person or corporate entity for exclusive self-determination over its economic data goods (Nagel & Lycklama, 2021, p. 27), data sovereignty highlights persistent tensions between individual autonomy and corporate data-driven business models (Lauf et al., 2022).

Accordingly, this dissertation adopts a human-centric notion of data sovereignty that encompasses individuals' decision-making authority over data and frames data governance as a core mechanism of social sustainability in digital systems. Against this background, this chapter addresses social sustainability through two complementary essays. While Essay 3 examines how human-centric DPPs can be designed to reconfigure data ownership and control, Essay 4 employs game-theoretic reasoning in the real estate context to analyze how privacy costs and incentive misalignments shape voluntary data-sharing behavior and collective sustainability outcomes. Table 3.1 provides an overview of the research designs of Essays 3 and 4.

Table 3.1: Research designs of Essay 3 and 4

Title	**Research design**
The human end-consumer as active enabler of a data-driven sustainable transformation	
Essay 3:	
Whose Passport Is It Anyway? A Decentralized Web3-inspired Architecture for Sovereign Digital Product Passports in the Circular Economy	**Design science** • Design and Development centered design science process driven by interestingness (Gregor et al., 2020) • Building on findings of a first design phase presented in Babel et al. (2022) to develop wallet and NFT-based DPP infrastructure • First design and development cycle: Transfer of technological infrastructure to multi-step assembled consumer goods • Formative evaluation of the artifact through benchmarking tests and presentation of the results at HICSS 2025 as Babel et al. (2025) • Second design and development cycle: incorporation of HICSS feedback and adjustment of research focus ensure benefits for end-consumers regarding data access • Summative evaluation: 1) descriptive argument on the artifacts ability to ensure sovereignty and long-term data access and 2) experimental (i.e., simulation and benchmarking test on the scalability of the artifact) • Systematic interpretation of demonstration and evaluation results to derive four prescriptive design principles
Essay 4:	
On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings	**Game theoretic modeling** • Empirically motivated through a three-months researcher-practitioner intervention with large German housing company • Conduction of structured literature review at the intersection of data sharing, privacy and end users yielding 806 initial articles (Webster & Watson, 2002) • Derivation of 27 final articles forming the basis for identifying recurring determinants of data-sharing behavior and the design of the game-theoretic model • Development of one-shot game characterized a prisoner's dilemma or problem of the common good aligned with IS research (Fernandes & Pereira, 2021; Li et al., 2024; Peng et al., 2025)

3.1 End users as active participants of sustainable transformation

The human-centric perspective on social sustainability becomes particularly salient in the context of the CE, where human end-consumers play an increasingly active role in extending product lifecycles through reuse, repair, resale, and recycling (Adisorn et al., 2021; Plociennik et al., 2022). In this setting, access to reliable and transferable product information is a prerequisite for enabling informed decision-making and sustained participation in circular value creation.

Existing research predominantly conceptualizes DPPs as inter-organizational digital infrastructures that support transparency, regulatory compliance, and information exchange among organizations (Jäger-Roschko & Petersen, 2022; King et al., 2023; Langley et al., 2023; Serna-Guerrero et al., 2022). Accordingly, current DPPs infrastructures primarily focus on Business-to-Business (B2B) data exchange (Adisorn et al., 2021; Berger et al., 2023; Heeß et al., 2024) granting human end-consumers only limited, read-only access to product-related information.

This organizationally centered design becomes problematic in CE contexts for two reasons. First, end-consumers are no longer merely passive recipients of product information but increasingly act as central stakeholders whose decisions directly affect product longevity and material circulation. Second, products in circular systems often outlive their original manufacturers, rendering centralized and issuer-dependent data ownership models fragile over extended lifecycles (Ducuing & Reich, 2023; Reich et al., 2025). As a result, prevailing DPP approaches insufficiently account for the long-term agency, sovereignty, and custodianship requirements of human end-consumers.

Addressing these imbalances requires a shift from access-oriented toward governance-oriented conceptions of data control. Following the notion of Gsenger et al. (2020) on end user empowerment within the digital space, consumer empowerment necessitates not only access to data, but also enforceable rights over how data are used, shared, and retained. This perspective is particularly relevant for DPPs, which currently prioritize regulatory compliance and inter-organizational objectives over end-consumer agency. Existing DPPs frameworks predominantly focus on B2B data sharing and inter-organizational infrastructures, thereby overlooking risks such as issuer market exits, data discontinuity, and dependencies on centralized repositories that undermine long-term data sovereignty (Babel et al., 2025a).

Recent work therefore argues that DPPs themselves should be conceptualized as data assets, requiring infrastructures in which data owners simultaneously act as data providers (Babel et al., 2025a; von Scherenberg et al., 2024). Achieving this vision implies a hybrid infrastructure design in which product-related data are partly treated as a public-good and partly governed by individual owners. By granting consumers ownership and governance rights over product-related data, human-centric DPPs can reposition individuals from passive recipients to active custodians of digital product information, thereby fostering sustained participation, resilience, and social legitimacy within circular product ecosystems.

Against this background, it remains unclear how DPPs must be designed to support social sustainability by ensuring sovereign and long-lasting access to product-related data for human end-consumers. Addressing this gap, Essay 3 asks: *How can Digital Product Passports be designed to ensure sovereign and long-lasting access to product-related data for human end-consumers in circular economy ecosystems?*

To address this question, Essay 3 adopts a DSR approach and builds on justificatory knowledge from web3 technologies. Accordingly, the study develops a wallet-based DPP infrastructure that combines Verifiable Credentials (VCs) and Non-fungible Tokens (NFTs) to implement two core objectives: (1) *sovereign data custodianship* through user-side storage and control of DPP data, and (2) *issuer-independent continuity* by enabling ownership transfer without requiring re-issuance of credentials by the original manufacturer. Concretely, VCs encapsulate product and lifecycle attributes, whereas NFTs implement transferable ownership relations. Importantly, the approach intentionally omits the typically static holder reference within VCs and manages ownership via the NFT layer, thereby avoiding lifecycle-long dependence on the original issuer for data portability and ownership transitions.

A central novelty of the artifact lies in its support for complex product structures and circular use cases through nested DPPs. Thereby, DPPs from various stages of value creation are combined into a single, nested DPP, enabling domain-agnostic representation of complex supply chains and composite products. In addition, the approach is refined to accommodate heterogeneous Consumer-to-X (C2X) use cases by supporting the later unnesting of child-DPPs. This enables scenarios where individual components (e.g., batteries of electric vehicles) enter new cycles of reuse, repurposing, or recycling while preserving their association with the broader product lifecycle history. In this way, the artifact operationalizes human-centricity by repositioning end-consumers from passive recipients of lifecycle information to active custodians who can carry product data into secondary markets and circular loops beyond the initial point of sale. Figure 3.1 presents the structure of the proposed human-centric DPP-infrastructure.

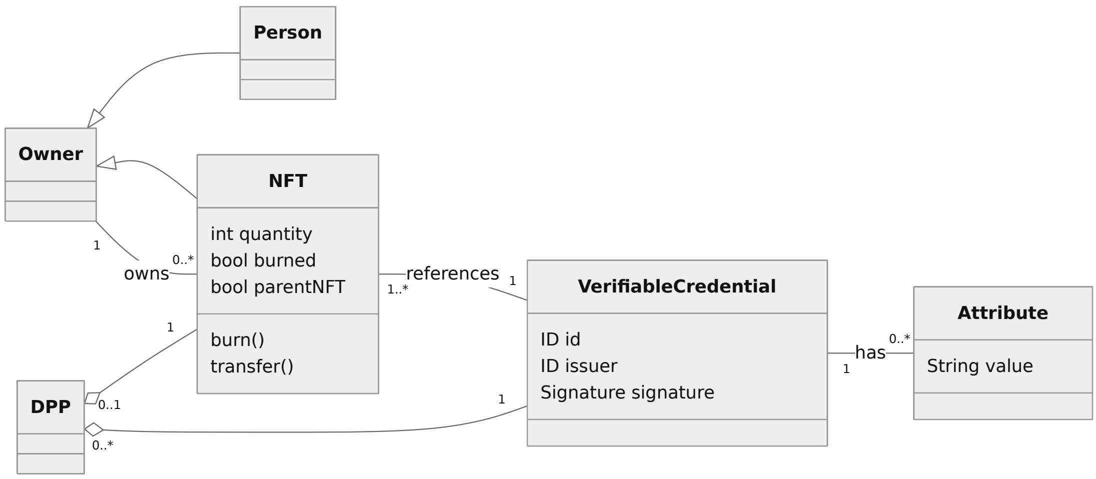

Figure 3.1: UML class diagram of a human-centric DPP-infrastructure (Essay 3)

Each DPP is represented by one VC and one NFT. Hereby, the VC encapsulates the DPP's data about the product, while the NFT implements the DPP's ownership structure. The VC stores its data as a set of attributes, the composition of which may vary depending on the specific class of DPP.

By binding each VC to at least one NFT we can use their flexible ownership structure. In cases where the ownership of one DPP is later distributed across multiple parties (e.g., cotton in Babel et al., (2025) or electricity in Babel et al., 2022 (2022), the NFT is fractionalized through applying the concept of fractionalizable NFTs, presented in Babel et al. (2022). This allows multiple NFTs to reference a single VC and thus also multiple DPPs to contain copies of a single VC. Since the underlying NFT infrastructure resolves the double-spending problem, the total of all fractionalized NFTs reliably adds up to the original amount represented in the original DPP. To manage DPPs, comprising both VCs and NFTs, each end-consumer must maintain a digital wallet (Babel et al., 2022, 2025b). This digital wallet securely stores all cryptographic key pairs on which NFT ownership is based and contains the necessary metadata for transferring NFTs. Additionally, it stores all VCs and supports the generation of Verifiable Presentations (VPs) from them (Babel & Sedlmeir, 2023; Babel et al., 2025b). To prevent double-spending, the infrastructure relies on a ledger that incorporates a second-layer rollup (Principato et al., 2023). This mechanism prevents the reuse of tokens and implements the concept of Shielded-fractionalized Non-fungible Token (SFNFT) as originally introduced in (Babel et al., 2022). This approach employs Zero-knowledge proofs (ZKPs) achieving that no transaction data are publicly visible to third parties or even to the ledger operator. Consequently, the trust required in the operator is limited to ensuring non-discriminatory access. Depending on the use case, this ledger could be implemented on a centralized database if a trusted stakeholder is available to fulfill this role. However, since this study advocates for maximum sovereignty and long-term resilience, we recommend deploying the ledger infrastructure on a public blockchain (Principato et al., 2023).

The artifact is demonstrated and evaluated through an Electric-Vehicle (EV) use case, chosen due to the long lifespan, modularity, and high economic and environmental relevance of EVs components. The demonstration instantiates a modular DPP separating the vehicle and its battery and illustrates three key lifecycle phases: (1) assembly and handover, in which the end-consumer receives a composite DPP and becomes custodian of the vehicle and component data; (2) utilization and servicing, in which third parties (e.g., workshops) can contribute verifiable lifecycle updates without reintroducing issuer dependency; and (3) resale of individual components, in which ownership of a component-DPP (e.g., the battery) can be decoupled and transferred independently to a new stakeholder while preserving provenance and lifecycle traceability. To prevent unauthorized decoupling, the artifact includes an algorithmic transfer allowance rule that ensures only the owner of the root-DPP can unnest and transfer child-DPPs.

Beyond the use case demonstration, we evaluate scalability characteristics through benchmarking. Results indicate that wallet processing time increases linearly with hierarchy depth, supporting practical feasibility for stacked and nested product structures. Further, analysis of DPP storage size shows robustness against data inflation: while attribute string length scales linearly, the number of attributes affects the verifiable credential structure in a predictable manner, yielding linear scaling with the number of attributes in the evaluation setup. Taken together, these findings provide initial evidence that the artifact can support complex, hierarchical DPP structures while maintaining user-side sovereignty and long-term data access. In line with recommended early-stage DSR evaluation approaches, the essay combines (i) a descriptive informed argument grounded in established design knowledge (e.g., VCs, NFTs, ZKPs) with (ii) an experimental simulation and proof-of-concept demonstration in a realistic domain context.

Based on the design and evaluation cycles, Essay 3 derives four prescriptive design principles that generalize the artifact's core mechanisms into transferable design knowledge for human-centric DPP infrastructures:

- **DP1**: Sovereignty emphasizes issuer-independent, long-term control over DPP data by enabling end-consumers to retain access to and ownership of product-related information even if manufacturers or issuers exit the market.
- **DP2**: Data Minimization focuses on privacy-preserving DPP usage by limiting data disclosure to what is strictly required for a given verification purpose through selective and verifiable presentation mechanisms.
- **DP3**: Modularity advocates nested DPP structures that mirror the physical composition of products, enabling component-level management, reuse, and circularity for composite and multi-component goods.
- **DP4**: Custodianship positions end-consumers as active stewards of their product-related data by granting them full control over DPP access and availability throughout the product lifecycle, particularly in circular and secondary-market contexts

Following Gregor et al. (2020), these design principles translate the artifact's design logic into reusable guidance for future DPP implementations.
Against this background, Essay 3 contributes to IS research in three primary ways. First, it advances human-centric DPP research by conceptualizing long-term data continuity and issuer-independent ownership transfer as infrastructural prerequisites for consumer participation in circular value creation. Second, it extends design knowledge on DPP architectures by introducing nested and reversible component-level DPPs structures that support complex assembly flows and C2X circularity scenarios. Third, it expands the scope of privacy-enhancing mechanisms in sustainability infrastructures by demonstrating how zero-knowledge rollup-based verification and wallet-based custodianship can enable verifiable exchange without exposing sensitive data to intermediaries.

Within this dissertation, Essay 3 substantiates the social pillar of digital sustainability by demonstrating that sustainability-oriented digital infrastructures require more than verifiable data and interoperability, they also require socially sustainable arrangements that preserve agency, sovereignty, and long-term control for human end users. In doing so, the essay operationalizes the dissertation's overarching argument that sustainable outcomes emerge from the interplay of (i) trustworthy digital infrastructures (verifiable and privacy-preserving product data), (ii) governance and sovereignty mechanisms (issuer-independent custodianship and enforceable control), and (iii) value creation mechanisms (component-level reuse and recirculation), thereby enabling digital sustainability initiatives to scale, endure, and remain valuable for their users.

3.2 Individual data sharing as enabler for decarbonization measures

Digital sustainability initiatives increasingly rely on the active involvement of human end users, not only as owners or beneficiaries of digital artifacts, but as contributors of data that enable system-level optimization and collective outcomes. While prior research (e.g., Babel et al., 2025a) has emphasized the importance of assigning data ownership and control to end users through human-centric infrastructures, ownership alone does not ensure that data are actually shared. In many sustainability-oriented contexts, meaningful progress depends on individuals' willingness to actively disclose behavioral or consumption-related data, particularly when such data are directly linked to environmental performance and decarbonization measures (Krasikov & Legner, 2023; Pan et al., 2022).

