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Exploring the Adoption of Service-Dominant Logic as an Integrative Framework for Assessing Energy Transitions

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Abstract: Energy transitions (ETs) can solve some societal problems but must transform societies. Accordingly, socio-technical transitions and other systemic frameworks have been used to assess ETs. However, based on these frameworks, assessments miss a value co-creation orientation, the focus on actors' researched benefits and enabled service exchange, and the consideration of needed de/re-institutionalization practices. Analyzing those elements could prevent socioeconomic shocks and loss of opportunities and unfold possible ET challenges against ET viability and sustainability. Intending to develop a theory synthesis work for enriching previous frameworks, we propose service-dominant logic (S-D logic) as an integrative framework to assess ETs. We offer a literature review on ET systems' frameworks to compare them with the proposal. We also identify the implications of adopting S-D logic for rethinking energy systems' dynamics and ETs. Thus, we contribute to the literature by providing an integrative framework for assessing ETs and we illustrate its potentialities by deriving some challenges of the current Italian ET. This study paves the way for deeper analyses on the contribution of S-D logic to ETs and the operationalization of other systems' frameworks in our integrative one. Merging with quantitative models could also follow.

Keywords: value co-creation; service ecosystem; institutional work; feedback loops; energy transition

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1. Introduction

The expression "energy transition" (ET) has recently become ubiquitous because it can address some contemporary societal issues (such as the climate crisis and increase in energy prices) thanks to the adoption of new renewable energy (RE) sources and related technologies toward much more sustainable energy production and consumption. However, an ET can be more than the substitution of energy sources, being able to transform society and the economy in a radically new and sustainable way. Indeed, an effective ET can be defined as "a timely transition towards a more inclusive, sustainable, affordable, and secure global energy system that provides solutions to global energy-related challenges while creating value for business and society, without compromising the balance of [such] ... energy triangle" [1]. Accordingly, governments, companies, citizens, and other actors are called to advance concrete actions to design and manage such important ETs. However, with opportunities, many threats can come, such as self-interests, short-term orientation, existent investments' preservation, ignorance of the systemic impact of REs strategies (for example, the environmental impact of non-recyclable wind turbine blades), relocation of workers, uncertainties for countries with economies heavily dependent on fossils, or misalignment of strategies with actually feasible solutions. Systemic and value co-creation views should be adopted to prevent socioeconomic shocks, loss of opportunities, and to unfold possible

ET challenges against ET viability. Indeed, a systems view (based on systems theories and systems thinking) can focus not just on single elements of the transition but on their system-wide interdependencies [2], behaviors, and the understanding of complex and emergent outcomes [3], determining uncertainties, thus allowing to grasp "the barriers to a rapid [energy] transition and the steps that can be taken to accelerate it" [4]. On the other hand, a value co-creation view (also informed by institutional theory) can help highlight the importance of actors' resources, interactions, searched benefits, and institutional arrangements (symbols, beliefs, rules, norms, etc.), which shape and are shaped by actors' behaviors. While the systems view is incorporated in multiple frameworks for ETs, the value co-creation one has had little attention. However, both the systems and value co-creation views are combined in the service-dominant logic (S-D logic [5–8]), a well-known mindset from marketing, only weakly applied to energy systems at the state-of-the-art level [9–12], and can leverage its recent advancements on transitions [13]. Thus, in this study, we propose S-D logic as an integrative framework for assessing ETs, showing that it is accommodative of many current ET frameworks, and it can offer new insights into the design and analysis of ETs (a comparison with socio-technical transition frameworks is shown in Table 1).

Table 1. Comparison of the proposal with the most used ET framework (details are provided in the manuscript).

Characteristics	Socio-Technical Transition Frameworks	S-D Logic as an Integrative Framework (Paper Proposal)
Systems theories	Some elements	Foundational to de-stabilize and re-stabilize energy service (eco)systems for ETs to occur.
Feedback loops	Usually not considered	
Institutional theory	Foundational, but not leveraged in applications	Foundational, fundamental for applications.
Considered structures (institutional arrangement)	Mainly formal, not explicitly identified for ET	Formal and informal. Identified for ET based on the literature review
Value co-creation approach	N.A.	Foundational to catch actors' contributions to the success of ETs
Analytical levels	Landscape, Regime, and Niche Innovation	Macro-, Meso-, and Micro-levels. Understanding these levels as overlapping makes it possible to better understand dynamics at all levels.
Transition process	Alignment of processes within and between the three levels of Regime, Landscape, and Niche Innovation	Loss of stability of an energy service (eco)system (tensions among institutional arrangements), de-institutionalization, re-institutionalization, and the emergence of new stability of the service (eco)system

Thus, the innovative contributions of the paper lay in:

- A literature review on ET frameworks, with an original categorization of frameworks, and a focus on systemic ET frameworks. Those elements are prodromal to make comparisons and show how S-D logic can be an integrative framework for ETs.
- The elaboration of the main tenets of S-D logic for rethinking energy systems' dynamics and ETs, highlighting the main, further contributions of S-D logic's roots to the discussion on ET, and proposing S-D logic as an integrative framework. Furthermore, a first attempt to operationalize S-D logic to such rethinking is provided.
- The illustration of the potentialities for assessing an ET through S-D logic by analyzing some aspects and deriving a list of challenges of the current Italian ET.

To do so, in this conceptual paper, a semi-systematic literature review [14] is presented to analyze and compare other frameworks dealing with energy ETs, in particular, the ones informed by a systems view (Section 2). Then, an overview of S-D logic is provided, reviewing and extending its adoption for the understanding of energy systems and ETs, thus developing a theory synthesis paper as described by Jaakkola [15] (Section 3). In Section 4, S-D logic is applied to a specific case study to show its potentialities in the identification of challenges for the current Italian ET, and conclusions follow (Section 5).

2. Materials and Methods

2.1. Literature Review on Frameworks for ET

We developed a semi-systematic literature review [14] to identify and analyze the main frameworks dealing with ETs to later integrate some insight from them into our proposal (theory synthesis [15]). The search has been based on keywords such as "Energy Transition" coupled with "Frameworks", "Models", "Systems", "Literature Review", "Socio-Technical Systems", "Quantitative Models", and "Reports", and it has been carried out on the main databases. A first selection has been based on the content of the abstracts. Then, both authors (having diversified and partially overlapping backgrounds and specialties ranging from management, power systems, and engineering) independently read and synthesized the content of the papers to categorize frameworks based on the adopted methods (as explained in Section 2.1.1) and deepen qualitative ET systems' frameworks (Section 2.1.2). Particular attention has been paid to papers published in the last 10 years and receiving more than 10 citations to make comparisons of our proposal with systems frameworks for ETs that have been recently diffused and appreciated. The content analysis and labeling developed by the co-authors have been compared and an agreement has been reached on critical differences through discussion. Standard and inclusive labeling ("the categories" provided in Section 2.1.1) has also been determined. A second-round search has been carried out based on the first insights of the study, coupling ET to keywords such as "typology of transitions", "quali-quantitative frameworks", "systems dynamics", and "governance". In the following, the results are presented. In particular, given the urgency of ET around the globe, there have been numerous proposals of frameworks for ETs, and a few systematic literature reviews. The latter presented some limitations, such as the time range of the analysis (until the end of 2015 in Batinge et al. [16]), the organization of intertwined and overlapping contents in distinct smaller classes (for example, transition management, socio-technical transition, and strategic niche management literature in [16]), the analysis of subcategories of ET frameworks, or the lack of adoption of systems' criteria. Hirt et al. [17] reviewed studies linking quantitative models with socio-technical transitions theories and theoretical/analytical frameworks for energy and climate solutions.

2.1.1. Categorizing ET Frameworks

Based on the conducted review, the ET frameworks can be categorized in Table 2: (i) Qualitative transition systems' frameworks, oriented to identify and explain the main dynamics related to political, social, and technological issues to determine and sustain a transition (socio-technical transition studies belong to this category). (ii) Quantitative models, aimed at defining mathematical formulations for transition problems, contextualized in specific regions or nations, which can leverage on studies related to (iii) transition targets, indicators of readiness, and cost of changes. (iv) Studies linking the first two categories, claim that quantitative models need the systemic perspective on the co-evolution of society, technology, and environment [17]. In the following, the main elements characterizing each category are presented.

Table 2. Details on studies related to the categories of frameworks for ETs.

Frameworks	Main Studies (Details)
(i) Qualitative transition systems frameworks	**Identification and explanation of the central dynamics related to political, social, and technological issues to determine and sustain a transition (socio-technical transition studies belong to this category).**
(ii) Quantitative models	**Definition of mathematical formulations for transition problems, contextualized in specific regions or nations. They can leverage category (iii).** Among quantitative models, quite diffused are the integrated assessment models of climate change (IAMs, used in reports by the Intergovernmental Panel on Climate Change), aimed at supporting climate policy considering the evolution of the economy, technology and environment, and energy system models (ESMs), applicable to special scales, focusing on technical, economic, environmental, and policy interactions. Specific reviews of those models have been developed (see, for example, Pfenninger et al. in [18]). A literature review on energy systems models—mathematical representations of energy systems used to assess ETs—has been developed by Chang et al. [19]. A literature review of the evaluation frameworks for supporting decision problems related to ET (for example, lifecycle assessment, cost-benefit analysis, and sensitivity analysis) has been presented by Bottero et al. [20]. Those computational methods present some limitations, such as simplifying assumptions and real-world complexities. In particular, they cannot capture the complexity of actors' behavior and activities, social acceptance, political feasibility, and institutional change [21], and most of the time, consider those elements as exogenous [18].
(iii) Indicators and targets of transition	**Transition targets, indicators of readiness, and cost of changes. Some studies deal with ET frameworks, although they provide hierarchies of indicators to measure transitions.** For our purposes, the World Economic Forum's [1,22] Energy Transition Index (ETI)—calculated for 114 countries—is interesting, which is composed of the system performance score (related to the three elements of the abovementioned energy triangle) and the transition readiness score (which used 23 indicators about capital and investment, regulation and political commitment, institutions and governance, infrastructure and innovative business environment, human capital and consumer participation, and energy system structure). Another set of indicators considered for a multicriteria analysis to assess ET readiness was developed by Neofytou et al. [23]. Among indicators, they cite RISE (Regulatory Indicators for Sustainable Energy) by the World Bank, which "reports scores of countries on how attractive their policy and regulatory environments are for investment in improving universal access to energy (electricity and clean cooking), RE, and energy efficiency, and ultimately achieving SDG7" [24]. Finally, it is worth noticing that the World Economic Forum [25] has also developed in collaboration with Accenture, the system value framework to evaluate policy, investments, and solutions, toward resilient transitions. It is relevant since it shifts the political and commercial focus beyond the costs to value creation. In particular, the 12 dimensions considered in the analysis are CO2 emissions, water footprint, air quality and health (which could be related to the sustainability sphere of benefits for the environment), jobs and economic impact, reliability and service quality, access to electricity, resilience, and security (more related to the sustainability sphere of benefits for the society), energy productivity and systemic efficiency, flexibility, systems' upgrade, foreign direct investments, cost, and investments' competitiveness (which could be related to the sustainability sphere of the economy, and technology).
(iv) Quali-quantitative systems' models	**Studies linking the categories (i) and (ii) claim that quantitative models need a systemic perspective on the co-evolution of society, technology, and the environment** [17,26]. The degree of integration varies depending on the application, such as merging qualitative approaches with agent-based modeling, systems dynamics, etc. A recent study concluded that research should be redirected to develop frameworks that provide more practical outcomes [17]. Li et al. [18] named as STET (socio-technical energy transition) those models that develop quantitative frameworks considering qualitative aspects. In particular, the requirements to belong to this category are techno-economic detail, to explore the price and performance of alternative technologies, explicit actors' heterogeneity, considering actors' agency to shape transitions, differentiated selection criteria, and behaviors, and transition pathway dynamics, to enable the assessment of normative goals, taking into account long time horizons to explore socio-technical change and path dependencies, and including the modeling of alternative technologies/behavior to phase out incumbent status quo. An alternative to integration is the iteration of diverse approaches (McDowall [27] has identified three ways) coming from qualitative and quantitative fields, with a dialectical and processual perspective. An example is a study by Geels et al. [21], who mixed the multi-level perspective (from socio-technical system studies) with quantitative models, and it is discussed in the following section with a focus on the qualitative part of the model. In such research, qualitatively based analyses on contemporary dynamics were recursively compared to quantitatively generated future pathways. The resulting transition bottlenecks were subsequently analyzed by qualitative approaches. Other studies have attempted to link qualitative and quantitative models applied at different levels of abstraction of the analysis (bottom-up and top-down models). For example, the meta-model of Crespo del Granado et al. [2] deals with distributed generation and demand, operations of electricity grids, infrastructure investments and generation dispatch, and macroeconomic interactions. Furthermore, there are studies on energy transition frameworks for unmet electricity markets [16], where energy supply is inadequate or lacking. In this category, an interesting role is played by system dynamics models, with the work of Freeman [28] on the socio-political feasibility of ET.

2.1.2. Qualitative ET Systems' Frameworks

Systems' frameworks (category i) overcome most of the limitations of other approaches and have been recognized as the starting point to develop promising [21] and more detailed and contextualized quali-quantitative frameworks (category iv) through integration with quantitative models (category ii) supported by measures and indicators of transition (category iii). Thus, this study focuses on qualitative systems' frameworks (category i) to contribute to them. In this way, we can pave the way to future successful integration of the proposed framework with quantitative models in particular contexts. In Table 3, we revise the main frameworks belonging to this category (i), highlighting their specific traits and differences.

Table 3. Comparison of systemic ET frameworks.

Characteristics	Socio-Technical Transition Studies	Regime Shift	Three Horizons	S-D Logic as an Integrative Framework (Discussed in Section 3)
Systems theories	Studies on complex adaptive systems	Regime (system) shift	Three-horizon model, based on systems thinking	Complex adaptive systems, cybernetics, and other systems theories
Feedback loops	Usually not considered. For example, actors highlight renewable integration challenges, and the delay of renewables to retail policy demonstrates negative pressure weakening guidance of search [29].	-Techno-economic: small- and medium-scale REs establish a decentralized ownership structure, which discourages investments in large-scale conventional energies. -Economic-political: REs beneficiaries support REs policies, fostering support	NO	The design of amplifying feedback loops can dislodge a service (eco)system from its initial stable state. Balancing feedback loops are needed for the (eco)system to gain new stability.
ET process	Alignment of processes within and between the three levels of Regime, Landscape, and Niche Innovation (see typologies of transition pathways).	Loss of resilience of previous regime (fossil-nuclear), creation of new regime (based on RE), shift, resilience of the new regime	Moving from the fossil-fuel horizon to the transitionary period, to achieve the zero-carbon smart energy systems horizon	Loss of stability (tensions among institutional arrangements), de-institutionalization, re-institutionalization, and the emergence of a new stability
Institutional theory	Mainly formal institutions, and a focus on public discourses (in the case of transition management).	NO	NO	Understanding of the context (service (eco)system) to design feedback loops to achieve a transition.
Value co-creation approach	N.A.	NO	NO	Understanding of each actor's potential service to provide and expected benefit from value co-creation (depending on contextual resources and institutional arrangements in place) to orient institutional work for ET.

In socio-technical transition studies, socio-technical systems are an "interlinked mix of technologies, infrastructures, organizations, markets, regulations, and user practices that together deliver societal functions … [in which] the alignment and co-evolution of their elements [oppose resistance] to change" [30]. Transitions in those systems have been investigated in multiple ways, but the most influential, such as transition management (TM), technological innovation systems (TIS), multi-level perspective (MLP), and strategic niche management (SNM), have all originated in the Netherlands [18] and leverage insights from sociology, history of technology, complex systems theory, and innovation studies. In Appendix A Table A1, these approaches are shortly presented because, due to the ability of S-D logic to be accommodative of other theories, it is still recommended to use them within the wider integrative framework proposed in this paper. However, from the analysis results the exogeneity of the landscape level of the multi-level perspective [31], is overcome by the inclusiveness of the S-D logic macro-level. Interestingly, since many studies have been focused on green niche innovations, it must also be highlighted that attention should be shifted to the resistance by incumbent regime actors to the transition, distinguishing among instrumental, discursive, material, and institutional forms of power and resistance [32]. In Appendix A Table A2, we offer further details on the multi-level perspective, mainly presenting some applications and the typologies of transitions [31,32]. Recognizing that the latter has been widely adopted to analyze ETs, we highlight a limitation concerning the proposed categorizations since technology and institutions can be seen as mutually related rather than two separate or sequentially dependent issues [33], as well as captured by S-D logic (explained later). This limitation, coupled with the specific focus on technology instead of the wide system, and the focus on formal institutions instead of all kinds of institutions, can affect the effectiveness of the typology in catching the dynamics of ETs.

For the regime shift approach, Strunz [34] conceptualized the ET (focusing on electricity) from a systemic perspective and a resilient-based approach. Resilience refers to the possibility for the system to "absorb disturbance and reorganize while changing, to still retain essentially the same function, structure, identity, and feedbacks" [35]. Thus, a high level of resilience in a system means that regime shifts should be avoided; in contrast, a low level of resilience is favorable when a regime shift is desired. Therefore, the author conceived the ET as a shift from a fossil-nuclear energy regime to a RE-based regime, achievable when the first regime loses resilience and the second one emerges and becomes highly resilient. Thus, the author analyzed the two systems' function, structure, and feedback. The paper helps describe the elements that should change (feedback, structure, and function), highlighting that some institutions should be weakened (loss of resilience) to favor the institutionalization of others. However, social structures are not considered, and the institutional theory is not even cited. Furthermore, there is no focus on value co-creation, which is instead foundational to S-D logic.

For the three-horizons approach, Radhakrishnan [4] used the three-horizon model [36], a tool based on systems thinking. It leverages the idea of short, medium, and long periods, considering them as three horizons: the fossil fuel, the transitionary period, and the zero-carbon smart energy system. The second one, in particular, considers the innovations and activities needed to evolve from the first to the third. The study tried to understand how horizons and their stakeholders impact each other and the overall transition. Thus, the framework considers stakeholder interests and possible evolution. It also focuses on the evolution of technologies, posing multiple questions for future studies. Institutional theory and value co-creation are not considered.

2.2. S-D Logic for Energy Systems

Service-dominant logic (S-D logic) is an acknowledged meta-theoretical framework born in the marketing discipline and rooted, among others, in institutional, practice, systems, complexity, and evolutionary theories [8]. It has become globally renowned [37] and broadly applied in diverse disciplines since it offers an accommodating mindset capable of reconciling and synthesizing insights from various research streams [38]. Moreover, its focus on value—intended as the viability of systems—contributes significantly to discourses about environmental and social sustainability. In particular, its interpretation lenses can allow understanding of the dynamics and transitions of complex adaptive systems as the energy ones. Some studies in the energy management field have already recognized that. In particular, S-D logic has been considered foundational to business model innovation in smart grids [10] and for the interpretation of the new actors and roles of knowledge, brokers deriving from the increased use of RE in smart cities [12]. In this view, utility companies have been recognized as enablers of value co-creation by facilitating the development of energy services companies (ESCO) in the electricity market [11]. Furthermore, energy services provided by energy services companies have been identified as aligned to S-D logic and stimulating business development in ETs [12]. Other studies on ET leveraged concepts that are also included in S-D logic, mainly value co-creation. In particular, Mihailova et al. [39] dealt with energy citizens' new role in creating sustainable value for the environment and the community in energy communities. Another example focused on identifying determinants of the co-creation process in the energy communities [40].

To provide a better understanding of energy systems' dynamics toward ETs, which is still missing at the state-of-the-art level, in the following we explain the main S-D logic's conceptualizations based on its five axioms. In the following section, we relate them to the insights on energy systems based on our reflections and the little available literature.

2.2.1. S-D Logic Axioms and Energy Systems

Service, actors, and resources (Axioms 1 and 3). Axiom 1 ("Service is the fundamental basis of exchange") means that every social activity can be explained as being due to an exchange of service among actors (individuals, organizations, etc.). Service is the integration of resources (as competencies or physical resources) for the benefit of a part. Thus, S-D logic transcends the traditional goods versus services divide and the idea that the "value" is embedded in goods and the service that each part can exchange, as well as the benefit that each part would obtain, become objects of analysis. Energy systems are easily interpreted with this logic. Indeed, not only is the main exchanged "good"—energy—immaterial, but no actor (company, householder, etc.) normally thinks such good is valuable by itself. Instead, the benefit is perceived in using energy for specific purposes (lighting, cooking, moving, etc.) in particular contexts through the integration of different resources. According to axiom 3, "all social and economic actors are resource integrators". Thus, great importance is given to the primary resources of knowledge and skills of individuals, which are applied by actors and integrated with others to provide a service. S-D logic recognizes the importance of accessing, adapting other resources, and integrating resources by employing networks of relationships among actors. Thus, networks are addressed as mediators for such integrations and value co-creation [41], which implies that value depends on the context of the co-creation [42].

Value and value co-creation (Axioms 2 and 4). The multiplicity of actors that can be related to energy production, management, and usage makes it clear that value (intended as a benefit, an increase in wellbeing [5]) is "co-created by multiple actors, always including the beneficiary" (Axiom 2). S-D logic overcomes the distinction between the producer (the creator) and the consumer (the recipient) of value as different parties. Indeed, although citizens could be seen as consumers of energy, they are also providers of data, or available to participate in demand–response initiatives [43] and could also be energy producers owning some photovoltaic panels. In contrast, according to a good-dominant logic, the exchange of energy-for-money not only considers predefined roles for actors but does not consider actors' involvement in value creation processes, such as those involving energy aggregators, energy service companies, smart grid managers, etc., overcoming the transactional view in favor of a collaborative one [7]. Smart grids adopted in ETs are practical examples of such overcoming: the linear and traditional logic of the producer-distributor–consumer structure is substituted given the distributed generation and the need for coordination of multiple actors in value constellations [9], and the "flow" of value in smart grids is multi-party, co-created [10]. Based on axiom 4, "value is always uniquely and phenomenologically determined by the beneficiary", it cannot be neglected that every actor can have a unique perception of the value—overcoming the conceptualization of value-in-use—which must be understood to design effective exchanges, actors' networks, and their value proposition. Indeed, value co-creation is not always positive for each actor involved and a lack of satisfaction with actors' interests and desires can compromise future exchanges and, in the long run, the overall system viability.

Institutional arrangements and service (eco)systems and the multi-level perspective (Axiom 5). Lastly, axiom 5 states that "value co-creation is coordinated through actor-generated institutions and institutional arrangements". S-D logic has embraced institutional theory, according to which institutions are not only the "rules of the game" [44], such as symbols, languages, and laws that are stable elements of social life that structure and organize it—Scott [45] identified regulative, normative, and cultural-cognitive institutions—but also the outcome of social interactions [46]. In other words, institutional arrangements (assemblages of institutions) frame the context, guiding actors with norms, rules, and beliefs, which enable but also constrain value co-creation, shaping them. Therefore, S-D logic considers change endogenously generated in (eco)systems. In this sense, as anticipated by commenting on the fourth axiom, smart grids enable and improve value co-creation in context thanks to the emergence of new institutional arrangements in the three interrelated dimensions of technology, practices, and feedback channels [10]. Examples are demand management systems and systems design improvements based on data collected by smart meters, which can be used to suggest new pricing policies [10]. Thus, feedback channels reproduce and enable continuous changes to institutional arrangements [10]. Finally, the success of resource integration depends on institutions and the congruence in the institutions guiding the interacting actors. That is, institutions provide meaning to resources ("resourceness") and enable actor engagement [47]. For example, based on the values of amusement and environmental harmony (institutional arrangements), old carbon plants (resources) were converted into places for concerts and cycling in Germany, dealing with its ET.

Service ecosystems. All of this happens in service (eco)systems, which are the unit of analysis of value co-creation [8] and are defined as "a relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional logics and mutual value creation through service exchange" [48]. Here, the word "connection" reminds us of networks and context. Indeed, Chandler and Vargo [42] adopted a multi-level context (micro, meso, and macro) to consider a framed service-for-service exchange from the dyad of the micro-level (helpful to understand actor-to-actor interactions), to the triads of the meso-level, to the complex network of the macro-level (comprehensive of all actors sharing institutional arrangements). The multi-dimensional evolution of a service (eco)system occurs across the levels of context, over time, and through replicated exchanges [42,46], employing institutionalization, which is the establishment—made by actors—of social norms, rules, values, symbols, etc., that includes not just the development, but also the diffusion of both technologies and markets [49].

2.2.2. Phase Transitions of Service Ecosystems

S-D logic conceptualizations have been recently enhanced by two strictly related concepts that further inform the understanding of the service (eco)systems' dynamics and uncertainty: emergence [3,50] and phase transitions [13]. In particular, concerning phase transitions, the following definition has been provided: "A phase transition of a service ecosystem is a large-scale step change which occurs when external environmental disturbances and internal interactions dislodge the ecosystem from a state of stability, into de-institutionalization and then re-institutionalization, when it then achieves a new stable state. The new state is characterized by the emergence of new institutional arrangements and value that provide order and organization to the interactions of the service ecosystem" ([13], p. 29). A simplified illustration of the phase transition process is shown in Figure 1.

In the phase transition definition provided above, it can be noticed the central role of value co-creation and institutional arrangements in the structure of the initial stable state of the service (eco)system, and are subverted in the final new stable state. Indeed, although institutions usually evolve with incremental changes, the changes are discontinuous during transitions. In particular, in the dynamics of service (eco)systems, interactions among actors or external forces (the latter ones coming from other nested and overlapping service (eco)systems or, as Kleinaltenkamp et al. [51] state, from megatrends stimulating behaviors not consistent with the prevalent institutional arrangements) can determine the emergence and institutionalization of new (eco)systems' properties (such as resources, institutional arrangements, value) that contrast current ones. Such tensions generate uncertainties in terms of weakening value co-creation processes for involved actors, mining the recurrent patterns of resource integration and service-for-service exchange that are enabled and constrained by institutional arrangements. This implies a loss of viability of the ecosystem. For example, if public opinion starts to ask insistently for sustainability in energy production—an emergent shared value—while rules from the government sustain carbon power, making carbon the only feasible way for obtaining energy, tensions among shared institutional arrangements emerge, and the energy (eco)system loses its viability because investors, citizens, and other actors feel discomfort and confusion in performing actions (for example, investments in carbon-based plants) due to the uncertainty that seems to characterize the future. When those tensions cannot be "absorbed" by the (eco)system (by slightly changing some institutional arrangements in place), a large-scale step change (a transition) may occur sooner or later, and a renewed stability can be achieved. Such new stability could be unpredictable to most of the ecosystem's actors, determining further uncertainty. However, actors capable of mapping the situation, for example through the proposed framework, could make sense of it, and make a new decision accordingly. However, other alternatives could also be available. For example, further changes could, over time, establish a status quo similar to the initial one, as in the case of public opinion, distracted by other public issues, that can turn back on sustainability to focus on cost savings. With different interpretative lenses, institutional arrangements constitute a dissipative structure [52] for stable service (eco)systems [53]: new emerging ideas, beliefs, and technological solutions that are not aligned with the status quo can generate entropy and confusion in the system but are usually dissipated. However, when entropy increases too much, tensions among institutional arrangements become too high, and a transition must occur. Then, a new dissipative structure emerges.

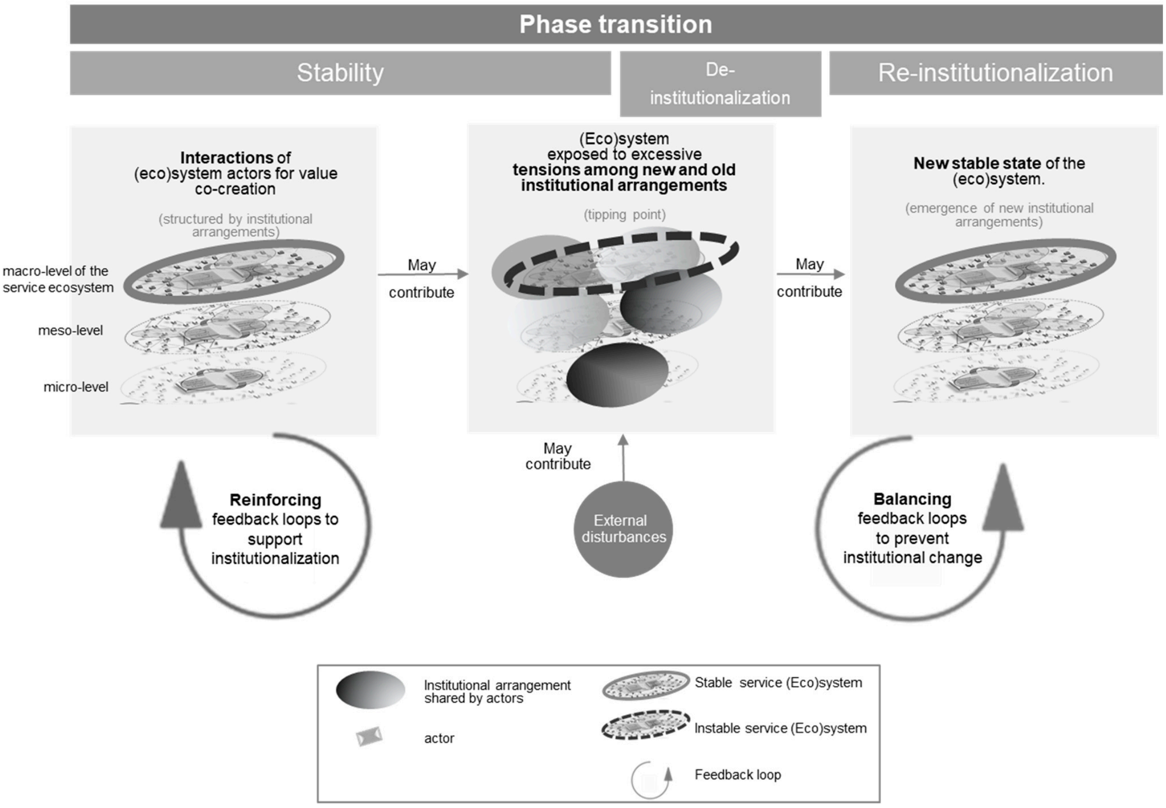


Figure 1. Essential dynamics characterizing (eco)system transitions according to S-D logic. Elaboration based on the phase transition process described in Polese et al. [13].

3. Results and Discussions

3.1. Implications of the S-D Logic Axioms for ET

3.1.1. Service, Actors, and Resources (Axioms 1 and 3)

ET can be understood by looking at the renewed service that each actor of the energy system might be able to provide after an ET based on available resources. Indeed, through digitalization, employing smart grids, smart sensors, etc., "energy" is accompanied by new resources, such as structured and unstructured data (related to production, usage, sales, exchange, etc.). Furthermore, smart grids allow actors to integrate not just their resources but also the ones available to other not directly connected actors [54]. Thus, data can be made available to new actors that can assume new resource integration roles. Data aggregators [10] and knowledge brokers can intermediate and solve diverse issues [9].

These analyses can identify the service that could be exchanged by other actors to manage loads and demand, optimize reliability, re-think offers, re-organize markets, etc. [10]. For example, it becomes possible to: solve problems related to fluctuating prices deriving from the extensive adoption of REs and micro-production and to the related information asymmetries and imperfect coordination of actor responses to economic and technological signals, take care of the electricity flow balance, and price negotiation and answer to the need for renewable assemblers and operators, as well as connectors, balancers, and electricity norm/rule-rebuilders, assure maintenance of power systems, provide financial services, and provide an energy system ombudsman by bringing in resources in the form of specialized knowledge based on distributed information, and new technologies [9].

Furthermore, old actors can assume new resource integration roles, as energy users that can become producers, exchangers, participants in energy communities, etc. With a particular focus on value co-creation roles associated with the utility company intermediaries, Badi [11] has identified relationship-enabling (in terms of orchestration of value network and co-development of trust), communication-enabling (facilitation of interactions and co-crafting of value propositions), and knowledge-enabling roles (as a knowledge repository and co-educator).

Moreover, the (un)availability of resources in the actor-network to provide the eventual envisioned service should be considered. This could bring about considerations and decisions related to network enhancement and policy revisions.

Finally, the potential for service should be identified to increase stakeholders' awareness (based on the list of key stakeholders in an energy system [24]) of the potentialities of ET and engagement, impacting, for example, political and legal dimensions of ET, by designing adequate policies, norms, and laws to make stakeholders able to take advantage of opportunities, also enabling new market possibilities (economic dimension) and business models; social dimension of ET, by enabling institutional work to diffuse awareness of the potentialities of ET, such as user empowerment, increasing, in turn, social acceptance; technological dimension of ET, by suggesting technological areas that need further improvements to enable the actor's provision of service, and environmental dimension of ET, by analyzing the environmental impact on each service, retrofitting this analysis to political and legal dimensions to prevent the possibilities of diffusion of less sustainable services.

3.1.2. Value and Value Co-Creation (Axioms 2 and 4)

Since each actor interacts in value co-creation processes, it should be reflected on how such participation can be facilitated to increase value co-creation opportunities and attract new actors to have an active and renewed role in ETs [12]. To do so, the benefit perceived by each actor in value co-creation processes should be considered. An essential list of benefits (value) expected from the ET can be found in the World Economic Forum [25]. It includes reduction of CO2 emissions, improvement of air quality and health, access to electricity, jobs and positive economic impact, reduction of energy costs and increase of investments in competitiveness and market attractiveness, systems' upgrades, resiliency, security, and an increase in energy productivity, flexibility, and reliability. Although all benefits should be significant to every (eco)system's actor for the viability of energy (eco)systems, some of them are more important to specific actors. For example, energy systems workers are usually focused on not losing their jobs, energy producers pay much more attention to energy efficiency, smart grid managers are interested in flexibility, and innovators are obsessed with market attractiveness. Those simple considerations make it clear that searched benefits can lead to actors' conflicts and negative value co-creation practices, leading to a loss of viability of the (eco)system. However, since institutional arrangements shape (and are forged by) (eco)systems' actors' perceptions, their understanding can enable them to envision how value is perceived by each actor in the energy service (eco)system.

Furthermore, the more connections are allowed among actors of energy (eco)systems, the more resources can be created, integrated, and exchanged (axiom 3), the more value can be obtained through actors' interactions, and the more potential for effective ETs (examples of the increase in connections and possibilities are the energy communities).

Those elements are prodromal to redesign networks, practices, policies, and norms belonging to the different dimensions of ETs. Finally, the value proposition of each actor could be revised to become more engaging to other actors.

3.1.3. Institutional Arrangements and Service (Eco)Systems and the Multi-Level Perspective (Axiom 5)

An energy system can be interpreted as a service (eco)system. Understanding institutional arrangements in place is fundamental to grasping the complexity of energy systems, understanding actors' viewpoints, and thus, perceived benefits. Then, institutional work should be operated to introduce and institutionalize new practices, beliefs, and rules. The diffusion and alignment of institutional arrangements shared by diverse groups of actors belonging to the same (eco)system are foundational for an (eco)system to be stable and viable since it can result in an alignment of value perceptions, toward the common objective of ET.

The multi-level perspective for analyzing service (eco)systems is similar to the one of the socio-technical systems literature. In particular, the macro-level can be considered as corresponding to landscape, the meso-level to the regime, and the micro-level to niches' innovation [49], so the narrative of transitions and the typologies proposed by socio-technical systems literature is still valid and can be enriched by the present considerations. