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Applying an ecosystem lens to low-carbon energy transitions: A conceptual framework

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ABSTRACT

Business model innovations aiming at systemic change influence the speed and direction of low-carbon transitions, thus supporting public decarbonization policies. However, their potential is often limited by institutional settings or a lack of alignment with potential partners. Therefore, to exploit the potential for systemic change of business model innovations in socio-technical systems, it is necessary to consider their interactions with their wider environment. In this conceptual study, we explore the mechanisms through which business activities interact with public policy goals under low-carbon energy transitions. We take an ecosystem lens to analyze value creation at the levels of customers, business, inter-organizational networks and the public. Based on an integrative literature review, we build a conceptual meta-model specifying the constitutive elements, dynamics and environmental dimensions describing regional energy ecosystems under transition. The main constitutive element of the ecosystem is the value network, i.e. the interlinked business models of collaborating organizations exchanging money, goods, services, information or intangible benefits. The value network interacts dynamically with a pool of resources (assets, capabilities and intangible resources) that improves the ecosystem's ability to enact systemic change. Orchestration is a crucial process to steer the ecosystem's development towards creating value for customers as well as for the public. Finally, the relevant environmental dimensions include policy, culture, markets, industry structure as well as potential future members or resources. We illustrate our conceptual model with the case of the development of low-carbon district heating to decarbonize space heating in a Swiss city. This illustrative case study shows that the ecosystem perspective combined with public value theory is well suited to describe the dynamics of a low-carbon energy transition and provides valuable insights on the prospects of novel business models.

1. Introduction

In transitions towards low-carbon energy systems, business models (BM), i.e. the logic of how organizations use their resources to create and capture value, play a crucial but complex role. Conceptual and empirical research shows that BM can be either drivers of, or obstacles to change (Bidmon and Knab, 2018; Sarasini and Linder, 2018). Materially, the linkages between BM of interacting organizations in a socio-technical system (STS) determine the flows of capital, goods and services, so that successful business model innovations (BMI) enable the diffusion of desirable technologies (Wainstein and Bumpus, 2016). In addition, BM also play a cognitive role, as the dominant BM in an industry tend to form a mental model in decision-makers' minds of how business is done (Bidmon and Knab, 2018). Therefore, current BM are a source of inertia, since technical and social innovations challenging the accepted "industry recipe" must overcome such cognitive barriers. Conversely, BMI impacts STSs beyond enabling new technologies, i.e. by challenging expectations, user practices and industry structure (Kallio et al., 2020; Wesseling et al., 2020). This demonstrates the importance of BM for successful low-carbon transitions, in interaction with political, policy and societal developments (Geels et al., 2017).

However, BMI at the level of individual organizations or products is often not enough to enact systemic change (Bolton and Hannon, 2016). Researchers point to the lack of a dynamic framework describing the co-evolution of BM and the STSs in which they are embedded (Bolton & Hannon, 2016, 2016van Waes et al., 2018). The relevant

Abbreviations: BE, Business Ecosystem; BM, Business Model; BMI, Business Model Innovation; DH, District Heating; REE, Regional Energy Ecosystem; RP, Resource Pool; STS, Socio-technical system; VN, Value Network; VP, Value Proposition.

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co-evolutionary aspects concern several dimensions: first, systemic innovations require contributions and adaptations from various actors, potentially supported by regulatory or policy measures (Brown et al., 2019; Zapata Riveros et al., 2021). Second, BM co-evolve with other dimensions of the STS, such as institutions, infrastructure and industry structure (Bolton & Hannon, 2016, 2016van Waes et al., 2018). Finally, organizations should identify, exploit and foster self-reinforcing innovation and market dynamics allowing them to increase their revenue on investments in technical and social innovations (van Waes et al., 2018).

The purpose of this paper is to build a conceptual framework describing BM dynamics under low-carbon transitions. We draw primarily upon the business ecosystem (BE) literature, a fast-growing research field focusing on the co-evolution of heterogeneous actors linked through economic, technical or cognitive interdependencies (Autio and Thomas, 2021; Moore, 1993). We synthetize the extant literature on BM in socio-technical transitions and integrate it in a dynamic framework based on an ecosystem perspective. While we focus on (inter-)organizational aspects, we also consider interactions with other dimensions of STSs. The ecosystem perspective was identified as a promising analytical lens for the development and diffusion of systemic innovations (Lazarevic et al., 2019). Furthermore, understanding the ecosystem is a crucial part of BMI in general (Frankenberger et al., 2013). We argue that this is particularly important under low-carbon transitions, as the goal of BMI is not only commercial success, but also contributing towards a purposive, complex change process in a STS. The output of this study is a conceptual meta-model charting the dimensions of analysis to describe the role of BM in regional energy transitions and to prospectively reflect on the systemic impact of BMI.

The remainder of this paper is structured as follows: Section 2 summarizes the state of research in the body of literature this paper seeks to contribute to (i.e. the role of BM in socio-technical systems under transition) and in the domains we draw upon (i.e. BE and public value theory). Section 3 describes the method used to construct the proposed framework (integrative literature review). Section 4 iteratively builds the framework, termed "Co-evolutionary business ecosystem perspective", based on a structured, integrative literature review and presents its application in an illustrative case study. Section 5 discusses the implications of the results, focusing on its potential for applied research aimed at governing transitions, the study's limitations and future research potentials. Section 6 summarizes this paper's contributions.

2. Theoretical background

2.1. Business models and business model innovation in socio-technical transitions

Given the urgency of transforming society's modes of production and consumption towards environmental and social sustainability, socio-technical transitions research investigates how to implement such radical changes (Geels et al., 2017; Köhler et al., 2019). Drawing on multiple disciplines, transition research analyzes the dynamics of STSs (i.e. the social systems around the production and application of technologies) along various dimensions, such as technologies, policy, politics, industry structure, markets, user practices or institutions (Geels, 2004). While the role of business and industries has been addressed relatively rarely, Köhler et al. (2019) identified several promising research directions at the interaction of these domains. We specifically focus on the role of BM in socio-technical transitions and review the state of the research at this interface.[1]

The role of BM within STSs has been studied conceptually and empirically in various contexts, such as renewable electricity (Bidmon and Knab, 2018; Kallio et al., 2020; Wainstein and Bumpus, 2016), district heating (Bolton and Hannon, 2016), building energy services (Brown et al., 2019; Lazarevic et al., 2019), industrial electrification (Zapata Riveros et al., 2021), and transport (Sarasini & Linder, 2018, 2018van Waes et al., 2018; Wesseling et al., 2020). Table 1 summarizes the insights from these contributions. Noting the lack of a firm-level perspective in transition theory, Sarasini and Linder (2018) explored how a BM perspective could help analyze and govern transitions. They selected the BM perspective due to its focus on innovation, while noting that it does not cover all aspects of an organization. Also, Bidmon and Knab (2018) integrated conceptual aspects of BM and socio-technical transition theories. Both studies built upon the conceptual heterogeneity of BM literature (Foss and Saebi, 2018) to explore the roles of BM as obstacles to, or as drivers of transitions. Existing BM reinforce the dominant industry logic, creating a cognitive barrier to change. New BM drive change, either as enablers to commercialize technical innovations, or as the object of non-technical innovation and experimentation. Therefore, a BM's sustainability impact can be direct or indirect. In examples of the latter, Wainstein and Bumpus (2016) provide the example of a large utility's BM being challenged by decentral power generation through market effects and the reconfiguration of resources along the value chain, and Kallio et al. (2020) show how a new BM modified long-held beliefs about customer expectations and the nature of energy services.

Researchers also investigated the constraining elements and success factors for BMI. These factors span multiple dimensions and include policy, user practices, institutions as well as industry structure (van Waes et al., 2018; Wesseling et al., 2020). As a result, actors may design their BM to conform to current socio-technical conditions, or to proactively influence these conditions to create a more favorable environment for radical innovations. Sarasini and Linder (2018) note that this requires activities outside the scope of BMI, such as institutional work, intermediation or system building. This is especially the case for systemic innovations, where multiple actors as well as policy development must be coordinated (Brown et al., 2019; Zapata Riveros et al., 2021).

2.2. Ecosystems as an organizational concept

The term "ecosystem" was introduced into management research by

Table 1
The different roles for business models in socio-technical transitions and how they impact the system. Based on the literature at the intersection of business models and socio-technical transition research (Bidmon and Knab, 2018; Bolton and Hannon, 2016; Brown et al., 2019; Kallio et al., 2020; Lazarevic et al., 2019; Sarasini & Linder, 2018, 2018van Waes et al., 2018; Wainstein and Bumpus, 2016; Wesseling et al., 2020).

	Role of BM in socio-technical transition		
	Obstacle to change	*Device to commercialize niche technologies*	*Non-technical innovation*
Direct impact of BM	Continued use of unsustainable technologies.	Enables diffusion of new technologies.	Accelerates diffusion of new technologies; reconfigures existing resources towards more sustainable use.
Indirect impact of BM	Increases system inertia by reinforcing dominant industry logic	Changes the economics and available resources for existing BM; challenges dominant industry logic; transforms industry structure; alters existing markets or creates new ones; changes users' perception and expectations of the new technology or practice.	
Activities supporting BM-driven change	Institutional work (e.g. lobbying, building legitimacy), intermediation, system-building		

[1] We acknowledge that this literature is part of a wider, highly active research stream on BM in sustainability transitions (e.g. Aagaard et al., 2021). We focus here on the literature with an explicit socio-technical focus.

Moore (1993), to describe how firms co-evolve their capabilities around innovations and value creation. In contrast to the traditional view of firms competing within an industry, the ecosystem perspective sees firms from different industries interacting both collaboratively and competitively. Despite ontological disagreements, it is generally accepted that an ecosystem includes a value network (VN), i.e. a set of actors (Allee, 2008) or activities (Peppard and Rylander, 2006), linked through the exchange of goods, services, or other tangible or intangible forms of value. According to Adner (2017), all of these aspects are necessary to describe an ecosystem's structure. Autio and Thomas (2021) identified four conditions that together set ecosystems apart from other inter-organizational collectives: a system-level outcome; heterogeneous participants; economic, technical or cognitive interdependence; and non-hierarchical governance. This definition implies that ecosystems are characterized by co-evolution, both between participants and between the ecosystem and its environment (Hou and Shi, 2021).

However, despite fast-growing academic attention to ecosystems, conceptual ambiguity has hampered progress (Aarikka-Stenroos and Ritala, 2017; Granstrand and Holgersson, 2020). This challenge manifests itself in different ways: First, it arises from insufficient delimitation from similar concepts, e.g. innovation systems (Oh et al., 2016) or business networks (Aarikka-Stenroos and Ritala, 2017). Second, the term is used sometimes as a metaphor and sometimes as a theory (Aarikka-Stenroos and Ritala, 2017). Third, various qualifiers of ecosystems have been used (e.g. "business ecosystem", "innovation ecosystem", "service ecosystem"), with inconsistent and overlapping definitions (Aarikka-Stenroos and Ritala, 2017; Cobben et al., 2022). A final source of confusion comes from scale: ecosystems sometimes refer to the "lower meso-scale" of inter-organizational networks, and sometimes to the "upper meso-scale" of business fields (Möller et al., 2020). Despite these conceptual challenges, the ecosystem perspective offers unique theoretical and practical insights if applied rigorously (Autio and Thomas, 2021; Phillips and Ritala, 2019).

The links between the BM and ecosystem concepts have often been highlighted (Frankenberger et al., 2013; Hellström et al., 2015; Leviäkangas and Öörni, 2020; Shaw and Allen, 2018). Shaw and Allen (2018) conceptualize ecosystems as "pathways of interlinked business models", with the analytical focus shifting from individual BM to the value flows between them. On the other hand, in the BMI literature, the ecosystem forms the dynamic context in which BM operates, so that knowledge of ecosystem structure and feedbacks is essential to assess an innovation's prospects (Frankenberger et al., 2013). As described by Hellström et al. (2015), collaboration in an ecosystem requires alignment of the different BM, i.e. coordinated adaptations in the participants' value creation and capture processes. This is not a one-off process, as changes in the ecosystem VP or in environmental conditions may trigger the need for re-alignment (Adner, 2017).

2.3. Public value theory

Public value creation requires a different logic than private-sector value creation (Cordella and Paletti, 2019; Walravens and Ballon, 2013). "Public value" refers to a philosophical theory (Meynhardt, 2009), a normative or empirical management theory (Bryson et al., 2017; Moore, 2000), and a public management paradigm (Bryson et al., 2017). Here, we focus on the first two dimensions. Different definitions of public value exist, with different dimensions of value and conceptualizations of the public (Petrescu, 2019). Moore (2000) gives a pragmatic, operational definition: public value is created by fulfilling a government agency's mission. This assumes that what citizens value gets translated into law or policy through political processes, and that public value changes over time.

Public value theory was pioneered by Moore (1995) as a normative theory of strategic management for the public administration. It was aimed at entrepreneurially minded public managers, giving them a heuristic tool to maximize impact. The underlying strategic triangle framework posits that successful public management organizations or initiatives must meet three criteria: they must put forward a VP that meets societal expectations, secure political and financial support from the "authorizing environment" (e.g. elected officials, citizens, interest groups or the media), and aim for feasible results given the available resources and capabilities. Crucially, the causal links between value creation, financial sustainability and organizational survival are much weaker than in the private sector. Another important difference is the fact that value is received collectively, whereas citizens do not necessarily have the role of customers (Petrescu, 2019). Public value theory gained popularity in public management research and practice (Bryson et al., 2017), but drew criticism from policy researchers (Rhodes and Wanna, 2007). The main points of critique were 1) that the focus on public managers was not transferrable to political traditions outside the USA; and 2) that this focus downplayed the importance of politics, naively assuming alignment of all actors towards a shared interest. Partly in response to these criticisms, Bryson et al. (2017) proposed a revised version of the strategic triangle accommodating multiple actor types and levels. Rather than focusing on managers only, which actors or functions govern public value creation is an open question, depending on context and research aims. There is increasing recognition that public value creation is a multi-actor process involving value co-creation, complementarity and orchestration (Cordella and Paletti, 2019; Petrescu, 2019).

3. Methods

3.1. Conceptualization of ecosystems in low-carbon energy transitions

We elaborate a conceptual framework mapping the key constitutive elements of a socio-technical energy system from an (inter-)organizational perspective, as well as the key processes influencing, and influenced by, those constitutive elements. This framework is a meta-model, as it does not postulate any specific causal mechanism, but provides a blueprint to formulate dynamic hypotheses.

The elaboration of the framework is based on an integrative literature review. To define its scope, we distinguish between domain theory (the body of research to which we contribute) and method theory (the body of research from which perspectives are drawn to advance the domain theory) (Jaakkola, 2020). As domain theory, we define the stream of research at the intersection of BM and socio-technical transitions. As this research stream is still recent, we complement our review by drawing on the broader literature on BM and transitions where appropriate. As method theories, we rely on 1) ecosystem literature in strategic management, marketing, innovation and entrepreneurship research, and 2) public value theory.

The literature review is structured following Phillips and Ritala (2019), who proposed a research agenda to conceptualize ecosystems as complex adaptive systems (Fig. 1). For each dimension of analysis, we identify the relevant themes in the domain theory literature, then review the method theory literature to determine how these themes are conceptualized and operationalized in the method theory literature. We then construct our conceptual framework iteratively, selecting the elements based on their appropriateness for the context of regional energy systems.

3.2. Illustrative case study

Next, we demonstrate the potential of the proposed framework by applying it to an illustrative case study on the decarbonization of regional energy ecosystems focusing on district heating (DH). DH has historically not been an innovative industry, as it has largely relied upon regulatory and public financial support (Knutsson et al., 2021; Sandoff and Williamsson, 2016). Hence, adapting to technological change, evolving customer needs and increased systemic competition has proved challenging for some DH operators (Lygnerud, 2018). Nevertheless, DH

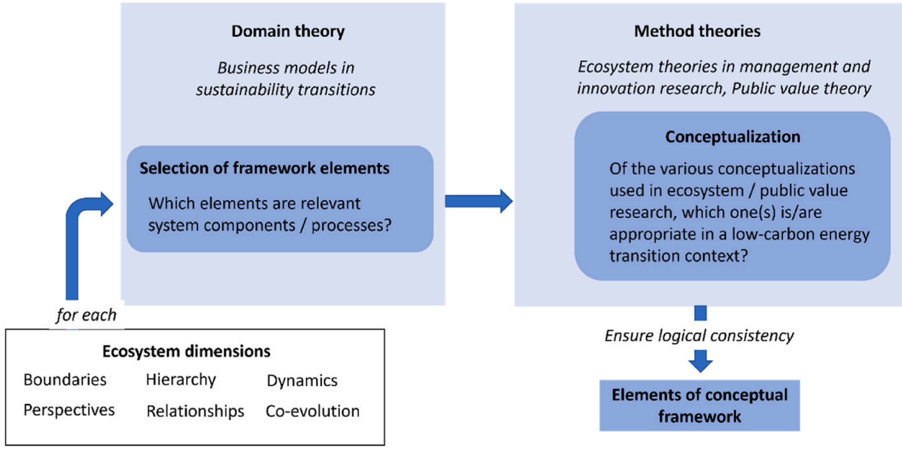


Fig. 1. Selected approach for the integrative literature review and construction of the conceptual framework.

is a key element for decarbonization (Chambers et al., 2019). Given the importance of DH for decarbonization and its *a priori* challenging environment for BMI, we chose our illustrative case from that sector.

Our illustrative case is located in Biel, a city of 55′000 inhabitants in Switzerland. While space heating is still predominantly provided by oil and natural gas, low-carbon DH is a crucial instrument of municipal energy policy. There are three thermal grids in operation, using heat from waste incineration (built in 1981), biomass (2014) and groundwater (2017), and a grid using thermal energy from the lake is under construction. About 15 further DH projects exist, at various stages of maturity, in the agglomeration.

Our illustrative case covers two interrelated topics: the ecosystem around DH in the Biel agglomeration, and the well-documented launch of an innovative BM supporting customer acquisition. Given the conceptual nature of this study, we use secondary data from policy documents, law texts, trade articles, documents from the involved organizations (annual reports, presentations, marketing material, websites) and media reports applying qualitative content analysis (all sources used are listed in the supplementary material).

4. Results

4.1. Conceptualization

Before describing the ecosystem dimensions, we outline the generic concept, termed "Co-evolutionary business ecosystem perspective on socio-technical transitions" (CEBEP). We further define the "regional energy ecosystem" (REE) as our unit of analysis. We define a REE as a BE centered around energy provision in line with public priorities, primarily regarding GHG emission reduction. The term "regional" does not imply a strict focus on a certain geographical scale, but specifies that the system falls under a certain jurisdiction, so that the authorities responsible for energy policy are clearly identified. With regard to transition theory, the CEBEP concept is most in line with the whole-system reconfiguration concept (Geels, 2018): decarbonization typically requires a combination of several changes, some incremental and some radical, impacting one or several regimes in different ways. The whole-system reconfiguration perspective "zooms out" by shifting the focus from individual innovations to a sectoral, longer-term perspective (Geels, 2018). On the other hand, the CEBEP perspective "zooms in" by focusing on the sphere of BM, whereas other dimensions of the STS are considered in less detail. The conceptualization of the various dimensions of the CEBEP is summarized in Table 2 and described in the following subsections.

Table 2
Summary of the conceptual framework construction, based on an integration of domain and method theories for different ecosystem dimensions.

Dimension	Themes from domain theory	Conceptualizations in domain theories	Elements of conceptual framework
Perspectives	Tension between economic value and sustainability impact	Purpose of ecosystems Public value proposition	Customer and public value propositions
Boundaries	Interactions within business sphere	Definitions of (business) ecosystems	Ecosystem boundaries and environment
	Interactions with other dimensions of socio-technical systems	Opportunity space	
Hierarchy	Niche-regime dichotomy and its limits	Hierarchy of value and value creation	BM within value chain; value chain within REE Hierarchy of administrative or organizational levels
Relationships	BM as a boundary-spanning concept	Interdependency Orchestration/ Alignment	Orchestration/ Ecosystem governance
	Intermediation/ Governance	Operational capabilities	
Co-evolution	Co-evolution within industry and with institutions	Co-evolution as a distinctive feature of ecosystems: co-evolution of what with what?	Resource pool Interactions with elements of the environment
Dynamics	Effects of BM on socio-technical regime System constraints on BM design	Assumptions on ecosystem emergence and transformation	Transformation and feedback

4.1.1. Perspectives

As discussed above, BMI may create direct and indirect sustainability impacts. This supposes that the factors for economic value creation and positive social or environmental impact are aligned internally at the BM level, and externally with their environment. For example, the power purchase agreement model described by Wainstein and Bumpus (2016) benefited from regulatory financial incentives, which helped establish a profitable BM to overcome investment barriers for photovoltaics. Elsewhere, alignment is less straightforward: for Bolton and Hannon (2016), the challenge for BMI under transitions is to achieve and maintain internal and external alignment by forming partnerships and reconfiguring available resources. Two examples illustrate how such a strategy helped launch innovative, integrated building energy BMs: Lazarevic et al. (2019) and Brown et al. (2019) describe how energy service providers applied an ecosystem strategy to attract complementary participants and govern collaboration among them. Bolton and Hannon (2016) suggest a tension between commercial and public goals, so that the potential of BMI to enact change is constrained by the involved actors' respective goals and power. Brown et al. (2019) describe a case where it is not yet certain whether the BM can become self-sustaining after initial subsidization. These examples demonstrate the challenge of aligning profitability and sustainability impact.

While BE are centered on a common value proposition (VP), typically fulfilled by continuous innovation, sustainable value creation has rarely been studied (Cobben et al., 2022; Oskam et al., 2021). The active role of public authorities has been highlighted regarding the sustainability impacts of BE: Ma et al. (2018) describe the co-evolution of urban sustainability with the shared mobility BE. Despite synergies between public policy and industry, they raise concerns on the potential mis-alignment of powerful private-sector actors' goals with sustainable development. Visnjic et al. (2016) conceptualize urban governance as an "ecosystem of ecosystems", where the administration's role is to directly or indirectly manage the activities delivering value to both citizens and firms, often with conflicting objectives. These studies demonstrate the need for public management to align BE with sustainability goals. This is especially the case when considering recent developments towards multi-level and multi-actor governance (Bryson et al., 2017).

The concept of a public VP (Moore, 1995, 2000) links public missions with economic activities. We propose that an REE is centered around two interdependent VPs, a customer and a public VP. Energy transitions consist of covering society's need for affordable and reliable energy, while increasing sufficiency and efficiency, and/or lowering emission intensity. The challenge is therefore to keep or improve the current customer VP, while aligning it with a public VP. Crucially, the beneficiaries of these two VP need not be identical. The customer VP targets every natural or legal person responsible for their energy supply. The public VP consists of fulfilling a mission given to the administration through public deliberation and decision processes. Its intended beneficiaries are all stakeholders with a voice in this process, through formal or informal mechanisms. Furthermore, these VP are realized differently: realizing the customer VP depends on customer acceptance, whereas public value is "created" by fulfilling the public mission (Moore, 2000). Therefore, public value depends on the success of the customer VP. Conversely, the public mission influences the customer VP, as the nature of climate policies constrains choices (e.g. the technologies to be deployed).

4.1.2. Boundaries

In describing the impact of BM beyond the focal firm, the domain theory focuses on interactions with other firms (Brown et al., 2019; Lazarevic et al., 2019), but also with other dimensions of STSs, such as policy (Bolton and Hannon, 2016; Brown et al., 2019) and informal institutions (Kallio et al., 2020). Another relevant dimension is the industry, including both the characteristics of the focal firm (van Waes et al., 2018) and the characteristics and relationships of firms in the industry in general (Wesseling et al., 2020), including managers' mental models (Bidmon and Knab, 2018). The importance of these interactions makes it essential to delimit the REE conceptually, not only geographically and sectorally.

According to Moore (2006), ecosystems are a community of actors co-evolving with each other and with their environment. However, different conceptualizations in the literature entail different system boundaries. For example, whereas Teece (2007) includes regulators in the ecosystem, they are part of the environment for Ma et al. (2018). To clarify this, Tsujimoto et al. (2018) proposed a framework where a BE is nested within a larger, multi-actor network. The BE consists of the economic actors in the value chain or VN,[2] whereas the multi-actor network includes policymakers, public administration, investors, users, as well as innovators and entrepreneurs currently outside of the VN. The latter category, termed "opportunity space", is boundless, since any offering or technology may become relevant to the ecosystem (Hou and Shi, 2021; Moore, 2006). Hou and Shi (2021) also discuss the representation of actors: they are sometimes viewed in terms of their role, i.e. their specific contribution to the ecosystem (e.g. Adner, 2017). However, this does not account for shifting roles as the ecosystem evolves (Hou and Shi, 2021).

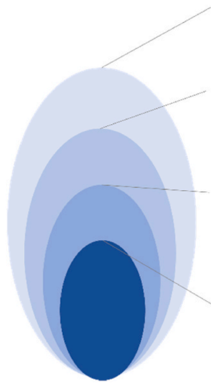
Based on the above discussion, we adopt a BE perspective (*sensu* Tsujimoto et al., 2018), defining a REE as the BMs making up the VN for energy supply, and focus on co-evolution between its members and the ecosystem's environment. Based on Section 2.1, we define the socio-technical environment interacting with the VN through five dimensions: policy and politics, markets, culture and industry structure. Public-sector actors are heterogeneous, and authority is often distributed between governing bodies, public agencies, courts, etc. The concrete activities also vary and include procurement, formulating public policy goals and strategies, or taking legislative or regulatory action. Such actions influence ecosystem structure and dynamics, e.g. by defining roles (Montakhabi et al., 2021) or determining the options available to customers (Blasi and Sedita, 2020). According to public value theory, two factors constrain the realization of a public VP: political approval and the administration's operational capabilities (Moore, 1995, 2000). Governing a REE therefore includes fostering the BE to attract or develop the resources required to fulfill the public VP, under the bounds set by the political environment. Regarding markets, the primary focus is on local energy demand, which may evolve due e.g. to increased energy efficiency. However, secondary markets may become relevant, e.g. rule energy markets. Culture refers to the acceptance and expectations for technologies, whereas the opportunity space includes all firms, technologies and resources that may contribute to the REE in the future. The industry, as part of the environment, refers primarily to the organizational aspects of the VN members that are outside the BM perspective (e.g. company structure, strategy or culture). Indeed, since the BM is only a partial description of an organization (Sarasini and Linder, 2018), BMI is distinct from other organizational processes, although closely related. For example, strategic choices may prompt a reconfiguration of the organization's BM (França et al., 2017), whereas BMI requires structural adaptations to secure the necessary resources.

4.1.3. Hierarchies

Transition studies place great emphasis on hierarchies: a central theme is the niche-regime interaction, which proved essential in theorizing the role of BM (Bidmon and Knab, 2018). However, the literature also shows the limits of this perspective: sustainable innovations can be launched by both niche and/or regime actors (Bolton and Hannon, 2016) and actors do not always unambiguously fall in either category (Ruggiero et al., 2021). Therefore, we define a complementary hierarchical perspective for the CEBEP. As discussed above, the REE consists of individual BM linked together in a VN. In the following, we discuss how such hierarchies are conceptualized in the method theories, focusing on the meaning of value at different levels.

Several authors (Allee, 2008; Den Ouden, 2012; Leviäkangas and Öörni, 2020) have -apparently independently - proposed hierarchical conceptualizations of value, depicted as nested circles or similarly (Fig. 2). While Allee (2008) describes value creation from individual actors in the network (each actor produces outputs, which are valued

[2] The value chain and value network concepts have been contrasted, either being more suitable for different contexts (Stabell and Fjeldstad, 1998). Here, we do not presuppose either, so that the REE's main constitutive element may be a value chain or a value network. For simplicity, we use the term "value network" here.



	Value dimensions	Value-creating activities
Public / societal value	Fulfillment of political mission	Regulatory action, subsidies, credits, …
Ecosystem value	Access to complementary resources / capabilities / demand	Orchestration, facilitation, building shared resources
Business value	Profit, economic sustainability	Business model, Innovation, R&D
Customer value	Satisfaction of needs (material, physiological, social…)	Value co-creation

Fig. 2. *Hierarchy of values, following* (den Ouden, 2012) *and* (Leviäkangas and Öörni, 2020)*, including examples for what is perceived as valuable, and how value can be created, at each level. Note that the terminology used may differ from these publications (see main text for details).*

differently by different recipients), den Ouden (2012) and Leviäkangas and Öörni (2020) use it to describe the hierarchy and interrelatedness of value in the ecosystem. The nested structure suggests first that value has different meanings at different levels (i.e. different things are valuable to different subjects), and second, that value creation at higher levels depends on success at lower levels.

Both den Ouden (2012) and Leviäkangas and Öörni (2020) place customer value at the center, while the remaining circles represent value for organizations, the VN and society (Fig. 2). Different customers perceive the value of products and services differently, due to different contexts and individual preferences (Bowman and Ambrosini, 2000). This value definition (termed "use value") determines how much a customer is willing to pay, but usually does not match the price paid in a transaction ("exchange value"). For a mutually profitable exchange, the exchange value must be lower than the use value for the customer (customer surplus), but higher than the costs borne by the supplier (profit). This applies not only to the relationship with the end customer, but throughout the value chain (Bowman and Ambrosini, 2000). For organizations, joining ecosystems often entails some opportunity costs (Jacobides et al., 2018). Ecosystems must therefore offer some additional benefits, such as stability, access to complementary resources or new markets, more effective value creation and/or fair value capture mechanisms (den Ouden, 2012; Laakkonen et al., 2019; Leviäkangas and Öörni, 2020; Peppard and Rylander, 2006). As discussed above, public value consists of fulfilling a mission determined through democratic processes.

It is also possible to attribute value-creating activities to these levels. We limit ourselves to the dimensions on Fig. 2, recognizing that other dimensions are relevant in other situations, e.g. the relationship between a firm and its employees (Lepak et al., 2007). Value creation for customers occurs when the customer's needs are satisfactorily addressed. This is usually linked to a firm's offering, but customers can also create value for themselves, e.g. through customization (Parolini, 1999). At the organizational level, value creation happens primarily through innovation (Lepak et al., 2007; Porter, 1985). At the ecosystem level, orchestration is *valued* by other participants, as it contributes to create the ecosystem benefits discussed above (Adner, 2017).

Based on this discussion, the CEBEP includes a hierarchy of value dimensions, ideally aligned to each other. We do not claim that alignment is necessarily the case, but rather define the degree of alignment between these value dimensions as a dimension for empirical research, and possibly a target variable for the transition governance. We note another important hierarchy for policy-driven transitions: energy policy often involves the interaction of different administrative levels. It is therefore useful to represent the REE (e.g. city-scale) as embedded in a larger ecosystem at a higher administrative level (e.g. country-scale).

4.1.4. Relationships

BM are a boundary-spanning concept, as the focal firm depends upon inputs from partners (Frankenberger et al., 2013). Therefore, the fit with adjacent BM must be continually monitored and adapted (Zott and Amit, 2013). This theme is reflected in the literature on BM in transitions: the value chain sets constraints for BMI, but is also impacted by the new BM (Wesseling et al., 2020). For example, Wainstein and Bumpus (2016) describe how firms offering innovative BM reconfigured their value chain, e.g. by pursuing vertical integration or assigning a more active role to customers. Coordinating change between multiple actors is challenging, particularly with more radical or systemic innovations (Brown et al., 2019; Sarasini and Linder, 2018). Lazarevic et al. (2019) describe how energy service companies actively developed a systemic innovation by building and managing actor-networks. Brown et al. (2019) describe how an actor launching a systemic innovation enabled BMI by coordinating between participants and brokering with policy-makers, users and investors. These examples show that intermediation is crucial for successful BMI.

A related concept in ecosystem literature is orchestration, i.e. managing interactions between participants (Autio, 2021). Garin (2022) identified five categories of orchestration activities: 1) creating incentives to persuade actors to contribute, 2) promoting knowledge mobility and partnership creation between participants, 3) aligning participants, i.e. managing conflicts and creating a common vision, 4) defining fair value capture mechanisms and 5) constantly exploring new ideas to adapt to changing conditions. For example, Hellström et al. (2015) show how focal firms persuaded complementors to adapt their BM by collectively identifying common value creation opportunities and defining value capture mechanisms. In another example, Adner (2017) shows how unaddressed alignment needs prevented the successful commercialization of a promising innovation. The orchestrator role can be contested (Adner, 2017) or distributed between several actors, potentially increasing the coordination challenge (Lingens et al., 2022). While ecosystem governance is still under-studied (Jacobides et al., 2018), recent research points to knowledge of the supply- and demand-sides (Lingens et al., 2022) and dynamic capabilities (Garin, 2022; Teece, 2007) as success factors for orchestration.

Building upon this discussion, we include orchestration as a descriptor of a REE. Concretely, orchestration consists of facilitating the VN's renewal by collectively identifying new value creation opportunities, managing conflicts, defining value capture mechanisms and attracting new actors required to update the ecosystem's VP. We do not specify here whether orchestration is done by one or several actors. Rather, we see this question as part of characterizing a specific REE, to be answered empirically.

4.1.5. Co-evolution

Co-evolution is a central concept in socio-technical transition. For example, Sarasini and Linder (2018) highlight the potential of BMI to bring together product technologies, process innovations and infrastructure, further inducing changes of actor strategies. Bolton and Hannon (2016) highlight the co-evolution between BM and their non-market environment, specifically infrastructure and institutions. For van Waes et al. (2018), successful scaling of BM depends on the co-evolutionary dynamics of increasing returns, industry structure and institutional fit. Nevertheless, authors have called for a more explicit description of the co-evolutionary processes influencing the constraints and prospects for BM under transitions (Bolton and Hannon, 2016; Lazarevic et al., 2019, 2019van Waes et al., 2018).

A co-evolutionary perspective distinguishes the ecosystem from other managerial frameworks (Aarikka-Stenroos and Ritala, 2017). Nevertheless, this aspect has been under-utilized (Hou and Shi, 2021), as research focused on structural aspects of ecosystems (e.g. Adner, 2017). A research stream has included a more explicit co-evolutionary perspective, where the VN interacts dynamically with an associated resource pool (RP) (Ma et al., 2018; Rong et al., 2021; Shi et al., 2022). Despite similar process descriptions, the RP is conceptualized in different ways. For example, Rong et al. (2021) emphasize social embeddedness of the ecosystem, associating the RP with the human, financial and social capital of the community in which the VN is embedded. Ma et al. (2018) define the RP as stakeholders with complementary resources, i.e. outside the current VN. By contrast, Shi et al. (2022) define resources as belonging to actors either within or outside of the current value chain, with a strong focus on technological know-how. Despite these differences, studies in this research stream share the view that transformation of the VN occurs through interaction with associated resources.

We propose that such mechanisms are also relevant for an REE, and therefore propose the RP as the second constitutive element of the CEBEP. We stress the importance of physical resources (e.g. infrastructure, localized energy potentials) in addition to financial, human and social capital and technological know-how. Importantly, we note that the value of resources changes over time: for example, energy conversion or storage appliances on the demand side may become sources of flexibility, to be valorized in secondary markets (Zapata Riveros et al., 2021). The RP is distinct from the opportunity space, as it contains the resources that are easily accessed by VN members. As for the VN, we conceptualize the local RP as embedded within a larger RP, e.g. at national scale. Again, this is distinct from the opportunity space, as we assume a much greater permeability within the national RP. By contrast, more effort is required to integrate resources from other countries or industries into the RP.

4.1.6. Dynamics

The literature describes how BM impact STSs: materially, e.g. through the implementation of clean energy conversion and distribution technologies (Bolton and Hannon, 2016; Wainstein and Bumpus, 2016); structurally, e.g. through value chain reconfiguration (Wainstein and Bumpus, 2016) and the modification of organizational structures (Bolton and Hannon, 2016); financially, e.g. by attracting outside capital (van Waes et al., 2018) or re-investing revenues to scale a BM (Bolton and Hannon, 2016); as well as cognitively, by modifying stakeholders' perceptions and expectations through successful experimentation (Bolton and Hannon, 2016; Sarasini and Linder, 2018) and exploitation (Kallio et al., 2020). These impacts in turn influence the opportunities and constraints for BMI, intentionally or not (Wesseling et al., 2020).

The co-evolutionary perspective on ecosystems (Ma et al., 2018; Shi et al., 2022) enables a holistic view on these dynamics. Two types of mechanisms are distinguished: industrial transformation and industrial feedback (Ma et al., 2018). Industrial transformation is a VN reconfiguration and may be prompted by changes in the RP or by exogenous influences such as policy change (Ma et al., 2018; Shi et al., 2022). Concretely, industrial transformation may take the form of new entrants joining the VN (Shi et al., 2022), BMI (Rong et al., 2018) or a change of the ecosystem's VP (Rong et al., 2021; Shi et al., 2022). Industrial feedback describes the reinforcement of the RP through the VN's activities, e.g. by generating ideas and technology designs, building production capacities and know-how, developing network ties or attracting capital (Ma et al., 2018; Rong et al., 2021).

We therefore define the endogenous dynamics of an REE as the interactions between the VN and the RP. This implies that the configuration of available resources influences how the VN adapts to exogenous changes (e.g. changes in policy, technology, customer requirements or organizational strategy), as well as the scope for proactive organization.

4.1.7. Conceptual framework

The CEBEP meta-model (Fig. 2) synthesizes the preceding discussion. The framework is centered on the interdependent customer and public VPs, and further defines two constitutive elements (VN and RP), two endogenous process types (industrial transformation and industrial feedback), proactive orchestration by one or several actors, as well as five environmental dimensions interacting with the REE. In the VN, the focus lies on the exchanges between the BM of individual actors (Shaw and Allen, 2018). The VN's actions impact the RP by developing infrastructure, integrating new technologies, generating know-how and knowledge of the energy system, etc. The RP determines which (inter-) organizational changes are indicated and feasible in response to new customer requirements, regulatory change or the integration of new technologies, thus impacting the speed, pattern and direction of the transition. Resources can also be modified through deliberate orchestration, e.g. by creating strategic shared resources or by attracting contributions by new actors.

4.2. Illustrative case study: the regional energy ecosystem around low-carbon district heating in a swiss city

4.2.1. Regional energy ecosystem

The socio-technical DH REE in the Biel agglomeration is analyzed through the CEBEP dimensions in Table 3. The development of DH in this case is strongly policy-driven, as municipal policies and laws codify the net-zero target and explicitly foresee the development of low-carbon DH. This results in orchestration by local authorities, e.g. by concretizing municipal policy and elaborating institutional resources, such as the inter-municipal spatial energy plan, which provide a common frame of reference for the spatio-temporal development of DH. Nevertheless, the energy utility of Biel is legally autonomous and seeks a (modest) profit from the projects being developed. To effectively provide this service, the utility depends on inputs from other VN members, both enabling grid development (planning and construction) and influencing customer decisions (Fig. 4). Therefore, proactive involvement of HVAC installers, consultants and large institutional customers is a key aspect of orchestration.

4.2.2. Business model innovation

The authorities of Biel and Nidau, the local energy utility and the local non-profit energy advice association jointly became customers of a start-up (geoImpact AG), providing an online platform facilitating planning and communication in the energy transition. The platform combines energy-related geospatial data from multiple sources at scales ranging from buildings to municipalities. Here, we describe this BMI and its impact on the local ecosystem. As the BMI's impact cannot yet be quantitatively assessed, the description is qualitative, based on the stated VP and initial reactions from the customers after some months.

Information and customer acquisition are key weaknesses for DH in Switzerland, as the utilities and authorities have little marketing experience (Meier et al., 2019). This has slowed the development of projects and poses a risk, as customer acquisition is crucial for economic viability. The platform addresses this pain point by automating part of

Table 3
Characterization of the Regional Energy Ecosystem in the illustrative case study.

REE element	Characteristics in case study
Customer value proposition	Affordable and reliable heat provision (low environmental impact as a secondary criterion for customers), decision support for heating system.
Public value proposition	Reduction of GHG emissions from energy use on municipal territory (since 2020: net-zero by 2050) in accordance with economic and social sustainability, including the integration of renewable heat potentials through new thermal grids.
Value Network	Heat customers, city utilities of Biel and Nidau, external ESCO, fuel and energy providers, energy advisors, construction and engineering companies (see also Fig. 4).
Resource Pool	*Physical resources:* renewable energy potentials identified in energy plans (lake, groundwater, biomass); underground space for pipes; thermal grid infrastructure. *Financial resources:* Own capital from value network; capital from financial markets; federal and municipal subsidies. *Institutions:* Municipal energy and climate strategy; inter-municipal strategic energy plan. *Information and knowledge:* Knowledge on local energy potentials, current and future energy demand and its spatial distribution. *Social capital:* Contribution of local engineering and construction firms. *Relational capital:* Regional and national inter-municipal networks (e.g. Energiestadt); Relations of municipal with cantonal/federal authorities.
Orchestration	By municipal authorities: concretization of energy policy (e.g. energy plan), proactive involvement of large customers, coordinating the use of physical resources. By cantonal authorities (as customers): alignment of the distribution of roles and responsibilities between the energy utility of Biel ESB and municipal executive of the neighboring city of Nidau regarding the realization of the lake water grid.
Value Network Transformation	Formation of new business unit for DH by the city utility; formation of durable partnerships for the realization and operation of thermal grids; proactive involvement and information of customers.
Industrial Feedback	DH-infrastructure development; customer acquisition; renewal of the knowledge base on energy potentials and feasibility through learning during implementation.
Interactions with the environment	*Policy & politics:* favorable authorizing environment for low-carbon energy; build-up of operational capacities by the REE. *Culture:* High social acceptance of DH. This is strengthened by the involvement of local construction and engineering companies, as well as by the policy choice to leave customers the choice to connect to the grids or not (no mandatory connections). *Markets:* Thermal grid development must be coordinated with evolution of heat demand. *Opportunity space:* Technological developments not yet used in the value network (e.g. demand-side management). *Organizational & industry structure*: New focus on low-carbon DH has prompted changes to the utility's organizational structure, and the creation of new joint ventures.

the customer acquisition process. Both municipalities have set up a webpage (termed "energy portal"), where building owners receive a recommendation for the heating system based on the geospatial data on the platform (e.g. building characteristics, local energy potentials, planned service areas of DH grids). Requests for a given address suggests interest of that building's owner for a heating system replacement. This information is transmitted to the city authorities and/or the utilities, who use it to contact customers when heating systems are a relevant topic for them.

For the local ecosystem, geoImpact was previously part of the "opportunity space" (Fig. 3) as one of many actors with a potentially relevant offering. It is now part of the VN, maintaining direct ties with the organizations realizing the ecosystem VP. It contributes to the RP: the platform's datasets and analytics capacities can be leveraged and combined with own data sources (e.g. DH development plans). Furthermore, the energy portals were elaborated jointly. This development influences the BM of providing DH: customer channels are directly improved, and the relative importance of customer segments is impacted. The city already involves large-scale customers (e.g. housing cooperatives) early in the planning process. It now has the possibility to monitor the market potential of small customers (e.g. single-building owners) more closely, and potentially to involve this customer segment earlier in the process. These new developments strengthen the ecosystem's operational capacity in developing DH, potentially facilitating the region's LCET.

5. Discussion

5.1. Implications for research and practice

This paper contributes to the literature on BM(I) in transitions in STSs by providing a conceptual framework with a dynamic view of the impacts and antecedents of BMI. Answering calls for a co-evolutionary view (Lazarevic et al., 2019, 2019van Waes et al., 2018), the framework considers co-evolution between VN members, as well as their dynamic interaction with the RP. Furthermore, the CEBEP framework considers the exogenous influence of politics and policy, culture, markets, industry structure and technological change. While this does not amount to a full co-evolutionary view of BM, institutions and industry (Bolton & Hannon, 2016, 2016van Waes et al., 2018), we argue that the framework's perspective is novel and useful for the discovery of feedback loops leading to increasing returns, as exemplified here by new valorization opportunities of extant data. The choice to "zoom in" on inter-organizational aspects makes the CEBEP a complementary view to other socio-technical perspectives with a stronger institutional or cultural focus. The inter-organizational hierarchic view adopted here is complementary to the widely used hierarchy of niches, regimes and landscape, as VN linkages transcend these levels, as noted by Derks et al. (2022).

BMI literature emphasizes the importance of understanding the focal firm's ecosystem, in particular the needs of other actors and the ecosystem-level drivers of change (Frankenberger et al., 2013). The CEBEP provides a template to map the context of a prospective BMI, enabling an empirically grounded analysis of the frame conditions for BMI, as well as a qualitative, *a priori* assessment of its impact. It is specifically geared towards sustainability transitions in STSs in that it focuses not only on commercial success of a BMI, but also on its contribution to a purposive, path-dependent development. To this effect, a dynamic perspective with a system memory – in the form of the VN and the RP – enables a reflection of the long-term impacts of a BMI under given policy settings or technological development pathways. Previous BMI efforts under socio-technical transitions have highlighted the need for systemic innovation with contributions from several independent actors, possibly accompanied by policy or regulatory change (Brown et al., 2019; Lazarevic et al., 2019; Zapata Riveros et al., 2021). The CEBEP is intended to assist the design of such systemic solutions. While the illustrative cases focused on the urban scale, the framework is also applicable at larger scales, to assist the VN transformation and resource reconfiguration of proposed national decarbonization strategies (e.g. Gyamfi et al., 2022). Also, while this study focuses on energy, the CEBEP is also applicable to other socio-technical domains. By mapping extant structure and resources, the framework accounts for inter-regional heterogeneity and specific opportunities and constraints. For example, regions with a mono-industrial past face limits for diversified development (Vesalon and Creţan, 2013), due e.g. to the difficulty of the extant VN to attract external capital (Creț;an et al., 2005).

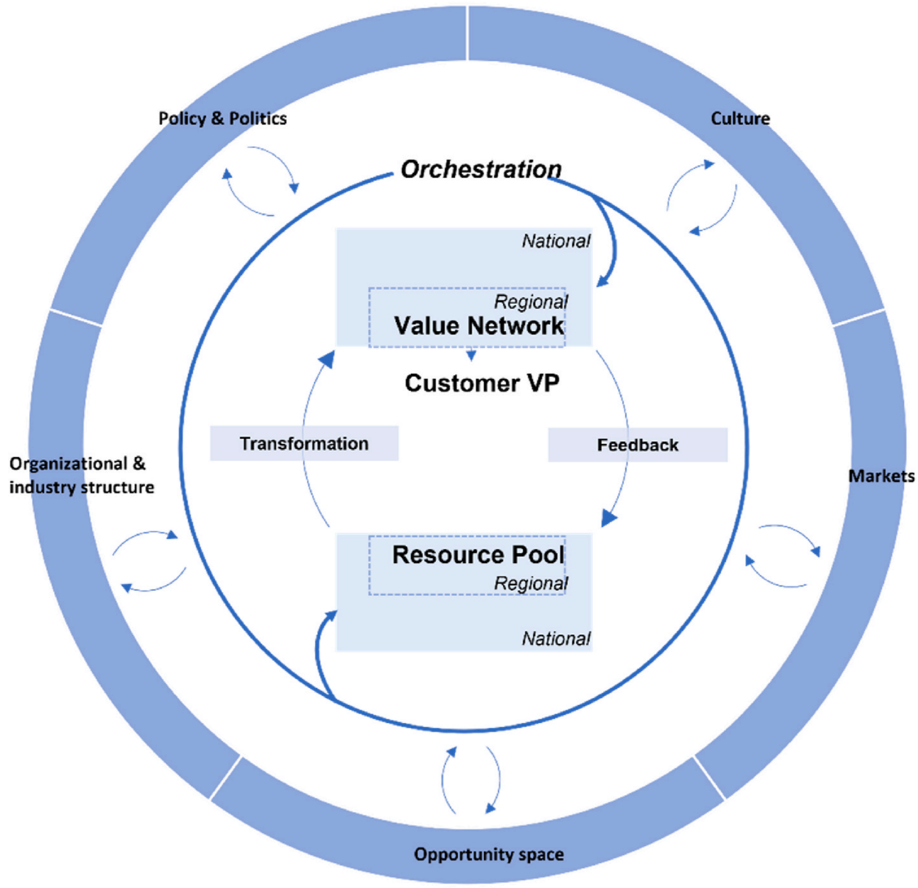


Fig. 3. Meta-model of the REE (CEBEP framework) and its environment.

As noted before, we make the epistemic choice of using ecosystems as an analytical construct, i.e. we do not presuppose that the REE's members view the ecosystem as such and manage it accordingly. Rather, we posit that the CEBEP is useful where there is an interdependence of public policy and business strategies, and a collective, system-level output is brought about by a heterogeneous set of actors. In our example, mapping the VN clarifies how the two VPs shape the local pattern of economic exchange, whereas the dynamics help understand how this pattern changes under new policy conditions. The remaining defining feature of ecosystems, non-hierarchical governance (Autio, 2021), likely varies from case to case, as different settings call for a different emphasis on the relative roles of regulation, policy, administrative action and business strategies. Nevertheless, we argue that transition governance can profit from the fast-growing literature on ecosystem orchestration (Autio, 2021; Garin, 2022; Lingens et al., 2022) and that the CEBEP assists the design of transition governance approaches. Importantly, we do not suggest that public policy should be managed like a private business. Rather, we recognize that public policy is increasingly seen as a process where value is co-created by public and private actors (Cordella and Paletti, 2019; Petrescu, 2019). This includes experimental governance approaches such as living labs, where universities, industry, authorities and citizens jointly elaborate and test technical and social innovations. As noted by Voytenko et al. (2016), living labs are embedded in extant regional structures, so that the CEBEP may help design appropriate approaches in specific contexts.

5.2. Limitations and outlook

The CEBEP framework was developed through conceptual analysis, with limited direct empirical basis besides the illustrative case study. Further research should therefore validate and refine the concept empirically through abductive research (Kovács and Spens, 2005). Empirical research will enable the postulation of concrete mechanisms in the areas under study, i.e. generating models from the meta-model presented here. Also, some of the core concepts of the CEBEP are necessarily phenomenological, such as "value" or "resources". While this paper outlines some potentially useful conceptualizations, the concrete dimensions to be analyzed vary between different contexts, so that specifying the dimensions of value and resources will be part of further empirical research. For example, studies in other energy sectors have highlighted the importance of guidelines and design criteria, as well as specific expertise, as key resources (Hafner et al., 2022; Lucchi, 2022). In addition, we expect quantitative methods, such as model-based simulations of ecosystem co-evolution (Aarikka-Stenroos and Ritala, 2017), to be a valuable complement to qualitative empirical research and a practical support for BMI and orchestration (Zapata Riveros et al., 2021).

The illustrative case presents a favorable authorizing environment (strong political and institutional support for decarbonization) and strong operational capacities of authorities (completed by the contributions of private actors). It is therefore necessary to include cases with a more challenging environment, with e.g. less public support or resources for decarbonization or greater techno-economic challenges. Also, the case focused on DH, a sector with strong state involvement. Further case studies should include domains with less public control or a more proactive role of private-sector actors in transitioning towards sustainability (França et al., 2017). Furthermore, direct inter-organizational competition has been under-emphasized in the discussion and is peripheral in the illustrative case study. In other contexts, this is more salient (e.g. a liberalized electricity market). The conceptualization of a VN consisting only of activities performed collaboratively would then be insufficient. We expect an ecosystem

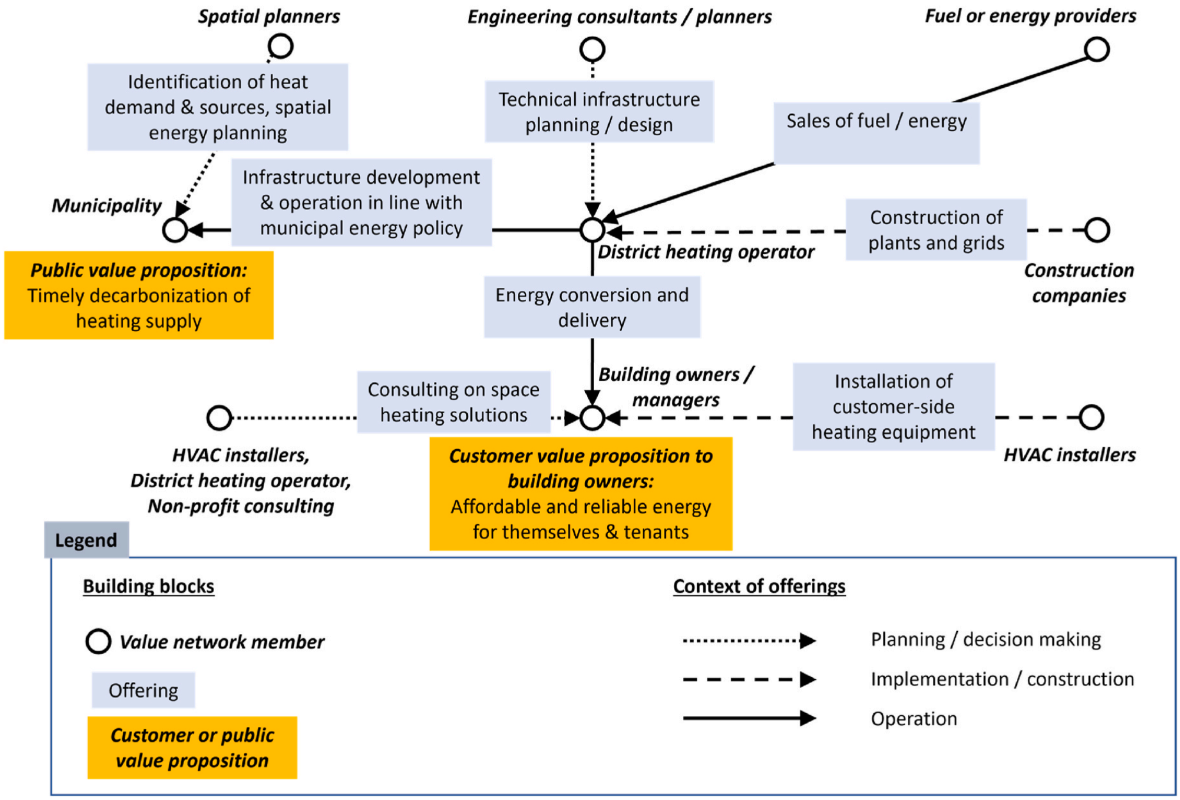


Fig. 4. Value network of the DH ecosystem in the Biel agglomeration. Nodes represent individual actors or actor types, and arrows with the blue boxes represent the offering of one actor to another. Yellow boxes specify the value propositions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

perspective to be valuable also then, as simultaneous collaboration and competition is a defining feature of ecosystems (Moore, 1993). It is then also necessary to disaggregate the RP: in our illustrative case, resources were assumed to be uncontested. In a more competitive setting, resource control or access is an important aspect of ecosystem dynamics (Yi et al., 2022). At the same time, shared resources, either emerging, such as knowledge spillovers (Shi et al., 2022), or intentionally created to facilitate system building (Musiolik et al., 2020) including digital platforms as in the illustrative case, are important elements of ecosystem governance.

6. Conclusion

This study contributes to the literature investigating the role of BM in STSs under transition. It addresses the recognition that BMI by individual organizations is often unable to enact systemic change and seeks to answer calls for a dynamic, co-evolutionary perspective on BM in transitions. Due to the many similarities of the ecosystem lens with transition studies - complexity, meso-level, influence of evolutionary economics, systemic approach – it is well-suited to link inter-organizational processes with the wider dynamics of STSs. However, due to the heterogeneity of ecosystem research, a careful assessment of its conceptual elements and their suitability to the low-carbon energy transition context was necessary. Based on an integrative literature review, we provide a coherent framework to describe the role of BM in their socio-technical context and to reflect on the contribution of prospective BMI to regional low-carbon transitions.

We expect this framework to guide both descriptive analysis and applied research aimed at elaborating BMI, governance arrangements, policy interventions or regulatory innovations. In particular, mapping a REE will help answer questions such as:

- Given a region's energy potentials, extant infrastructure, workforce and inter-organizational structures, which BMI are promising to realize region-specific decarbonization strategies?
- Which new actors, technologies or cognitive resources support the ecosystem's development in line with its customer and public VPs, and which steps are required to integrate or build them?
- How should members of the regional VN adapt their offerings and modes of collaboration under changing policy, markets, culture and technology?

CRediT authorship contribution statement

Matthias Speich: Conceptualization, Writing – original draft, Visualization, Project administration. **Silvia Ulli-Beer:** Conceptualization, Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

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