Empirical studies across diverse domains, including finance (Bijlsma et al., 2024), healthcare (Anderson & Agarwal, 2011), and online social networks (Krasnova et al., 2010), highlight that data-sharing behavior depends on a tradeoff between perceived benefits (e.g., personalization, efficiency, collective welfare) and perceived risks related to privacy, misuse, or loss of control (Dinev & Hart, 2006; Fernandes & Pereira, 2021). From this perspective, data sharing resembles a collective action problem in which common goods such as innovation and sustainability depend on individuals' voluntary data contributions (Alashoor et al., 2025; Cichy et al., 2021; Duparc et al., 2024).

Building on this logic, prior IS research has extensively examined data sharing in Business-to-Consumer (B2C) contexts, emphasizing its role in enabling digital services and the associated privacy and trust dynamics (Alashoor et al., 2025; Cichy et al., 2021). Much of this work focuses on substitutable digital services, such as e-commerce platforms or connected vehicles, where users can switch providers at relatively low cost (Crossler & Bélanger, 2019; Dinev & Hart, 2006; Krasnova et al., 2010). While these studies provide valuable insights into individual disclosure decisions (Cichy et al., 2021; Teubner & Flath, 2019), they typically conceptualize data sharing as an isolated choice rather than as an interdependent decision embedded in a collective setting. As a result, they offer limited insight into situations in which coordinated participation is required to realize system-level sustainability benefits.

At the same time, research on digital sustainability (cf. Körner et al., 2024a) demonstrates that achieving environmental and decarbonization goals requires more than the deployment of digital technologies and infrastructures such as IoT sensors or data platforms. Sustainable outcomes critically depend on the availability, circulation, and coordinated use of data across organizational and individual boundaries (Watson et al., 2021). Despite increasing technical connectivity, many socio-technical systems remain characterized by fragmented data flows that prevent information from being leveraged for overarching sustainability objectives (Cichy et al., 2021). These coordination failures highlight a persistent challenge: enabling data sharing among distributed actors while preserving individual expectations regarding privacy, control, and autonomy.

Taken together, these insights point to a conceptual gap at the intersection of digital sustainability and data-sharing. While human-centric infrastructures can allocate ownership and control to end users, and while digital technologies can generate sustainability-relevant data, collective outcomes ultimately depend on whether individuals are willing to share data under conditions of strategic interdependence. Understanding data sharing in sustainability-oriented contexts therefore requires moving beyond individual privacy calculus models toward an analysis of collective action settings in which individual contributions jointly determine environmental and social outcomes.

The housing sector provides a particularly illustrative field of application for the identified gap. The operation of buildings accounts for approximately 30% of global final energy consumption and 26% of energy-related emissions (Cabeza et al., 2022; International Energy Agency, 2023). Residential buildings alone are responsible for about 20% of global final energy demand and more than 22% of energy-related carbon emissions (Nejat et al., 2015; Wiethe & Wenninger, 2023). Consequently, residential housing represents a critical leverage point for decarbonization efforts. However, optimizing energy consumption in buildings increasingly relies on digitally supported systems that integrate sensor data, user behavior, and automated control mechanisms (Bahramian & Yetilmezsoy, 2020). While such systems are already being deployed in single-family homes, socio-technical challenges become more pronounced in multi-apartment dwellings, where legally independent actors use shared infrastructures (Tang et al., 2023).

Tenants and landlords are embedded in long-term contractual relationships, and data-driven decisions, such as adjustments to heating behavior, generate interdependent outcomes that affect both individual comfort and collective energy efficiency. Despite the technical potential of smart building systems, data are often only partially used. Privacy concerns, misaligned incentives, and fragmented data governance continue to hinder effective data circulation, thereby limiting the realization of energy optimization, demand-side flexibility, and predictive maintenance use cases (Cavalheiro & Carreira, 2016; Fridgen et al., 2021; Gholamzadehmir et al., 2020; Michaelis et al., 2024)

These dynamics reveal a fundamental tension between individual protection and collective welfare. While collective data sharing enables improved energy efficiency and reduced emissions, individual tenants may refrain from sharing behavioral data due to privacy concerns or fear of losing control. This tension constitutes a digital public-goods dilemma in which individually rational behavior can undermine collectively desirable outcomes (Hillebrand et al., 2023; Li et al., 2024). In contrast to classical public-goods settings, the cost of contribution in digital environments is not primarily monetary but is shaped by perceived privacy risks and the regulatory and technological safeguards surrounding data use. Privacy therefore becomes a structural element of collective decision-making that can either reinforce free-riding behavior or enable cooperation (Alashoor et al., 2025; Cichy et al., 2021; Duparc et al., 2024).

Building on this perspective, social sustainability in the housing context cannot be understood without considering tenants' control over behavioral data and the conditions under which such data are shared. While centralized data collection may maximize technical efficiency, it often undermines trust, autonomy, and long-term acceptance. Conversely, user-centric and privacy-preserving data infrastructures can enable cooperation while safeguarding individual rights, thereby aligning social sustainability with collective decarbonization goals. Investigating this aspect, is essential for understanding how digital infrastructures and privacy-preserving technologies can be designed not only to protect individual rights but also to promote cooperative behavior in sustainability-oriented systems. Accordingly, Essay 4 asks the question, *how do privacy* *costs affect tenants' willingness to share behavioral data in digitally supported housing environments?*

Essay 4 follows an exploratory, design- and theory-oriented research approach to analyze privacy-sensitive data sharing as a collective action problem in digitally supported housing environments. The study combines three elements. First, it draws on a structured literature review to identify recurring determinants of individual data-sharing behavior and privacy-related barriers in IS research. Second, it is grounded in empirical insights from a researcher-practitioner interaction with a large German housing company, which provided access to a real-world sustainability challenge, data-driven heating optimization and mold prevention in multi-apartment dwellings, and helped to motivate key behavioral assumptions and relevant cost drivers. Third, building on these empirical and theoretical insights, the study develops a non-cooperative game-theoretic model of tenants' data-sharing decisions and evaluates its equilibrium outcomes through a full-factor simulation and a Monte Carlo parameter sweep, where parameters are randomly varied across many simulation runs to assess the robustness of equilibrium outcomes. This combination enables a rigorous exploration of how privacy costs and technological privacy assurances jointly shape stable cooperation patterns under strategic interdependence.

The model represents a multi-tenant building as a one-shot game in which each tenant decides whether to share behavioral or indoor climate data (share vs. withhold). Collective data sharing improves the effectiveness of mold prevention and heating optimization, thereby reducing expected building-level losses that are distributed across tenants. At the same time, sharing imposes an individual cost that captures two components: (i) privacy sensitivity, reflecting perceived risks of surveillance, misuse, or control loss, and (ii) residual behavioral factors, capturing comfort deviations, convenience perceptions, or autonomy concerns associated with automated optimization. The key mechanism is interdependence: the collective benefit of sharing increases with the number of contributors, but the marginal benefit decreases (diminishing returns), such that stable outcomes depend on whether the marginal reduction of expected collective losses exceeds each tenant's perceived contribution cost. Privacy-preserving digital technologies enter the model as a moderating design intervention that reduces privacy-related costs, thereby shifting the boundary conditions under which cooperative equilibria emerge. Table 3.2 depicts the parameters of the game theoretic model.

Table 3.2: Core parameters of the tenant data-sharing game

Component	Symbol	Domain	Meaning / role in the model
Tenants (players)	N	$N \in \mathbb{N}$	Number of tenants in the multi-apartment dwelling (baseline: $N = 8$).
Strategy (tenant n)	s_n	$\{0, 1\}$	Binary decision: share data ($s_n = 1$) vs. withhold ($s_n = 0$).
Strategy profile	s	$\{0, 1\}^N$	Vector of all tenants' strategies.
Total sharers	k	$\{0, \dots, N\}$	Number of tenants sharing data: $k = \sum_{n \in N} s_n$.
Collective loss (mold damage)	L	$L > 0$	Potential monetary loss due to mold formation (distributed equally across tenants).
Baseline mold probability	r_0	$r_0 > 0$	Mold probability without data sharing ($k = 0$).
Effectiveness parameter	r_1	$r_1 < 0$	Effect of additional sharers on mold probability (diminishing marginal returns).
Residual risk function	$\eta(k)$	$(0, 1)$	Probability of mold given k sharers: $\eta(k) = r_0 e^{r_1 k}$ (decreasing and concave in k).
Expected mold cost share	$C_m(k)$	> 0	Expected mold-related cost borne by each tenant: $C_m(k) = \frac{L}{N}\eta(k)$.
Privacy sensitivity	$PRIV_n$	$(0, 1)$	Tenant-specific aversion to disclosing personal/behavioral data.
Residual behavioral sensitivity	PRZ_n	$(0, 1)$	Tenant-specific non-privacy frictions (e.g., comfort deviation, autonomy loss, convenience).

$$
\begin{aligned}
P_n(s_n; s_{-n}) &= -\big(C_m(k) + s_n \cdot C_i\big) \\
&= -\bigg(\frac{L}{N}\,\eta(k) + s_n\,(PRIV_n + PRZ_n)\,x\bigg),
\end{aligned}
\tag{3.1}
$$

where $k = \sum_{j \in N} s_j$ denotes the number of tenants sharing data.

To validate and visualize the analytical equilibrium conditions, the study conducts a twodimensional parameter sweep across perceived cost levels and system effectiveness. The simulation evaluates all strategy profiles in the full strategy space and identifies Nash equilibria by testing unilateral deviations. To reflect realistic heterogeneity, tenants' privacy and residual behavioral sensitivities are randomly drawn and held constant across the parameter grid, and the procedure is repeated across multiple seeds. Two modes are compared: a baseline mode without privacy-preserving digital technologies and a treatment mode in which privacy costs are proportionally reduced. This design allows quantifying how privacy-preserving technologies reshape the equilibrium landscape and participation levels.

The simulations show that stable cooperation is highly sensitive to the interplay between perceived sharing costs and the technical effectiveness of data-driven mold prevention. In the baseline scenario, full cooperation (all tenants share) emerges only in a narrow region characterized by low perceived costs and high effectiveness. When privacy-preserving digital technologies are introduced, this cooperative region expands substantially: the share of parameter combinations supporting an all-share Nash equilibrium increases from 2.02% to 3.56%, a relative expansion of 75.6%. Importantly, this shift is not merely incremental but structural. The simulation indicates that privacy-preserving technologies lower the boundary at which cooperation becomes self-enforcing, thereby increasing the feasibility of Pareto-efficient outcomes even under moderate cost levels

Beyond the all-share equilibrium, the results show that privacy-preserving technologies systematically increase participation even in partially cooperative equilibria. Rather than only enabling full cooperation at the upper boundary, privacy mitigation shifts the entire equilibrium landscape toward higher levels of collective engagement. In other words, privacy-preserving technologies do not merely unlock ideal outcomes but also stabilize intermediate coordination patterns that would otherwise collapse under individual cost considerations. This finding is particularly relevant for real-world sustainability settings, where perfect cooperation is rarely attainable but incremental participation can still generate substantial collective benefits.

A central mechanism underlying these shifts is a bottleneck effect driven by heterogeneity in privacy sensitivities. The feasibility of collective data sharing is governed by the most cost-sensitive participant: if the "weakest link" faces sufficiently high privacy costs, cooperation collapses even when most other actors would benefit from sharing. This dynamic illustrates how social sustainability outcomes in data-driven systems are constrained not by average preferences but by distributional extremes. Privacy-preserving technologies alleviate this binding constraint by reducing the privacy component of individual costs, thereby increasing the system's tolerance for heterogeneity and stabilizing cooperative equilibria under higher perceived burdens.

In theoretical terms, Essay 4 advances IS research by shifting the analysis of privacy and data sharing from an individual disclosure problem toward a collective action perspective in socio-technical systems. First, it reframes privacy as a structural property of shared digital infrastructures: privacy costs do not merely influence individual willingness to disclose but determine equilibrium outcomes when benefits depend on coordinated participation. Second, it models privacy sensitivity as a strategic determinant that produces non-linear, system-level effects, where marginal changes in perceived costs can trigger coordination failures or enable socially efficient outcomes. Third, it conceptualizes data sharing in sustainability-oriented contexts as a socio-technical public-goods dilemma and demonstrates how privacy-preserving technologies function as design levers that reshape the equilibrium topology toward cooperation.

Importantly, these insights complement Essay 3 by clarifying the behavioral conditions under which human-centric data infrastructures translate into collective welfare. While Essay 3 addresses how ownership and control over data can be reconfigured toward end users, Essay 4 shows that participation in data sharing depends on a composite contribution cost that includes both privacy sensitivity ($PRIV$) and residual behavioral preferences (PRZ). Privacy-preserving technologies mitigate the $PRIV$ component and increase willingness to share, but cooperative equilibria may still be constrained by the remaining PRZ component. This highlights that socially sustainable data ecosystems require privacy protection alongside governance mechanisms that address perceived control, comfort, and other non-privacy frictions.

Together, Essay 3 and 4 provide an integrative account of social sustainability in digital systems: from the institutional and infrastructural conditions that enable human agency to the behavioral and strategic conditions under which this agency translates into collective sustainability outcomes.

4 Economic Sustainability

Economic sustainability refers to practices that support economic growth while preserving environmental assets, maintaining or improving living standards, and strengthening social institutions (Anand & Sen, 2000; Foy, 1990; Kotlarsky et al., 2023; Spangenberg, 2005). Importantly, this definition underscores that economic sustainability is inherently intertwined with environmental and social sustainability. Economic outcomes are thus not merely assessed in terms of short-term financial performance, but in terms of their contribution to long-term economic welfare and societal stability.

This integrative perspective has become increasingly salient in light of the growing economic impacts of climate change. Recent research demonstrates that climate-related disruptions place significant stress on economic welfare, affecting productivity, infrastructure, and institutional stability (Breckenfelder et al., 2023; Dang et al., 2025; Waidelich et al., 2024). As a result, economic sustainability is no longer a purely strategic aspiration, but an urgent concern for organizations and societies alike.

IS research has long acknowledged the role of digital technologies in supporting economic sustainability, particularly through the diffusion of Green IT and Green IS. Early studies emphasize efficiency gains and cost reductions enabled by IT-supported sustainable practices (Bengtsson & Ågerfalk, 2011; Bose & Luo, 2011; Thomas et al., 2016). Subsequent work broadens this view by conceptualizing Green IS as the configuration and application of IS to achieve environmental objectives while simultaneously improving economic performance and supporting organizational decision-making (Hedman & Henningsson, 2016; Leidner et al., 2022; Loeser et al., 2017; Malhotra et al., 2013).

Despite these advances, prior research often adopts an implicitly dualistic understanding of economic sustainability. On the one hand, economic benefits are primarily conceptualized as cost savings enabled by decision support systems, Internet of Things devices, or behavioral defaults (Bengtsson & Ågerfalk, 2011; Loock et al., 2013). On the other hand, studies in ICT for development and e-government highlight broader, systemic economic outcomes, such as income diversification and upward mobility (Hsieh et al., 2011), and enhanced financial security through reliable welfare payments (Ncube et al., 2023).

This fragmentation points to a central tension in the literature: while digital sustainability initiatives may generate immediate economic efficiencies, their contribution to long-term economic welfare and resilience remains insufficiently theorized. Addressing this tension is essential, as prior work suggests that environmental performance can act as a driver of economic performance, motivating organizations to engage in sustainabilityoriented initiatives in the first place (Ryoo & Koo, 2013).

Accordingly, this chapter approaches economic sustainability along two complementary dimensions: identifying economic value created by sustainabilityoriented digital initiatives and understanding how such value supports long-term economic welfare and organizational capability building. The chapter comprises four essays. Essay 5 examines how real estate tokenization enables economically viable value creation in decentralized financial infrastructures. Essay 6 investigates how organizations can systematically identify and assess economic value creation opportunities arising from DPPs as sustainabilityoriented digital infrastructures. Essay 7 develops a conceptual framework of resource-based digital innovation and shows how organizations can collaboratively create and recombine digital resources to enable sustained digital innovation under conditions of resource constraints and limited market access. Essay 8 analyzes how dynamic capabilities enable the implementation and scaling of Digital Strategic Initiatives (DSIs) that translate digital resources into sustained economic outcomes. Table 4.1 summarizes the research designs of Essays 5, 6, 7, and 8.

Table 4.1: Research designs of Essays 5, 6, 7, and 8

Title	**Research design**
Identification of value opportunities from sustainable actions and translation into organizational initiatives	
Essay 5: From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi	**Design science** • Problem- and development-centered DSR process (Hevner et al., 2004; Peffers et al., 2007) • Literature screening on real estate investments and conduction of six semi-structured expert interviews leading to nine areas for improvement (AfI) (Mayring, 2000) • Derivation of nine design objectives from the AfIs • Design of a tokenization framework and core smart contract logic • Evaluation through 12 semi-structured expert interviews in two iterative cycles • Simulation and testing of smart contract functionality (batch transfer, base prospectus, relay functionality) • Derivation of four generalizable design principles for investment token
Essay 6: Twin Transformation with Digital Product Passports: Developing a Method for Identifying Organizational Value Creation Opportunities	**Design Science and Situational Method Engineering** • Problem-centered design induced by literature screening and three interviews • Development of six design objectives for a DPP value assessment method • Application of a four-step situational method engineering process (Brinkkemper, 1996; Bucher et al., 2007; Henderson-Sellers & Ralyté, 2010) • Structured literature review of 277 articles on DPPs, leading to a final sample of 106 relevant articles (Webster & Watson, 2002) • Real-world application of the DPP Value Method in a researcher-practitioner workshop • Evaluation through researcher focus group • Final refinement of the DPP Value Method
Essay 7: Moo-Ving the Dairy Industry - The Building Blocks of Resource-Based Digital Innovation	**Consortium Research** • Invoked by a publicly funded research project with the German dairy industry • Conduction of four-phase consortium research approach (Österle & Otto, 2010) • Data collection through longitudinal involvement as engaged scholars within the research project, structured literature review, and additional expert interviews • Design of a conceptual framework of resource-based digital innovation • Evaluation of the framework through summative and naturalistic real-world demonstration within the consortium (Venable et al., 2016)
Essay 8: Uncovering the Role of Dynamic Capabilities in Digital Strategic Initiatives	**Multiple-case study** • Guided by phenomenon-driven interestingness in prior research • Selection of three longitudinal industry cases (Eisenhardt, 1989; Hollweck, 2015) • Data collection (2023–2025), including 19 semi-structured interviews (Alvesson, 2003; Glaser & Strauss, 1967) • Multi-step coding approach using MAXQDA (Gioia et al., 2013) • Derivation of 251 open codes, 18 first-order concepts, nine second-order themes, and three aggregate dimensions • Development of a conceptual framework of the role of dynamic capabilities (Teece, 2007) within the DSI phases and the capability development roadmap

4.1 Tokenization of real estate as economic value creation mechanism

Economic sustainability is closely linked to the ability of financial systems to mobilize capital efficiently and enable broad participation in value creation (Medaglia & Damsgaard, 2020; Prinz & Trauth, 2025). In capital-intensive asset classes, however, high entry barriers, illiquidity, and transaction frictions often limit access for smaller investors and constrain capital allocation (Baum, 2021). Real estate, despite being one of the world's largest asset classes, remains difficult to access and trade for many investors, restricting financial inclusion and participation in long-term economic value creation (Baum, 2021; Kranz et al., 2025).

Digital technologies, and blockchain-based infrastructures in particular, have been proposed as mechanisms to reduce these frictions by enabling programmable, fractional, and interoperable representations of assets (Guggenberger et al., 2023; Prinz & Trauth, 2025). Building on public blockchains and smart contracts, decentralized finance (Decentralized Finance (DeFi)) provides financial services without centralized intermediaries. Yet, despite rapid growth, DeFi remains largely confined to cryptocurrency-native assets, limiting its maturity and adoption in regulated investment contexts and among non-crypto investors (Brennecke et al., 2022; Chen & Bellavitis, 2020; Gramlich et al., 2022, 2023; Qin et al., 2021).

A key mechanism for extending DeFi beyond cryptocurrency markets is tokenization, i.e., the digital representation of assets on distributed ledger infrastructures (Baum, 2021; Prinz & Trauth, 2025; Sunyaev et al., 2021). For real-world assets, tokenization links off-chain value and on-chain transferability, enabling assets to be traded, recombined, and integrated into programmable markets. However, for economically significant assets such as real estate, tokenization hinges not only on technical representation but also on organizational structuring and regulatory embedding to ensure legal enforceability, investor protection, and scalable issuance (Guggenberger et al., 2023; Sunyaev et al., 2021).

Despite this relevance, existing research and practice predominantly focus on the tokenization of traditional securities such as stocks and bonds (Guggenberger et al., 2023; Roth et al., 2019). In contrast, the tokenization of real estate, despite its economic significance and broader sustainability relevance (cf. Essay 2), remains comparatively underexamined. While blockchain technology enables the fractionalization of large and illiquid assets, only few studies address how tokenized real estate can be integrated into DeFi ecosystems (Chen & Bellavitis, 2020; Oza et al., 2024; Rao et al., 2024). Prior work provides partial solutions and often leaves key design challenges insufficiently addressed, including support for different investment product types (e.g., equity and debt), scalable regulatory compliance, and technical interoperability with prevailing DeFi standards (Baum, 2021; Garcia-Teruel, 2019; Gramlich et al., 2023).

As a result, it remains unclear how real estate can be tokenized in a way that enables end-to-end integration into DeFi across the investment lifecycle while meeting regulatory and organizational requirements and maintaining technical interoperability. Against this background, Essay 5 asks:

How can a tokenization framework for real estate investment tokens be designed to enable a fully-fledged integration of real estate into the DeFi ecosystem?

To address this gap, Essay 5 adopts a DSR approach (Gregor & Hevner, 2013) to develop and evaluate a tokenization framework for the integration of real estate investments into DeFi. Following a build-and-evaluate logic, the study synthesizes prior research on real estate investments, blockchain-based tokenization, and DeFi, complemented by expert interviews with stakeholders from financial law, real estate asset management, tokenization services, and blockchain research. Based on the identified deficiencies in existing investment structures, the study derives meta-requirements and design objectives that guide artifact development. The framework specifies organizational, regulatory, and technical design elements across the investment lifecycle and is evaluated through expert-based assessments of regulatory feasibility and market relevance as well as smart-contract simulation experiments assessing technical feasibility and efficiency.

The resulting framework supports issuers, platform operators, and regulators in designing real estate investment products that are interoperable with DeFi infrastructures. It comprises three interrelated design dimensions.

First, in the organizational and regulatory dimension, the framework specifies how real estate assets can be embedded in legally compliant investment structures that support multiple product types. Building on established real estate investment practices, the artifact enables the issuance of equity-, debt-, and mezzanine-based participation rights within a single, passportable regulatory setup. This directly addresses limitations of approaches that focus on single product types or jurisdiction-specific constructs (Baum, 2021; Guggenberger et al., 2023; Kreppmeier et al., 2023). By aligning token issuance with supra-national regulatory standards, the framework supports investor protection and scalability beyond experimental use cases (Brennecke et al., 2022; Gramlich et al., 2023).

Second, in the technical dimension, the framework operationalizes real estate investment tokens as security tokens compatible with prevailing blockchain and DeFi standards. Building on ERC-20 compatibility and extending it via the EIP-1400 security token proposal, the artifact enables integration into existing DeFi protocols while preserving key legal characteristics of regulated financial instruments (Grigo et al., 2020; Guggenberger et al., 2023; Schär, 2021; Sunyaev et al., 2021).

Third, in the process and efficiency dimension, the framework incorporates smart-contract mechanisms that affect economic performance. Smart-contract simulations indicate that batch transfers and relayer-based meta-transactions substantially reduce transaction frictions: batch transfers reduce transaction costs by more than 50% compared to individual transfers, and gasless transactions lower entry barriers for non-crypto-native investors. These results suggest that the economic sustainability potential of DeFi depends not only on asset availability but also on reducing frictions in issuance, distribution, and onboarding (Fridgen et al., 2018; Gramlich et al., 2022).

The evaluation further indicates that technical efficiency, regulatory compliance, and organizational embedding are mutually reinforcing rather than substitutable. Expert assessments suggest that isolating any single dimension (e.g., technical innovation without compliance, or regulatory soundness without efficiency) limits adoption and scalability. Economic sustainability therefore emerges from aligning these layers rather than from tokenization as a purely technical innovation. Figure 4.1 depicts the multi-layered high-level tokenization framework.

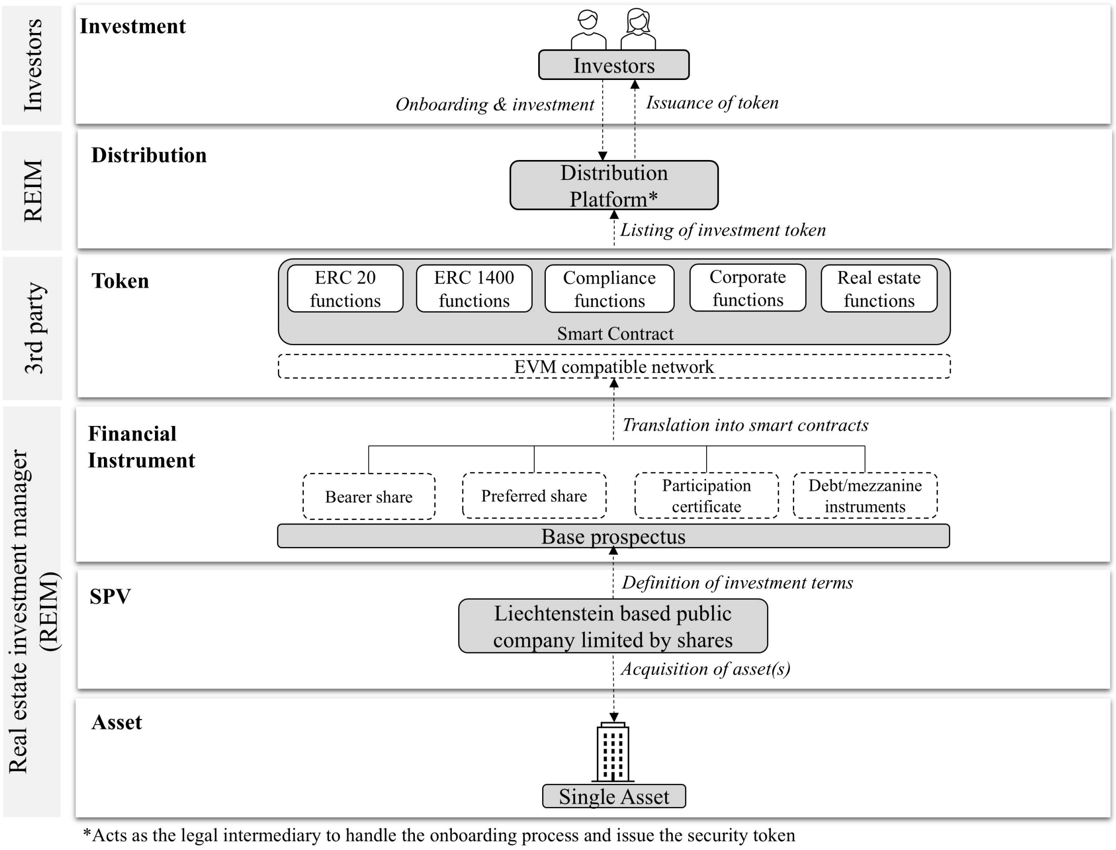

Figure 4.1: High-level framework for the tokenization of real estate (Essay 5)

In sum, Essay 5 extends prescriptive knowledge on blockchain-based financial infrastructures by providing a design-oriented and empirically grounded framework for integrating real estate into DeFi. While prior studies emphasize the potential of tokenization for liquidity, disintermediation, and automation (Chen & Bellavitis, 2020; Schär, 2021), they offer limited guidance on how economically significant real-world assets can be structured, issued, and operated within decentralized financial ecosystems.

The findings suggest that tokenization contributes to economic sustainability only when embedded in robust organizational and regulatory arrangements and complemented by efficiency-enhancing smart-contract mechanisms. By showing how micro-level design decisions translate into measurable cost reductions and lower participation barriers, the study links artifact design to the conditions for market viability in emerging decentralized financial markets (Brennecke et al., 2022; Gramlich et al., 2023; Prinz & Trauth, 2025).

4.2 Measuring the economic value of sustainability initiatives

DPPs are increasingly conceptualized as standardized, product-specific, inter-organizational data-sharing systems that support sustainability- and circularity-oriented product and data management (Chaudhuri et al., 2024; Jensen et al., 2023; Neramballi et al., 2024). By enabling structured access to lifecycle data across organizational and value-chain boundaries, DPPs represent a digital sustainability infrastructure at the intersection of digital technologies and sustainability, with the potential to enhance transparency, coordination, and data-driven ecosystems (Gieß & Möller, 2025; King et al., 2023).

From a digital sustainability perspective, such infrastructures can only contribute to environmental and social objectives if they are embedded in economically viable value creation structures that enable organizational adoption, scaling, and long-term persistence (Melville et al., 2004; Schoormann et al., 2025; Watson et al., 2010). Accordingly, the economic perspective of digital sustainability focuses on how digital resources and artifacts translate sustainability objectives into sustainable value creation and economic welfare at the organizational level (Ixmeier et al., 2024; Veit & Thatcher, 2023).

Prior research suggests that DPPs can generate both intra-organizational value, such as efficiency gains, improved data quality, and improved internal coordination, and inter-organizational value, including enhanced transparency and collaboration across value chains (Elling & Petrik, 2025; Psarommatis & May, 2024). These effects may strengthen digital and sustainability-related capabilities and support the twin transformation, i.e., the mutual advancement of digital and sustainability transformations (Crome et al., 2023; European Commission, 2022). However, such benefits do not materialize automatically. Instead, they depend on whether organizations actively leverage DPPs as interoperable data infrastructures rather than limiting their implementation to regulatory compliance (Gieß & Möller, 2025).

In practice, many organizations perceive DPPs primarily as a regulatory burden. Producers, who bear primary responsibility for data collection and reporting, face substantial implementation and coordination costs, while the distribution of economic benefits across actors often remains unclear (Adisorn et al., 2021; Jansen et al., 2023; Schoormann et al., 2025). Without a clear, organization-specific value proposition, firms risk restricting DPP adoption to the regulatory minimum, thereby missing opportunities for value creation within broader data ecosystems (Berger et al., 2023; Lopes & Barata, 2024; Zhang & Seuring, 2024).

While existing studies acknowledge that DPP-related value is contingent on organizational context, business models, and ecosystem roles, we still lack a systematic understanding of how organizations can identify and assess organization-specific value creation opportunities arising from mandatory DPP implementation (King et al., 2023; Psarommatis & May, 2024). This gap is further amplified by the absence of methodological guidance tailored to DPPs: current value assessment approaches either focus on other digital technologies, remain overly generic, or fail to capture the interdependencies between digitalization, sustainability objectives, and regulatory requirements (Åström et al., 2022; Baltuttis et al., 2022; Lopes & Barata, 2024).

As a result, organizations lack (1) a structured overview of DPP-related value creation opportunities and their dependencies, and (2) systematic support to identify and evaluate the economic value of DPP implementation in relation to their specific organizational characteristics and strategic goals. Addressing this gap is essential for positioning DPPs not merely as compliance instruments, but as economically viable components of digital sustainability and the twin transformation. Against this background, Essay 6 asks: *How can organizations effectively identify organization-specific value creation opportunities arising from the mandatory implementation of Digital Product Passports?*

In answering this question Essay 6 follows a design-oriented research approach to develop and evaluate a method for identifying organization-specific value creation opportunities arising from DPP implementation. The study builds on the DSR paradigm, which supports the iterative construction and evaluation of artifacts for addressing practice-relevant and ill-structured problems (Hevner et al., 2004; Peffers et al., 2007). To ensure contextual fit and applicability across heterogeneous organizations, the research further draws on Situational Method Engineering (SME) for assembling a context-sensitive method from existing method fragments (Brinkkemper, 1996; Bucher et al., 2007; Henderson-Sellers & Ralyté, 2010). Methodological triangulation is achieved by combining a structured literature review (Webster & Watson, 2002) with empirical insights from expert interviews, an industry workshop, and an academic working session, thereby integrating theoretical and practical perspectives (Gregor & Hevner, 2013). The key artifact of Essay 6 is the DPP-VALUE Method, a structured approach that supports organizations in identifying and prioritizing organization-specific value creation opportunities arising from the mandatory implementation of Digital Product Passports. Within the evaluation cycles, the DPP-VALUE Method is iteratively refined and evaluated against established design criteria, including ease-of-use, operationality, efficiency, and generality (Sonnenberg & vom Brocke, 2012), yielding transferable prescriptive design knowledge for organizations subject to mandatory DPP implementation.

The study comprises three interrelated artifacts. First, the Value Lever (VL) Longlist provides a comprehensive, literature-grounded overview of potential DPP-enabled value creation opportunities. The longlist consolidates fragmented insights from prior research into a structured set of value levers that capture both intra-organizational effects (e.g., efficiency gains, improved data governance) and inter-organizational effects (e.g., enhanced coordination with suppliers and customers). Second, the VL framework organizes these value levers into distinct value creation opportunity spaces along the value chain and visualizes their causal relationships and interdependencies. This enables organizations to understand where value emerges, through which mechanisms, and for which stakeholders. Third, the **DPP-VALUE Method** combines these artifacts into a five-step procedure that links strategic objectives, organizational context, and DPP-specific characteristics to economically relevant value creation opportunities.

The application and evaluation of the method demonstrate that DPP-related value is strongly context-dependent and cannot be inferred generically. Instead, the relevance and economic potential of individual value levers depend on organizational characteristics such as industry, role within the value chain, digital maturity, and sustainability ambitions. The results further show that DPPs simultaneously enable exploitative value creation, for instance through improved reporting efficiency and data quality, and explorative value creation, such as the development of circular business models or new data-driven services. By explicitly structuring these dual value paths, the method makes visible how DPPs can support both short-term efficiency gains and longer-term strategic transformation. Table 4.2 depicts the five activities of the DPP-VALUE Method.

Table 4.2: Activities of the DPP-VALUE method (Essay 6)

Activity	Technique	Tool	Role	Output
Activity 1: Gap analysis based on sustainability, digitalization and DPP target picture	• Creating common understanding of DPPs • Identifying target pictures in the areas of digitalization, sustainability, and DPP implementation • Collecting current issues, limitations, and identifying gaps between the status quo and the target picture in each area	Gap analysis	DPP project manager; strategy manager; digitalization expert; sustainability expert	• List of gaps for achieving digitalization and sustainability goals • List of gaps for the successful implementation of DPPs
Activity 2: Identification of VLs from implementation of DPPs	• Selecting direct and indirect VLs from the VL Longlist that are relevant for the producer with respect to the gaps identified in Activity 1	VL Longlist	DPP project manager; IT expert; digitalization expert; sustainability expert	• Shortlist of VLs from the implementation of DPPs
Activity 3: Mapping of VLs to VL Framework	• Visually mapping selected VLs onto the VL Framework based on allocation to value and opportunity spaces • Discussing the visualization to enhance understanding of VL characteristics, causal relationships, and interdependencies • Optional: Adding additional VLs	VL Framework	DPP project manager; IT expert; digitalization expert; sustainability expert	• Allocation of the VLs to the VL Framework • Optional: additional VLs
Activity 4: Prioritization of VLs from implementing DPPs	• Prioritizing identified VLs according to urgency and importance by aligning them with identified gaps (Activity 1)	Eisenhower matrix	DPP project manager; (Senior) management; IT expert	• Shortlist of prioritized VLs from the implementation of DPPs
Activity 5: Definition of the next steps for realizing the VLs of DPPs	• Identifying relevant KPIs to determine economic value of prioritized VLs • Initiating a business case calculation for implementing DPPs • Identifying next steps (incl. responsibilities) for DPP implementation and VL realization based on prioritized VLs (Activity 4) and target pictures (Activity 1)	Roadmap; existing KPIs	DPP project manager; strategy department; (Senior) management	• Roadmap with next steps for realizing the VLs • Shortlist of prioritized VLs with respective KPIs as a basis for business case calculation

Overall, the results demonstrate that when organizations are equipped with structured methods to identify, assess, and prioritize value creation opportunities, DPPs can move beyond being perceived as compliance-driven reporting obligations and become economically viable digital sustainability infrastructures. Thereby, Essay 6 makes three main contributions.

First, it advances the economic perspective of digital sustainability by explaining how sustainabilityoriented digital infrastructures generate economic value at the organizational level. While prior DPP research has primarily emphasized societal, environmental, or consumer-facing benefits, this essay foregrounds producers as central economic actors and shows that DPPs support sustainable value creation only when embedded in organizational strategies and processes. In doing so, it responds to calls to move beyond normative claims and explicitly account for the economic conditions enabling adoption, scaling, and persistence of sustainabilityoriented digital technologies.

Second, the essay contributes prescriptive design knowledge by developing and evaluating the DPP-VALUE Method, a structured approach for identifying organization-specific value creation opportunities arising from mandatory DPP implementation. By integrating regulatory requirements, sustainability objectives, and digital transformation considerations, the method extends existing digital value assessment approaches and provides a reusable artifact that supports organizational decision-making under uncertainty.

Third, Essay 6 enriches the twin transformation literature by demonstrating how DPPs function as a concrete link between digital and sustainability transformations at the organizational level. The findings show that DPPs strengthen digital and sustainability-related capabilities simultaneously, but only when organizations actively translate regulatory data requirements into economically meaningful initiatives. Value assessment thus emerges as a critical mechanism for preventing DPPs from remaining compliance-oriented and fragile.

Taken together, Essay 6 complements this dissertation by showing how organizations can translate mandatory DPP implementation into economically viable digital sustainability initiatives. While the infrastructural and governance-oriented essays (Essays 1 and 2) focus on the conditions for sustainable data ecosystems, Essay 6 provides a prescriptive method to identify, structure, and prioritize DPP-enabled value creation opportunities and derive concrete next steps, thereby explaining how DPPs can become scalable and persistent building blocks of digital sustainability ecosystems.

4.3 Resource-based digital innovation through collaborative digital resource creation

Economic sustainability in digital sustainability does not only depend on organizations optimizing existing resources or realizing efficiency gains. Rather, long-term economic welfare and resilience increasingly hinge on whether organizations can build and renew the digital resource base that enables sustained innovation over time (Püchel et al., 2024). This challenge is particularly pronounced in inter-organizational settings in which innovation potential is distributed across actors, yet access to markets and data are structurally asymmetric (Kranz et al., 2024). Similar to the dependence between intra- and inter-organizational governance in Essay 1 (cf. 2.1), economic value creation in digital innovation is often shaped by whether actors can mobilize resources beyond firm boundaries and establish viable collaboration arrangements for shared resource creation (Oberländer et al., 2025; Piccoli & Rodriguez, 2020).

Against this backdrop, Essay 7 addresses a central gap in the digital innovation literature. Prior research has offered rich insights into digital innovation from a market-based view, emphasizing customer proximity, market knowledge, and external partnerships as key inputs for innovation (Porter, 1985; Schaffer et al., 2022; Svahn et al., 2017). However, this perspective is less informative for lower-tier actors in supply chains, such as producers, that face two structural constraints: limited access to customer and market data (often controlled by downstream actors) (Esbjerg et al., 2016; OECD, 2013) and persistent cost pressures that restrict their ability to invest time and effort into innovation (Demartini et al., 2018; OECD, 2013). As a result, these actors struggle to sense emerging digital opportunities and to sustain innovation efforts, despite being directly affected by digital disruption and broader transformation pressures (Bharadwaj et al., 2013; Heinz et al., 2021). While resource-based perspectives highlight that digital innovation relies on creating, recombining, and orchestrating digital resources (Henfridsson et al., 2018; Oberländer et al., 2021; Piccoli et al., 2022), we still lack detailed empirical insights into how organizations can engage in digital innovation when market access is constrained and collaboration becomes the primary path to resource creation (Kreuzer et al., 2022; Piccoli et al., 2022) To address this gap, Essay 7 adopts the lens of the extended resource-based view and introduces the concept of *resource-based digital innovation*, emphasizing collaborative digital resource creation as an alternative path to digital innovation. The study asks: *How can organizations engage in digital innovation from a resource-based view?*

Methodologically, Essay 7 follows a consortium research approach in the sense of Österle and Otto (2010), which is particularly suited to generating prescriptive knowledge for complex, practiceoriented problems through close researcher-practitioner collaboration. Over twelve months, the research was conducted with six partners from the German dairy industry, including three large dairies and three industry interest groups. In the role of engaged scholars, the research combined (i) an analysis of the industry context and innovation challenges, (ii) theory-informed design work grounded in a structured literature search on digital resources and digital innovation, and (iii) iterative refinement and evaluation through a real-world demonstration in the consortium (Venable et al., 2016).

The primary outcome of the study is a conceptual framework that specifies five building blocks of resource-based digital innovation. The framework is structured along an input-process-output logic. The input comprises existing IT and digital resources as well as digital innovation capabilities (B1). At the core of the process is the creation of digital resources (B2), which includes both transforming existing IT resources into digital resources (B2.1) and generating new digital resources (B2.2). This is complemented by the creation of supporting IT resources (B3) and accom-

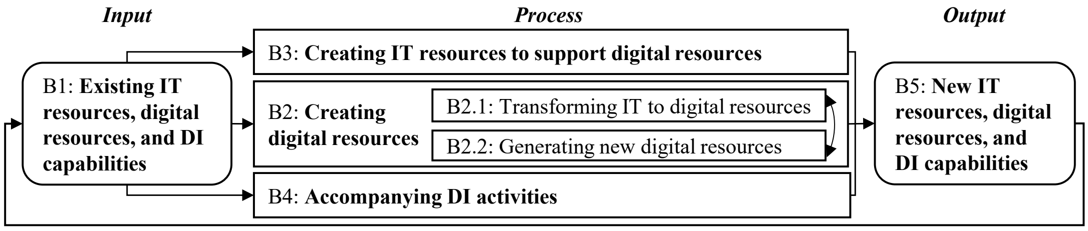

Figure 4.2: The five building blocks of resource-based digital innovation (Essay 7)

panying digital innovation activities (B4) that enable and stabilize the resource creation process. The output consists of new IT resources, new digital resources, and newly developed digital innovation capabilities (B5). Importantly, the framework conceptualizes resource-based digital innovation as inherently iterative: (i) the transformation and generation of digital resources can alternate depending on the innovation context, and (ii) outputs can become inputs for subsequent innovation cycles, thereby enabling sustained innovation trajectories rather than isolated projects. Figure 4.2 depicts the framework of the five interrelated building blocks.

To refine and evaluate the framework, Essay 7 demonstrates it in a real-world scenario focusing on demand forecasting in the dairy industry. Historically, demand forecasting relied on internal data and manual expert judgment, often resulting in inaccuracies that translate into economic losses (e.g., underproduction and missed sales) or increased costs and waste (e.g., overproduction and writeoffs). The real-world demonstration centered on collaboratively developing a shared, machine learning-based demand forecasting capability as a digital capability that multiple dairies can use while preserving data sovereignty. A key design element is the integration of privacy-enhancing technologies that allow the use of distributed data for model training without exposing sensitive internal datasets. The demonstration thereby illustrates how collaborative innovation can produce shared digital resources (e.g., a shared forecasting capability, shared interfaces, and complementary data assets) while simultaneously triggering the need for supporting IT resources and governance arrangements (e.g., standardized data preparation, verification routines, and joint operational responsibilities).

Essay 7 contributes to this dissertation's economic sustainability perspective by explaining how collaborative digital resource creation can become a viable path to sustained value creation under structural constraints.

First, it conceptualizes *resource-based digital innovation* as a complementary lens to market-based digital innovation, highlighting that innovation can be driven not only by customer proximity and market knowledge but also by the deliberate creation and recombination of digital resources in collaborative constellations (Henfridsson et al., 2018; Kreuzer et al., 2022; Piccoli et al., 2022). Second, it provides a structured conceptual framework with an explicit iterative logic that specifies how organizations transform IT resources into digital resources and generate new digital resources, and how innovation capabilities both enable and emerge from these processes (Oberländer et al., 2021; Piccoli et al., 2022). Third, it demonstrates the framework in a consortium setting and thereby shows empirically how lower-tier actors can jointly create shared digital resources despite data asymmetries, cost pressures, and coopetition dynamics (Esbjerg et al., 2016; OECD, 2013).

Within Chapter 4, Essay 7 provides the missing link between identifying economic value creation opportunities (Essay 6) and sustaining and scaling digital strategic initiatives over time (Essay 8). While Essay 6 clarifies where economic value from sustainabilityoriented digital infrastructures can emerge, Essay 7 explains how organizations can build the shared digital resource base required to realize such value when market access is constrained. This resource-based and collaboration-centered view strengthens the chapter's argument that long-term economic welfare and resilience depend not only on efficiency gains within firms, but also on crossorganizational capacity-building through shared digital resources that reduce innovation barriers and enable persistent innovation trajectories.

4.4 Leveraging dynamic capabilities for organizational transformation

Digital sustainability initiatives increasingly confront organizations with the challenge of simultaneously pursuing environmental objectives and economic viability (Hahn et al., 2015). While digital technologies are widely regarded as key enablers of sustainability transformations, their contribution to long-term value creation remains uneven (Almatooq & Al Mubarak, 2025). Many sustainabilityoriented digital initiatives struggle to scale, persist, or translate environmental ambitions into durable sources of competitive advantages (Fadare & Sun, 2024).

IS occupy a unique dual role in this context. Prior research highlights that IS can both contribute to environmental degradation and serve as a potential solution to sustainability challenges (DesAutels & Berthon, 2011; Elliot, 2011; Zhang et al., 2011). On the positive side, IS are argued to enable regulatory compliance (Butler, 2011), support sustainable human behavior (Elliot, 2011; Melville, 2010), facilitate environmentally sustainable processes (Watson et al., 2021), and contribute to the development of sustainabilityoriented organizational capabilities (Dao et al., 2011). Despite these insights, how and under what conditions such positive effects materialize at the organizational level remains insufficiently understood (Seidel et al., 2013).

From an economic perspective, this gap is particularly problematic. sustainabilityoriented digital initiatives may generate societal or environmental benefits, but their organizational persistence depends on whether they also contribute to competitive positioning and long-term economic welfare. Prior research suggests that organizations can improve both environmental and economic performance when digital technologies are embedded in appropriate IS capabilities (Doherty & Terry, 2009; Kotlarsky et al., 2023). However, existing literature offers limited insight into which IS capabilities are required, how they interact, and how they support the sustained realization of economic value from digitally enabled initiatives.

DSIs provide a useful lens for addressing this gap. DSIs structure how organizations intentionally create, recombine, and orchestrate digital resources to achieve competitive advantage (Piccoli et al., 2022, 2024). Conceptually, DSIs represent goal-oriented and non-transitory patterns of resource deployment that involve commitment, coordination, and irreversibility, thereby distinguishing them from isolated or ad hoc IT projects (van den Steen, 2017). DSIs typically unfold along two complementary paths: organizations either orchestrate existing digital resources into novel value propositions or create new digital resources to address identified resource gaps (Piccoli et al., 2022). Accordingly, DSIs extend beyond technology adoption and require coordinated action across strategy, structure, and operations. They unfold over extended time horizons, involve multiple organizational actors, and are characterized by uncertainty regarding outcomes and value realization (Kranz et al., 2024).

Accordingly, the success of DSIs depends less on access to individual digital technologies and more on organizations' ability to purposefully mobilize, adapt, and reconfigure digital resources over time (Helfat & Peteraf, 2009). Prior research emphasizes that identifying and understanding available digital resources constitutes a critical starting point (Kranz et al., 2024; Piccoli et al., 2022), while the strategic primacy of newly created digital resources can trigger broader transformations of organizational structures and value creation mechanisms (Oberländer et al., 2025; Piccoli et al., 2024). Yet, how organizations develop and leverage the dynamic capabilities required to enact these processes remains underexplored.

Against this background, Essay 8 addresses a central gap at the intersection of dynamic capabilities and digital strategy. It examines how dynamic capabilities enable firms to design, implement, and scale DSIs, and how these capabilities shape organizations' ability to translate digital resources into sustained strategic and economic outcomes. Essay 8 therefore asks: *How do organizations implement digital strategic initiatives by developing and leveraging dynamic capabilities?*

In pursuing this question, Essay 8 adopts a qualitative, theory-building research design to examine how dynamic capabilities enable the implementation of DSIs. Given the limited empirical understanding of capability-based mechanisms in DSIs and their processual, context-dependent nature, the study employs a multiple-case study approach (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). Three DSIs were selected using ex ante theoretical sampling to capture heterogeneous organizational contexts while allowing for theoretical replication. The cases - ROBOTICS, DAIRY, and ENERGY - span different industries, regulatory environments, and levels of digital maturity, but all involve large, established organizations in which DSIs challenge existing structures and routines. Data were collected longitudinally through semi-structured interviews, collection and analysis of internal documents, and sustained researcher-practitioner engagement over multiple years, enabling the analysis of both implementation processes and post-implementation outcomes. The data analysis followed the coding approach of Gioia (2013), through which micro-level activities were aggregated into dynamic capabilities and subsequently structured along the sensing, seizing, and transforming dimensions of dynamic capabilities (Teece, 2007). This approach connects empirically grounded capability mechanisms to an established theoretical lens while preserving sensitivity to the processual nature of DSIs.

The cross-case analysis reveals a consistent three-phase pattern through which organizations progress from trigger factors to embedded digital resources (Figure 4.3: a sensing phase in which a *digital resource gap* is constructed, a seizing phase in which a *nascent digital resource* is created, and a transforming phase in which a *fully established digital resource* is institutionalized). The phase transitions depend on the enactment and reconfiguration of specific dynamic capabilities and their underlying micro-foundations. Importantly, capability development is not sequential: elements of seizing and transforming already emerge during sensing, as organizations establish early alignment, governance arrangements, and architectural foresight.

In the sensing phase, DSIs are triggered when organizations construct a digital resource gap, defined as the perceived mismatch between an opportunity or problem and the existing digital resource base. This phase is enabled by sensing-related DSI capabilities that combine domain expertise and market insights, assessment of IT and data landscapes, and interpretive activities that translate trigger events into articulated opportunity spaces (Piccoli et al., 2024). The digital resource gap thus emerges as a shared organizational understanding of which digital resources are missing, why they matter, and how they relate to the intended DSI.

In the seizing phase, organizations translate the constructed gap into a nascent digital resource: a technically functional but only partially institutionalized artifact that stabilizes early design decisions and embeds strategic intent. This phase is shaped by IS capabilities related to resource optimization, collaboration and governance, and capability development. Across cases, organizations recombined internal and external resources, developed modular architectures, and established partnership and governance arrangements to manage interdependencies and access complementary expertise (Kranz et al., 2024; Piccoli et al., 2022). The nascent digital resource functions as a structuring device, partially codifying architectural choices, roles, and collaboration logics that preconfigure subsequent transformation demands.

In the transforming phase, nascent resources are converted into fully established digital resources that are embedded in routines, structures, and business model logic. This phase relies on IS capabilities that strengthen digital innovation culture, support digital business model development, and enable the continuation of the DSI beyond the initial project. Institutionalization requires sustained organizational effort to stabilize ownership, align governance, and support adoption and scaling. At this stage, long-term DSI outcomes are shaped less by technical maturity and more by the organization's ability to continuously reconfigure capabilities to overcome inertia and ensure persistence (Teece, 2007).

Taken together, Essay 8 conceptualizes DSI development as a capability-driven progression of digital resource maturity. Dynamic capabilities act as transition mechanisms that reduce ambiguity during sensing, mobilize and recombine resources during seizing, and embed and scale outcomes during transforming. This phase-spanning role of dynamic capabilities becomes visible through a longitudinal, process-sensitive perspective and remains difficult to capture in cross-sectional designs. Figure 4.3 illustrates the impact and interplay of dynamic capabilities on the development and continuation of a DSI.

The results of Essay 8 offer three contributions to IS research.

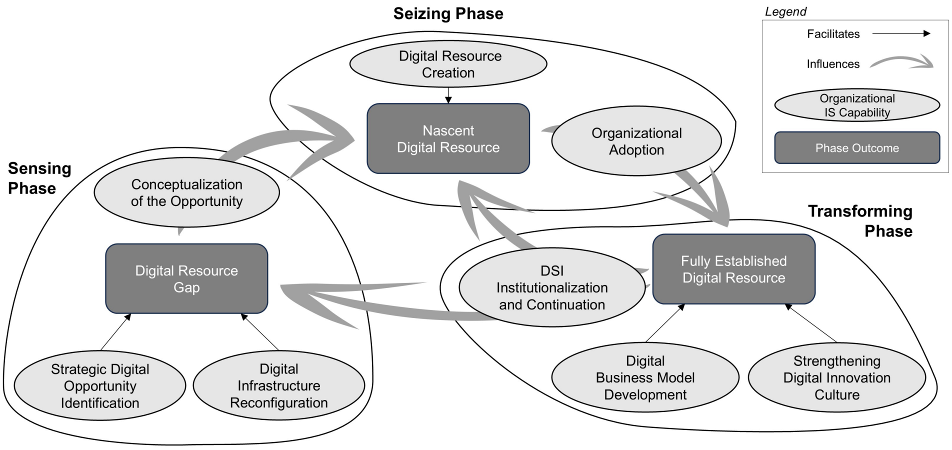

Figure 4.3: Conceptual framework of dynamic capabilities by DSI phases (Essay 8)

First, the study develops a phase-based conceptual framework of dynamic capabilities in DSIs. Building on longitudinal evidence, we show that DSIs progress through a sensing phase (framing opportunity spaces), a seizing phase (mobilizing and orchestrating resources to develop digital resources), and a transforming phase (embedding and institutionalizing these resources). These phases are iterative and mutually conditioning rather than linear, thereby providing a temporal lens for studying DSI progression and phase transitions (e.g., Piccoli et al. (2022, 2024)).

Second, the study specifies the phase-internal resource concepts around which dynamic capabilities emerge and are reconfigured. Drawing on dynamic capability theory (Teece, 2007), we anchor capability enactment in (i) constructing *digital resource gaps* (sensing), (ii) stabilizing *nascent digital resources* (seizing), and (iii) institutionalizing *fully established digital resources* (transforming). This vocabulary refines theorizing on how capabilities shift as digital resources mature and highlights dynamic capabilities as mechanisms that enable DSIs to overcome phase-specific bottlenecks.

Third, the study reconceptualizes dynamic capabilities as co-evolving enablers that connect strategic intent with operational realization. Capabilities adapt as resources develop, while institutionalized resources reshape subsequent capability configurations, highlighting the cumulative nature of DSIs. Further, the findings underscore collaboration as a capability-relevant mechanism that enables access to complementary expertise and supports iterative resource refinement across organizational boundaries.

Against this background, Essay 8 contributes to the economic sustainability perspective of this dissertation by explaining how organizations sustain and mature DSIs beyond initial implementation. By tracing how digital resource gaps evolve into nascent and fully established digital resources, the study illuminates capability-based mechanisms through which DSIs persist and generate long-term economic value. In doing so, Essay 8 integrates with the chapter's overall argument across the four essays: while Essay 5 establishes how economically viable digital infrastructures can be designed to reduce frictions and enable participation in new markets, Essay 6 specifies how organizations can identify and prioritize concrete value creation opportunities arising from sustainabilityoriented digital infrastructures, and Essay 7 explains how collaborative digital resource creation can build the shared resource base required to pursue innovation under constraints, Essay 8 shows how organizations mobilize and reconfigure dynamic capabilities to implement, scale, and institutionalize these initiatives over time. Thereby, Essay 8 translates designed infrastructures, identified opportunities, and collaboratively created resources into sustained economic outcomes.

5 Conclusion

5.1 Summary

Sustainability represents a defining grand challenge of the 21st century and is increasingly understood as an interdependent configuration of environmental integrity, social well-being, and economic welfare (Owsiany & Brohman, 2024; UNDP, 2025; United Nations, 1987, 2015). As digital technologies increasingly shape socio-technical systems rather than merely represent them, sustainability outcomes have become deeply intertwined with the design, governance, and use of digital resources and artifacts (Kotlarsky et al., 2023; Watson et al., 2021). Within the IS discipline, this development has motivated the notion of digital sustainability, which conceptualizes sustainability as the development and deployment of digital technologies toward improving environmental, social, and economic outcomes (Kotlarsky et al., 2023, p. 938).

Despite growing scholarly attention, digital sustainability research remains fragmented to some extend, partially focusing on isolated technologies, governance mechanisms, or organizational practices. Against this backdrop, this cumulative dissertation examined how digital technologies enable environmental, social, and economic sustainability by addressing information asymmetries, governance challenges, and incentive misalignments in socio-technical systems. Rather than conceptualizing sustainability impacts as direct technological effects (Owsiany & Brohman, 2024), this dissertation adopts an enabling perspective and shows that sustainable outcomes emerge only when digital infrastructures, governance arrangements, and organizational value logics are aligned. Across eight essays, this dissertation develops an integrative account of the conditions under which digital technologies can scale, endure, and achieve sustainability outcomes beyond isolated use cases. In doing so, this dissertation aims to enrich digital sustainability research by explaining how data infrastructures, data management and governance arrangements, and resource orchestration interact to environmental integrity, social well-being, and economic welfare.

The first set of contributions establishes verifiable data infrastructures as a foundational condition for digital sustainability. Essays 1 (cf. Section 2.1) and 2 (cf. Section 2.2) demonstrate that environmental sustainability outcomes depend critically on the availability of reliable, granular, and verifiable data across organizational boundaries.

Essay 1 shows that DPPs require a fundamental reconfiguration of intra-organizational data management. Rather than treating DPPs as inter-organizational reporting artifacts, the essay outlines that sovereign, role-based, and interoperable internal governance structures are necessary to ensure long-term data verifiability across product life cycles. Without such adaptations, sustainability-oriented infrastructures risk reinforcing control asymmetries and limiting participation in heterogeneous value chains. Essay 2 complements this perspective by focusing on operational decarbonization in the building sector. It demonstrates that digital technologies enable environmental sustainability only when emission-related data are verifiable and embedded in digital infrastructures that support accountability and decision-making. Together, these essays show that digital sustainability initiatives depend on data infrastructures that render environmental impacts measurable, comparable, and actionable across organizational boundaries.

Building on the availability of verifiable data, the second set of contributions examines governance and participation as critical enablers of digital sustainability. Essays 3 (cf. Section 3.1) and 4 (cf. Section 3.2) demonstrate that sustainability-oriented digital systems depend on socially legitimate arrangements that balance transparency, control, and participation.

Essay 3 contributes to a human-centric perspective on DPPs by conceptualizing end users as active custodians of product-related data. Through design principles such as issuer-independent control, data minimization, modularity, and custodianship, the essay shows how digital infrastructures can preserve human agency and long-term control, thereby enabling inclusive participation in circular value creation. Essay 4 extends this perspective by analyzing data sharing as a collective action problem. By modeling privacy costs as a structural determinant of equilibrium outcomes, the essay demonstrates that sustainability-oriented data ecosystems resemble digital public-goods dilemmas. While privacy-preserving technologies reduce barriers to participate, cooperative outcomes depend on how privacy-related and non-privacy-related contribution costs interact. Together, Essays 3 and 4 demonstrate that verifiable data infrastructures should be complemented by governance mechanisms that ensure social acceptance and sustained participation.

The third set of contributions addresses economic sustainability by examining how digital sustainability initiatives can be financed, embedded into organizational value logics, and sustained over time. Essays 5 (cf. Section 4.1), 6 (cf. Section 4.2), 7 (cf. Section 4.3), and 8 (cf. Section 4.4) demonstrate that verifiable data and legitimate governance are necessary but not sufficient unless digital sustainability initiatives are economically viable and organizationally integrated.

Essay 5 addresses economic sustainability at the market level by examining the mobilization of capital for long-term transformation processes. Using blockchain-based tokenization of real estate as an illustrative case, the essay shows that tokenization contributes to economic sustainability only when technical mechanisms are embedded in robust organizational and regulatory arrangements. By enabling liquidity and financial inclusion in capital-intensive domains, the essay highlights that inclusive and efficient capital allocation mechanisms are a prerequisite for financing sustainability-oriented investments. Essay 6 shifts the focus to the organizational level by examining how firms can identify and realize value from sustainability-oriented digital infrastructures. Through the development of the DPP-VALUE Method, the essays show that digital sustainability initiatives become scalable and persistent only when organizations can translate regulatory requirements into economically meaningful strategies rather than treating them as compliance-driven burdens.

Essay 7 adds a critical collaborative perspective by explaining how organizations, particularly lower-tier actors facing limited customer proximity and market-data access, can nonetheless engage in sustained digital innovation. By conceptualizing resource-based digital innovation and specifying its iterative building blocks, the essay explains how collaboration enables actors to create and share digital resources and capabilities that would be difficult to develop in isolation. In doing so, Essay 7 highlights that economic sustainability depends not only on internal optimization and value capture, but also on inter-organizational resource creation as a pathway to reduce innovation barriers, distribute investment burdens, and build a persistent innovation capacity under structural constraints.

Finally, Essay 8 explains how dynamic capabilities enable the long-term integration of DSIs. It conceptualizes DSIs as phased processes, from the identification of digital resource gaps to the institutionalization of fully established digital resources. Drawing on dynamic capability theory, the essay shows that sensing, seizing, and transforming capabilities are required to embed and sustain digital initiatives over time. This is particularly relevant for sustainability-oriented initiatives, which are characterized by long time horizons, high uncertainty, and deep organizational embeddedness.

Taken together, the findings of this dissertation seek to provide a coherent answer to the overarching research objective (cf. *to investigate how data-driven digital technologies can be designed, governed, and implemented to support environmental, social, and economic sustainability in socio-technical systems*). Data-driven digital technologies can support environmental, social, and economic sustainability when they address information asymmetries through verifiable data infrastructures, mitigate governance challenges through sovereign and participatory arrangements, and reduce incentive misalignments by embedding sustainability into organizational value creation and organizational capabilities. Sustainable outcomes are unlikely to arise from digital technologies in isolation, rather they depend on the alignment of infrastructures, governance, participation, and organizational integration.

5.2 Limitations and future research

Like any research, the results of this dissertation are subject to limitations that open fruitful avenues for future research. This section provides an overarching reflection on these limitations and outlines directions for further research at the intersection of digital sustainability and digital technologies. More detailed, essay-specific limitations are discussed in the individual essays (cf. Appendix A).

First, this dissertation focuses on a limited set of application domains and focal technologies**.** While this dissertation adopts a broad conceptualization of digital sustainability, several essays center on specific digital infrastructures, most prominently DPPs, BEEMS, and blockchain-based tokenization. This focus was a deliberate design choice to enable in-depth analysis and prescriptive contributions. However, it also limits the generalizability of the findings to other sustainability-relevant domains such as agriculture, mobility, healthcare, or urban governance. Future research could examine whether the identified governance mechanisms, design principles, and capability configurations similarly apply to other digital sustainability infrastructures or whether domain-specific adaptations are required.

Second, this dissertation is constrained in its ability to empirically capture long-term dynamics across sustainability dimensions. Several of the contributions, particularly those addressing dynamic capabilities, value realization, and participation dynamics, concern processes that unfold over extended time horizons. While the dissertation draws on longitudinal data, design iterations, simulations, and theoretical reasoning, the full interplay between environmental, social, and economic sustainability often materializes only over longer periods. Future research would benefit from extended longitudinal studies that observe how digital sustainability initiatives evolve, stabilize, or fail over time, and how tradeoffs between sustainability dimensions emerge, shift, or are resolved in practice.

Third, the underlying dissertation does not comprehensively measure sustainability impacts across all dimensions simultaneously. Although individual essays focus explicitly on environmental (e.g., emission data and decarbonization), social (e.g., participation, privacy, and governance), or economic (e.g., value creation, financial inclusion, and persistence) aspects, the dissertation does not provide an integrative, quantitative assessment of impacts across all three dimensions. This limitation reflects a broader methodological challenge in digital sustainability research, where causal attribution and measurement across heterogeneous outcome dimensions remain difficult. Future research could build on the presented frameworks to develop multi-dimensional impact assessment approaches that combine environmental metrics, behavioral data, and economic indicators in a coherent evaluation logic.

Finally, the complexity of digital sustainability poses inherent methodological challenges**.** Digital sustainability emerges from the interaction of digital technologies, management and governance arrangements, dynamic capabilities, and stakeholder involvement within evolving socio-technical systems. Capturing these dynamics requires the combination of multiple research designs, including design science, qualitative and quantitative empirical studies, simulations, and conceptual theorizing. While this dissertation integrates several of these approaches, no single research design can fully capture the complexity of sustainability-oriented digital transformations. Future research would therefore benefit from interdisciplinary collaborations and mixed-method research programs that combine technical, organizational, behavioral, and regulatory perspectives.

In sum the limitations outlined above suggest several directions for future research. First, replication and extension studies across additional application domains could examine the transferability and boundary conditions of the proposed mechanisms and design principles. Second, longer-term longitudinal work could more fully capture how initiatives evolve and how tradeoffs across sustainability dimensions emerge over time. Third, research on measurement and evaluation could further develop integrative approaches that combine environmental, social, and economic outcomes. Finally, interdisciplinary and mixed-method programs could help link technical design choices to governance arrangements and organizational implementation in real-world socio-technical settings. Following these paths for future research may further support the understanding of how digital technologies can enable environmental, social, and economic sustainability at scale.

Use of writing assistance

Please note that I have used various writing assistance software programs (e.g., ChatGPT, DeepL, and Grammarly) to enhance the language and readability of this work. Nevertheless, I take full responsibility for its content and have thoroughly reviewed and edited the material as necessary.

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A Overview of essays

A.1 Essays included in this dissertation

Essay 1: Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports
Körner, M.-F., Kranz, T., Schick, L., & Strüker, J. (n.d.). Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports [Under Review]. *Blinded due to peer review process* (VHB-JQ3[1]: A, VHB-R4[2]: A, ABDC[3]: A*, SJR[4]: Q1, IF[5]: 11.8)

Essay 2: From bricks to bytes: Verifiable data for decarbonizing the building sector
Körner, M.-F., Kranz, T., Rockstuhl, J., & Strüker, J. (2024b). From bricks to bytes: Verifiable data for decarbonizing the building sector. *Energy Informatics*, *7*. https://doi.org/10.1186/s42162-024-00328-0 (VHB-JQ3: -, VHB-R4: C, ABDC: -, SJR: Q2, IF: -)

Essay 3: Whose Passport Is It Anyway? A Decentralized Web3-inspired Architecture for Sovereign Digital Product Passports in the Circular Economy
Babel, M., Guthmann, C., Körner, M.-F., Kranz, T., & Strüker, J. (n.d.). Whose passport is it anyway? a decentralized web3-inspired architecture for sovereign digital product passports in the circular economy [Under Review]. *Blinded due to peer review process* (VHB-JQ3: B, VHB-R4: B, ABDC: A, SJR: Q1, IF: 6.8)

Essay 4: On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings
Kranz, T., Schick, L., Körner, M.-F., & Strüker, J. (n.d.-b). On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings [Prepared for submission]. *Blinded due to peer review process* (VHB-JQ3: B, VHB-R4: B, ABDC: A, SJR: Q1, IF: 10.4)

Essay 5: From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi
Kranz, T., Schaaf, V., Guggenberger, T., & Strüker, J. (2025). From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi. *IEEE Access*. https://doi.org/10.1109/ACCESS.2025.3648172 (VHB-JQ3: -, VHB-R4: B, ABDC: -, SJR: Q1, IF: 3.6)

Essay 6: Twin Transformation with Digital Product Passports: Developing a Method for Identifying Organizational Value Creation Opportunities
Steinkopf, J., Tadic, J. M., Körner, M.-F., Kranz, T., & Strüker, J. (n.d.). Twin transformation with

[1] VHB-JQ3: VHB-JOURQUAL3
[2] VHB-R4: VHB Publication Media Rating 2024
[3] ABDC: Australian Business Deans Council Journal Quality List
[4] SJR: Scimago Journal & Country Rank, 2023
[5] IF: Impact Factor, 2024

digital product passports: Developing a method for identifying organizational value creation opportunities [Under Review]. *Blinded due to peer review process* (VHB-JQ3: B, VHB-R4: B, ABDC: A, SJR: Q1, IF: 6.8)

Essay 7: Moo-Ving the Dairy Industry - The Building Blocks of Resource-Based Digital Innovation
Kranz, T., Kreuzer, T., Oberländer, A. M., Rex, A., & Ketenidis, D. (2024). Moo-ving the dairy industry - the building blocks of resource-based digital innovation. *Proceedings of the European Conference on Information Systems 2024*. https://aisel.aisnet.org/ecis2024/track02_general/track02_general/16/ (VHB-R3: B, VHB-JQ4: A)

Essay 8: Uncovering the Role of Dynamic Capabilities in Digital Strategic Initiatives
Kranz, T., Kreuzer, T., Oberländer, A. M., & Rex, A. (n.d.-a). Uncovering the role of dynamic capabilities in digital strategic initiatives [Under Review]. *Blinded due to peer review process* (VHB-JQ3: B, VHB-R4: B, ABDC: A, SJR: Q1, IF: 2.3)

A.2 Index of further research papers

Over the course of the dissertation, I also co-authored the following essays and reports. These papers are not part of this dissertation.

Babel, M., Guthmann, C., Körner, M.-F., Kranz, T., & Strüker, J. (2025a). Human-centric digital product passports: Enabling verifiable information sharing for sustainable consumption through wallet-based identity management and zero-knowledge proofs. *Proceedings of the 58th Hawaii International Conference on System Sciences*. https://doi.org/10.24251/HICSS.2025.527

Adelhardt, C., Enggaard, C. E., Funke, A., Gaytandjiev, A., von Guttenberg, L., Kaltwasser, A., Kranz, T., Matta, J., Nolting, L., Schmitt, L., Simon, L., & Subiron, S. (2024). Coalition of the willing on bidirectional charging: Joint report by european working group 1 “car charging and aggregators” and european working group 2 “energy and grid topics”. https://www.bundeswirtschaftsministerium.de/Redaktion/DE/Downloads/P-R/coalition-of-the-willing-on-bidirectional-charging-en.pdf

A.3 Individual contribution to the included essays

This cumulative dissertation comprises eight essays, all co-authored with multiple collaborators. This section details the context and outlines my contributions to the eight essays. The descriptions adhere to the CRediT (CRediT) (Allen et al., 2019).

Essay 1 entitled “Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports” (Körner et al., n.d. Chapter B) was written by a team of four authors. Jointly with another co-author I developed the research idea and set up the research project. I was involved in all phases of the research project, particularly I contributed by conducting the multi-vocal literature review, designing the research approach, organizing and conducting the expert workshop and interviews, and analyzing the collected data. I further was engaged in structuring the paper, positioning the study within the Digital Sustainability, and developing the theoretical contribution in the form of design principles and mechanisms. Additionally, I engaged in textual elaboration and participated in discussions of the research content.

Essay 2 entitled "From bricks to bytes: Verifiable data for decarbonizing the building sector" (Körner et al., 2024b, Chapter C) was written by a team of four authors. While one co-author was initially engaged with the structured literature review, I was involved in refining the initial set of design principles, conducting and analyzing the expert interviews and deriving the final design principles. Further, I was particularly engaged in strengthening the theoretical foundation and implications for the real estate sector. Therein, I did a thorough analysis of the literature on Energy Informatics and Energy Management in the building sector, carved out our understanding of the key constructs, and were hence able to take the leading role in the discussion of our contribution and theoretical implications. Overall I was involved in writing the initial manuscript as well as revising the study after the initial minor revision.

Essay 3 entitled "Whose Passport Is It Anyway? A Decentralized Web3-inspired Architecture for Sovereign Digital Product Passports in the Circular Economy" (Babel et al., n.d. Chapter D) was written by a team of five authors. Within the team of co-authors, I contributed the theoretical foundations related to Digital Product Passports and derived the associated design requirements. While two co-authors were primarily responsible for the technical implementation of the artifact, I contributed to the design and description of the simulation experiment in the electric vehicle domain. In addition, I conducted the literature screening on DPP infrastructures and developed the core theoretical contributions of the study. I took a leading role in drafting the manuscript for both the initial submission and the subsequent re-submissions following major and minor revisions. Throughout the project, I was actively involved in all phases of the research process.

Essay 4 entitled "On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings" (Kranz et al., n.d.-b, Chapter E) was written by a team of four authors. Within this research project I was the leading author. Specifically, I gathered the theoretical foundation, led the conduction of the structured literature review as well as the development of the simulation model, developed the results, and theorized on their implications. Although the research article represents, to a large extent, my work, the other co-authors were involved in each part of the project, contributed their own perspectives on the model development and the handling of data sharing in light of privacy preserving technologies. Further they helped to discuss and advance our results, and refined the manuscript.

Essay 5 entitled "From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi" (Kranz et al., 2025, Chapter F) was written by a team of four authors. I initiated and co-developed the research project. I contributed by establishing the design objectives, designing and implementing the tokenization framework, conducting and analyzing the evaluation interviews, conducting the simulation, and developing the theoretical contribution in the form of design principles. Additionally, I engaged in textual elaboration, participated in research discussions and provided feedback on the paper's content and structure. Overall, I was involved in all phases of the research project.

Essay 6 entitled "Twin Transformation with Digital Product Passports: Developing a Method for Identifying Organizational Value Creation Opportunities" (Steinkopf et al., n.d. Chapter G) was written by a team of five authors. All co-authors jointly worked on the theoretical foundations that underlie the DPP-VALUE Method and contributed their knowledge on the related theoretical lenses. Two of the co-authors and I were primarily responsible for the collection and initial analysis of data. I was specifically engaged with supervising the research process, conceptualizing the theoretical foundations, the development of the design objectives, as well as the workshops. Overall, I was involved in the writing of every section and all stages of development.

Essay 7 entitled "Moo-Ving the Dairy Industry - The Building Blocks of Resource-Based Digital Innovation" (Kranz et al., 2024, Chapter H) was written by a team of five authors. Within the team of co-authors, I contributed to the conceptual development of the study and helped establish the theoretical foundations through a focused literature review. I was actively involved in preparing and conducting the interviews and supported the close consortium interaction throughout the project. I took a leading role in drafting substantial parts of the manuscript and in shaping the overall narrative and positioning of the paper. Further, I remained strongly engaged during the revision process, contributing to the refinement of arguments and the iterative improvement of the paper in response to reviewer feedback. Throughout the project, I was actively involved across all phases of the research process.

Essay 8 entitled "Uncovering the Role of Dynamic Capabilities in Digital Strategic Initiatives" (Kranz et al., n.d.-a, Chapter I) was written by a team of four authors. While this study builds on prior research conducted and published by the same team of authors, I was responsible for formulating the core research idea of examining dynamic capabilities in DSIs. I conducted the literature screening and was actively involved in the collection and analysis of interview data. The qualitative data were jointly coded with another co-author. Further, I was primarily responsible for developing the theoretical foundation of the study and, based on this, led the derivation of both theoretical and practical implications. In addition, I was involved in writing throughout all phases of the project, with particularly strong engagement during the first major revision.

B Essay 1: Assessing the duality of organizational data governance in circular ecosystems: A multi-level perspective on digital product passports

Authors:
M.-F. Körner, T. Kranz, L. Schick, and J. Strüker

Submitted to:
Blinded due to peer review process

Extended Abstract[1]**:**
Prior research has advanced our understanding of data as a strategic resource shaping competitive advantage, market positioning, and the viability of sustainable business models (Black et al., 2023; Grover et al., 2018; Günther et al., 2022; Püchel et al., 2024). This understanding is particularly salient for sustainability transformations, where business models depend on ecosystem collaboration rather than firm-level optimization (Abraham et al., 2019; Adner, 2017; Konopik, 2025): In a digital CE, value creation requires product-related information to remain available, interpretable, and transferable across lifecycle stages and actors (Morseletto & Haas, 2023; Stenzel & Waichman, 2023). Accordingly, circular practices hinge on sharing and reusing product data across multi-tier value chains and heterogeneous networks (Jäger-Roschko & Petersen, 2022; Zeiss et al., 2021), supported by infrastructures for tracing, verification, and decision-making across organizational and lifecycle boundaries (Körner et al., 2025).

Acknowledging the centrality of product data for circularity, regulatory entities such as the European Union (EU) have introduced initiatives to institutionalize cross-organizational data sharing. Most notably, the Ecodesign for Sustainable Products Regulation (ESPR) positions DPPs as a core instrument for structuring and exchanging product lifecycle information across value chains. In line with Petrik et al.'s (2026) IS-centered definition of DPPs, a DPP functions as a policy-driven standardization vehicle that supports CE transitions (Chaudhuri et al., 2024; Gieß & Möller, 2025; Jensen et al., 2023).

However, DPPs success depends not only on inter-organizational interoperability but, more fundamentally, on organizations' internal readiness to provide, manage, and verify DPP-relevant

[1]At the time of writing, this research paper is under review for publication in a scientific journal. Therefore, an extended abstract is provided here.

sustainability data (Berger et al., 2023; Paeplow et al., 2026; Stenzel & Waichman, 2023). A DPP may standardize the sharing interface, yet it cannot resolve where data originates, who owns it, how it is validated, or how it is maintained over time. This bottleneck is intra-organizational: product and sustainability data are typically distributed across heterogeneous systems and fragmented responsibilities, complicating timely, consistent, and verifiable provision (Stenzel & Waichman, 2023).

While data interoperability has long been a focus in IS research (e.g., Oberländer et al., 2021; Piccoli et al., 2022; Schemm and Legner, 2008), the intra-organizational capabilities required to produce verifiable, lifecycle-persistent product data for cross-organizational sharing remain underexplored (Püchel et al., 2024), particularly in regulated DPP contexts. Prior work highlights barriers such as heterogeneous data landscapes, fragmented responsibilities, and competitive concerns (Heeß et al., 2024; Jansen et al., 2023; Lefebvre et al., 2025; Plociennik et al., 2022). Yet, much of the emerging DPP discourse emphasizes technological and economic aspects (Adisorn et al., 2021; Babel et al., 2025; Berger et al., 2023; Jensen et al., 2023), leaving limited attention to the organizational management required to operationalize DPPs strategically through internal practices, roles, and controls for curating, verifying, and provisioning sustainability data. Consequently, it remains unclear how organizations may adapt intra-organizational data management and governance to enable structured and verifiable data sharing across stakeholders and product lifespans. Additionally, recent industry studies reveal the need for practical guidance: up to 90% of affected organizations are not prepared for DPPs (Büchel & Neligan, 2025).

To theorize this gap, we draw on data strategy and governance perspectives that frame inter-organizational data sharing as a pathway to value creation (Günther et al., 2022; Jussen et al., 2024; Xu et al., 2024): Data sharing is shaped by data maturity, incentives and value capture, and ecosystem structures such as interoperability and access coordination (Dreller, 2018; Fassnacht et al., 2024; Gelhaar & Otto, 2020). Complementing this view, IS research emphasizes the inherent duality of data governance: organizations must enable data-driven value creation while protecting data against misuse and regulatory or ethical risks (Vial, 2023). Building on this tension at the level of data strategy, DalleMulle & Davenport (2017) theorize a shift from "defense-oriented" strategies prioritizing risk mitigation, privacy, and compliance toward "offense-oriented" strategies leveraging more flexible data management for value creation. Yet, many organizations remain rooted in an internal compliance and control logic (Abraham et al., 2019; Otto, 2011), which can conflict with the ecosystem imperative to make data usable and shareable at scale to create value. DPPs exemplify and intensify this development by institutionalizing cross-organizational data sharing within regulated ecosystems, increasing demands for data verifiability, accountability, and controlled sharing (Ducuing & Reich, 2023; Körner et al., 2025). Accordingly, we specify the intra-organizational governance structures, routines and controls, and data practices through which organizations can operationalize DPPs-enabled data sharing and value creation in ecosystems.

Motivated by this challenge, our study foregrounds intra-organizational data management as a prerequisite for scalable and trustworthy DPPs implementation. We position this work at the intersection of Green IS (Jenkin et al., 2011; Pan & Nishant, 2023; Seidel et al., 2018) and data studies in IS research (Guggenberger et al., 2025; Legner et al., 2020; Parmiggiani et al., 2023). Accordingly, we ask:

How can organizational data management be structured to enable the introduction of DPPs and the strategic sharing of product-related data that advances the transition toward the circular economy?

To answer our research question, we develop prescriptive design knowledge that specifies how organizations should structure intra-organizational data management for DPP-relevant sustainability data. Our study adopts a design-oriented research approach informed by the design science research paradigm (Hevner et al., 2004; Peffers et al., 2007) and draws on three complementary sources: a structured multi-vocal literature review, an expert workshop, and semi-structured expert interviews with leading international stakeholders from academia and industry. We synthesize academic and high-quality gray literature to derive initial requirements, consolidate and refine the requirements during the workshop, and translate them into design principles and supporting mechanisms. We then use expert interviews to assess the applicability and completeness of the prescriptive guidance and iteratively refine the resulting design knowledge for organizations implementing DPPs.

Our study contributes to research on data ecosystems, data management, and sustainability-oriented data sharing by clarifying how inter-organizational sustainability data sharing depends on intra-organizational operational data management. Building on work in the field of data studies we conceptualize DPPs implementation as a multi-level challenge in which macro-level regulatory and ecosystem requirements are translated into meso-level organizational management strategies and enacted through micro-level data management principles. By doing so, we explain why DPPs may standardize external data-sharing interfaces yet remain compliance-oriented unless organizations also adopt a value-creating data strategy.

Keywords:
Data Governance,Digital Product Passports,Green IS,Circular Economy,Data Ecosystems,Data Management

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C Essay 2: From bricks to bytes: Verifiable data for decarbonizing the building sector

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Körner, M.-F., Kranz, T., Rockstuhl, J., & Strüker, J. (2024b). From bricks to bytes: Verifiable data for decarbonizing the building sector. *Energy Informatics*, *7*. https://doi.org/10.1186/s42162-024-00328-0

Abstract:
Amidst the pressing need to combat climate change and curb greenhouse gas (GHG) emissions, the building sector emerges as a pivotal sector, substantially impacting worldwide emissions. Despite efforts to improve energy efficiency and incorporate non-fossil energy sources, the sector still lags in achieving the necessary decarbonization goals. Existing Building Energy Management Systems primarily prioritize economic criteria, overlooking the vital aspect of emissions reduction. Energy Informatics and Information Systems hold the potential to bridge this gap by enabling precise and verifiable GHG emissions accounting, end-to-end real-time tracking, and automated verification within Energy Management Systems (EMS). This paper presents research on designing the advancement of EMSs in the form of a Building Energy Emission Management System (BEEMS) leveraging verifiable emission data for emission-based actions. The central research question revolves around designing BEEMS to facilitate emission-based actions based on verifiable data. Following a multi-step approach, the research methodology encompasses a comprehensive literature review and iterative evaluation of our design principles through a workshop and semi-structured interviews with experts from industry and research. The contributions include a conceptual architecture of a BEEMS and six design principles for future BEEMS development. Ultimately, this research strives to facilitate end-to-end verifiable GHG emissions management in the building sector to enable emission-based energy consumption decisions, contributing to the existing body of knowledge of the Energy Informatics field on BEEMS.

Keywords:
Building energy emission management system,Energy informatics,Decarbonization,Building sector,Verification,GHG accounting

D Essay 3: Whose Passport Is It Anyway? A Decentralized Web3-inspired Architecture for Sovereign Digital Product Passports in the Circular Economy

Authors:
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Extended Abstract[1]**:**
The environmental crisis requires a shift from linear production and consumption to a CE (European Parliament, 2023; Geissdoerfer et al., 2017; Graham-Nye, 2022; Kirchherr et al., 2017). In this context, digital technologies are seen as key enablers for circular business models and data-driven sustainability (Reich et al., 2025; Zeiss et al., 2021). A core prerequisite is reliable product-related data. For consumer goods, human end-consumers need information about origin, materials, and durability to make informed decisions on purchase and circular actions (e.g., reuse, repair, resale, recycling) (Jäger-Roschko & Petersen, 2022). Yet, many relevant attributes are not visible at purchase and only emerge over time (Morseletto, 2020), while global supply chains hinder tracing and collecting such data (Legner & Schemm, 2008).

DPPs promise structured and verifiable information transfer on a product's origin, life cycle, and environmental footprint (Gieß & Möller, 2025; Reich et al., 2025). However, current infrastructures largely prioritize B2B exchange and grant end-consumers only limited, read-only access (Adisorn et al., 2021; Berger et al., 2022; Heeß et al., 2024). This organization-centric design may mitigate competitive concerns (Lefebvre et al., 2025), but it limits consumers' ability to engage in circular practices and makes CE participation dependent on issuer continuity, a growing risk as products remain in use longer and manufacturers may exit the market. Accordingly, long-lasting access, continuity, and sovereignty over product-related data remain insufficiently addressed (Ducuing & Reich, 2023; Reich et al., 2025).

While the General Data Protection Regulation (GDPR) protects personal data, it provides limited guidance on ownership and control of product-related data generated through human-product

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interaction (Human & Cech, 2021). Data sovereignty, the self-determined control over one's economic data goods (Nagel & Lycklama, 2021), would allow consumers to manage, share, and access such data independently from centralized systems or original issuers (Babel et al., 2025; von Scherenberg et al., 2024). Yet, existing DPP design proposals remain predominantly organization-centric and largely neglect mechanisms for sovereign and persistent consumer access (Adisorn et al., 2021; Plociennik et al., 2022; Walden et al., 2021). Hence, the key gap lies in embedding human-centric data sovereignty into DPP infrastructures.

Against this background, we ask:

> *How can DPP infrastructures be designed to ensure sovereign and long-lasting data access for human end-consumers?*

To answer this question, we follow the DSR paradigm (Hevner et al., 2004; Peffers et al., 2007). Using a design- and development-centered entry point (Gregor & Hevner, 2013; Peffers et al., 2007), we construct an innovative artifact that evolved from a domain-specific use case in the energy sector toward a generalized infrastructure for human-centric DPPs. We apply iterative cycles of design and evaluation, combining formative and summative strategies to assess functionality, usability, and theoretical contributions. Building on web3 technologies such as Self-Sovereign Identity (SSI) and wallet-based ownership, the artifact repositions consumers from passive recipients to empowered custodians of product-related data.

Our artifact proposes a design pattern integrating VCs and NFTs to decouple data authenticity from ownership. This enables issuer-independent data transferability and dynamic ownership management, ensuring that product data remains verifiable and accessible across ownership transitions. Thereby, we provide a technical foundation for embedding end-consumer data sovereignty into decentralized product data infrastructures and contribute to a more inclusive and consumer-oriented understanding of human-centricity in DPP design.

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E Essay 4: On the socio-technical prisoner's dilemma in data sharing: A game theoretical approach to environmental sustainability in multi-tenant housings

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Extended Abstract[1]**:**
Digital technologies increasingly shape how organizations and societies pursue sustainability and decarbonization goals (Kotlarsky et al., 2023). Yet, effective decarbonization depends not only on digital infrastructures (e.g., IoT sensors or data ecosystems) but on the availability and sharing of data that connect resource demand, supply, and user behavior (Watson et al., 2010). Despite technical connectivity, many socio-technical systems still suffer from fragmented data flows that prevent information from being used toward overarching sustainability objectives (Cichy et al., 2021). A persistent IS challenge therefore is how to enable data sharing among actors while preserving privacy and control expectations in pursuit of collective decarbonization goals.

Prior IS research has examined data sharing in B2C contexts and highlighted privacy and trust dynamics (e.g., Alashoor et al., 2025; Cichy et al., 2021). However, much of this work focuses on substitutable services (e.g., platforms or connected products) where users can switch providers at relatively low costs (Crossler & Bélanger, 2019; Dinev & Hart, 2006; Krasnova et al., 2010). These studies provide important insights into individual disclosure decisions (Cichy et al., 2021; Teubner & Flath, 2019), but typically address isolated choices rather than interdependent decisions that jointly determine collective welfare outcomes. In contrast, decarbonization in many industries requires coordinated data sharing by multiple individuals to realize system-level benefits.

The housing sector illustrates this challenge particularly well. Building operations account for around 30% of global final energy consumption and 26% of global energy-related emissions (Cabeza et al., 2022; International Energy Agency, 2023). Residential buildings, in particular, are a major lever for carbon reduction, representing roughly 20% of global final energy demand

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and over 22% of energy-related carbon emissions (Nejat et al., 2015; Wiethe & Wenninger, 2023). Improving energy efficiency increasingly relies on intelligent management of connected devices (Bahramian & Yetilmezsoy, 2020). While such applications can be implemented in single-family homes, socio-technical hurdles emerge in multi-apartment dwellings where legally independent parties share common infrastructure (Tang et al., 2023). Tenants and landlords are bound in long-term relationships, and data-driven interventions (e.g., heating optimization) create interdependent outcomes affecting both individual comfort and collective building performance. Yet, despite the diffusion of smart building systems, data are often underutilized: privacy concerns, misaligned incentives, and fragmented data governance hinder information flows (Cavalheiro & Carreira, 2016; Gholamzadehmir et al., 2020), limiting use cases such as heating optimization, demand-side flexibility, and predictive maintenance (Bjørndal et al., 2023; Fridgen et al., 2021; Michaelis et al., 2024).

These dynamics constitute a digital public-goods dilemma in decarbonization contexts (Hillebrand et al., 2023; Li et al., 2024). Collective data sharing enables efficiency gains and risk prevention, but individual tenants may withhold data due to privacy concerns or fear of losing control (Adeyeye, 2024; Cichy et al., 2021). In such settings, the cost of contribution is less financial than privacy-related: perceived privacy risks and safeguards shape whether individuals cooperate or free-ride (Alashoor et al., 2025; Cichy et al., 2021; Duparc et al., 2024). While this perspective is gaining relevance in adjacent disciplines, it has not yet been systematically formalized for IS research on decarbonization-oriented data sharing. Formalizing these socio-technical components can inform system design and help identify appropriate incentive or compensation mechanisms, especially when sensitive energy data reveal both household behavior and operational processes.

Against this backdrop, privacy-preserving digital technologies (e.g., local processing, anonymization, differential privacy) can reduce perceived risks and thereby alter the equilibrium structure of multi-party data sharing. Rather than treating privacy solely as a constraint, it can be reframed as a designable variable that shapes the conditions under which digital systems support cooperative, data-driven sustainability initiatives (Conde et al., 2024). Accordingly, we pose the following research question:

> *How do privacy costs affect tenants' willingness to share behavioral data in digitally supported housing environments?*

To answer this question, we adopt a game-theoretic approach to model how privacy costs affect tenants' data-sharing decisions and how privacy-preserving digital technologies can mitigate these costs to promote cooperation. We model the setting as a one-shot, simultaneous-move game in which each player chooses whether to share behavioral data or withhold it. Collective benefits (e.g., reductions in building-related damages and efficiency losses) depend on the number of contributors, while individual costs reflect privacy, preference, and contribution sensitivities. Privacy-preserving technologies are conceptualized as reducing or eliminating the privacy component of individual costs, thereby changing strategic incentives.

We contribute to IS research by conceptualizing decarbonization-relevant data sharing in multi-actor housing environments as a collective action problem and by integrating privacy as a design parameter into public-goods modeling. Our analysis shows how design interventions that lower privacy costs can shift equilibria toward cooperative outcomes, illustrating that privacy protection can function as a design lever for addressing common-goods problems in digital sustainability contexts. Practically, we derive implications for designing digitally supported data-sharing infrastructures that align privacy protection with cooperation incentives to support energy optimization and broader decarbonization goals.

Keywords:
Game Theory,Privacy costs,Data sharing,Public Goods Dilemma

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F Essay 5: From Bricks to Blocks: Designing a framework for the tokenization of real estate for DeFi

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Abstract:
Decentralized Finance (DeFi) promises to lay ground for a more open financial system enabled by blockchain technology. Therein, stablecoins have recently gained momentum as regulated and trusted payment instruments, increasingly adopted for cross-border transactions and supported by initiatives such as the GENIUS Act in the U.S. and the European MiCAR framework. While stablecoins create the foundation of trust for linking DeFi with traditional finance, the ecosystem still depends heavily on cryptocurrency markets due to limited real-world asset integration. Existing research largely focuses on traditional securities and tradable assets, but scant attention has been paid to one of the world's largest asset classes, real estate. To address this gap, we propose a framework for the tokenization of real estate for integration into the DeFi ecosystem. Using the Design Science Research (DSR) approach, we construct and evaluate our framework through expert interviews and smart contract simulations. The simulations validate technical feasibility and demonstrate efficiency gains, with batch transfers reducing transaction costs for portfolio purchases. Building on these evaluations, we derive design principles for the nascent field of real-world asset tokenization. These principles highlight the importance of covering the entire product range, pursuing end-to-end compliance, leveraging token standards for interoperability, and extending their functionality for efficiency and scalability. By combining regulatory, organizational, and technical perspectives, our work advances design knowledge for compliant integration of real-world assets into DeFi.

Keywords:
Blockchain; DeFi; DSR; Real-world asset; Tokenization

G Essay 6: Twin Transformation with Digital Product Passports: Developing a Method for Identifying Organizational Value Creation Opportunities

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Extended Abstract[1]**:**
In 2024, the EU introduced the Eco-design for Sustainable Products Regulation (ESPR) to improve product environmental performance by increasing the availability of reliable product information of products placed on markets within the EU (European Parliament and Council of the European Union, 2024). Therein, the introduction of DPP marks a fundamental pillar of the EU's CE ambitions. The EU defines DPPs as product-specific datasets linking lifecycle information to physical products and enabling electronic registration and seamless data exchange across supply chains (European Parliament and Council of the European Union, 2024). Further, DPPs act as standardized, product-specific, inter-organizational data-sharing systems for sustainability-relevant product data, ensuring that critical information remains accessible across organizational and value-chain boundaries throughout a product's life cycle, marking a significant development at the intersection of digital technologies and sustainability (Chaudhuri et al., 2024; Jensen et al., 2023; Neramballi et al., 2024). Realizing DPPs potential as interoperable data artifacts, enabling transparency, trust, actor integration, and data-driven ecosystems, requires effective intra-organizational integration (Gieß & Möller, 2025). Without a clear, organization-specific value proposition and identification of tangible benefits (Lopes & Barata, 2024), organizations may perceive DPPs primarily as a regulatory burden, missing their potential for data provision within data ecosystems beyond the regulatory minimum (Berger et al., 2023; Zhang & Seuring, 2024). Prior research shows that DPPs enable both intra-organizational value (e.g., efficiency, data quality) (Psarommatis & May, 2024) and inter-organizational value (e.g., transparency, coordination) (Elling & Petrik, 2025), thereby strengthening digital and sustainability-related capabilities

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(Crome et al., 2023) and supporting Twin Transformation (TT) (European Commission, 2022). However, ecosystem-level benefits only emerge when organizations actively leverage DPPs as data infrastructure (Gieß & Möller, 2025). While existing studies acknowledge these contextual contingencies, we still lack understanding of how DPP-related value arises across heterogeneous organizational structures (King et al., 2023; Psarommatis & May, 2024). This gap is amplified by the lack of methodological guidance (Lopes & Barata, 2024), leaving organizations without (1) an overview of DPP-related advantages and dependencies and (2) structured support to identify and evaluate the economic value of DPP implementation. Against this background, our study sets out to answer the following research question:

How can organizations effectively identify organization-specific value creation opportunities arising from the mandatory implementation of DPPs?

To answer our research question, our study follows the DSR paradigm (Hevner et al., 2004; Peffers et al., 2007) and applies SME (Brinkkemper, 1996; Bucher et al., 2007; Henderson-Sellers & Ralyté, 2010). We draw on rich data from four sources: A Structured Literature Review (SLR), real-world data from interviews with three industry experts of the globally operating metal manufacturer Aurubis, an in-depth workshop with five Aurubis employees from different departments, and an interactive working sessions with researchers in the field of Digital Sustainability. Thereupon, we introduce three interrelated artefacts: The DPP-VALUE Method, a step-by-step approach guiding the identification of organization-specific value creation opportunities, along with the VL Longlist, which is a structured compilation of effects derived from literature and practice (Gioia et al., 2013; Webster & Watson, 2002; Wolfswinkel et al., 2013), and the VL Framework, integrating these effects into a visual model of value creation within the DPP ecosystem. Thereby, we contribute to digital sustainability research by conceptualizing DPPs as interoperable digital infrastructures that enable sustainable value creation in data ecosystems, and to electronic markets research by highlighting their role in fostering standardized data exchange. As a practical contribution, our method serves as starting point to engage with DPP implementation by providing a step-by-step process to determine the economic value of DPPs based on organizational characteristics and strategic goals. By providing organizations with a methodology for identifying DPP-related value, our research supports Digital Transformations, Sustainable Transformations, and the use of DPPs as a strategic instrument for advancing TT capabilities (Christmann et al., 2024).

Keywords:
Digital Product Passport,Digital Sustainability,Twin Transformation,Design Science Research,SME

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H Essay 7: Moo-Ving the Dairy Industry - The Building Blocks of Resource-Based Digital Innovation

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Abstract:
Digital innovation is an important driver of competitive advantage for organizations. However, there is an imbalance in our knowledge of digital innovation perspectives, leaning towards a market-based view. This poses a problem for lower-tier actors in supply chains, like producers, that have limited customer access and are subject to cost pressures from retailers. Against this backdrop, we adopt an extended resource-based view on digital innovation and introduce the concept of resource-based digital innovation, emphasizing the potential of collaborative digital resource creation. Based on a consortium research approach in the dairy industry, we design a conceptual framework comprising five building blocks of resource-based digital innovation and evaluate the framework through a real-world demonstration in the consortium. Our findings link the existing bodies of knowledge on digital resources and digital innovation, inspire scholars to further explore the concept of resource-based digital innovation, and guide practitioners in creating digital resources

Keywords:
Digital Innovation,Digital Resources,Resource-based View,Consortium Research

I Essay 8: Uncovering the Role of Dynamic Capabilities in Digital Strategic Initiatives

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Under Review:
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Extended Abstract[1]**:**
Digital technologies have become deeply embedded in contemporary society, transforming how organizations create, deliver, and capture value (Baskerville et al., 2020; Yoo et al., 2010). As organizations pursue digital transformation, they increasingly rely on digital technologies as digital resources, encompassing both digital assets and digital capabilities that can be leveraged and recombined across multiple value creation contexts (Henfridsson et al., 2018; Piccoli et al., 2022). Effective utilization of digital resources is widely recognized as a critical determinant of competitive advantage and organizational adaptability in the face of digital disruption (Bharadwaj et al., 2013; Heinz et al., 2021). Yet, orchestrating digital resources poses substantial managerial and organizational challenges. Digital resources are often embedded in layered technological architectures, distributed across organizational boundaries, and governed by shared control structures (Eaton et al., 2015; Oberländer et al., 2021). As a result, organizations must align and coordinate technical and organizational components, tasks that go beyond isolated technology adoption or process optimization (Helfat & Peteraf, 2009; Oberländer et al., 2025).

In this context, DSIs have emerged as a promising phenomenon to examine how organizations create and orchestrate digital resources. DSIs are "identifiable competitive moves that depend on the use of digital resources to create and appropriate economic value" (Piccoli & Rodriguez, 2020, p. 52) and represent a central mechanism through which digital transformation efforts are operationalized. Prior research further emphasizes that digital transformation is not a one-time journey ending in a stable state, but a shift into continuous innovation and ongoing digital resource development (Hanelt et al., 2021; Piccoli et al., 2024). Accordingly, DSIs have been theorized as initiatives that "lead to the creation of a digital resource or the orchestration of digital resources into a value proposition" (Piccoli et al., 2022, p. 2298). Illustrative examples of successful DSIs are the DBS Bank's multi-year digital transformation program that built scalable digital and AI-enabled banking capabilities (McKinsey & Company, 2023), and Siemens' Digital Enterprise/Twin initiative that created a digital-twin resource for designing, simulating, and

[1] At the time of writing, this research paper is under review for publication in a scientific journal. Therefore, an extended abstract is provided here.

optimizing products and production systems (Siemens AG, 2025).

Despite this progress, it remains insufficiently theorized how organizations implement DSIs in a repeatable manner, that is, how they consistently recognize digital resource gaps, mobilize the necessary competencies, and institutionalize newly created resources. We argue that addressing this challenge requires a capability perspective that bridges digital strategy and technical execution within DSIs. Importantly, these DSI-related organizational capabilities are distinct from the digital capabilities embedded in digital resources. Digital capabilities refer to the programmable, modular functionalities of a digital resource, what the resource can do once created and stabilized (Piccoli et al., 2022). DSI-related organizational capabilities, in contrast, reside in organizational routines, structures, and managerial practices that enable organizations to repeatedly progress from identifying a digital resource gap, to developing a nascent resource, and ultimately institutionalizing a fully established digital resource through a DSI.

Building on this distinction, we conceptualize DSI-related organizational IS capabilities as dynamic capabilities that represent the change-oriented organizational abilities through which firms integrate, build, and reconfigure competencies in rapidly changing environments (Teece, 2007, 2012). Accordingly, we use the sensing, seizing, and transforming triad as conceptual vocabulary to examine how organizations recognize digital opportunities and threats, mobilize and configure IS-related competencies to create and orchestrate digital resources, and renew structures as DSIs unfold (Teece, 2007). While prior research has examined foundational IT capabilities (e.g., flexible infrastructure, IT-business alignment, and relationship structures) (Sullivan et al., 2023) and higher-order digital capabilities emphasizing the malleability and recombination of digital resources (Sting et al., 2024), it remains unclear how the required technical and non-technical capabilities are configured and enacted across the implementation of DSIs. In particular, existing work often adopts a high-level strategic orientation or focuses narrowly on technical enablement, lacking an integrated perspective that captures the interplay of stakeholder engagement, IS governance, infrastructure management, and business development required for DSIs (Baiyere & Salmela, 2014; Wessel et al., 2021).

This lack of integration risks limiting organizations' ability to translate strategic intent into viable DSIs and to purposefully develop and orchestrate digital resources for value creation (Lawson, 2021). Consequently, Piccoli et al. (2022, p. 2309) explicitly call for research to identify and examine the "*organizational IS capabilities needed to foster DSI creation and orchestration*."

Accordingly, we pose the following research question: *How do organizations implement digital strategic initiatives by developing and leveraging dynamic capabilities?*

To address this research question, we conducted a multiple case study and investigated three DSIs. Thereby, we explain DSI implementation and unpack how sensing, seizing, and transforming manifest as empirically grounded DSI phases with underlying dynamic capabilities that enable progress across distinct phases of digital resource development and institutionalization.

To the best of our knowledge, this study is the first to empirically address the call of Piccoli et al. (2022) by explaining how DSIs are implemented through dynamic capabilities. Our longitudinal analysis further reveals how these capabilities help organizations navigate frictions and overcome structural barriers that commonly hinder DSIs progression. Finally, we translate our insights into practice by providing a capability development roadmap that supports managers in diagnosing resource maturity, aligning capability-building efforts, and systematically advancing DSIs from initiation to institutionalization.

Keywords:
Digital Innovation,Digital Resources,Resource-based View,Consortium Research

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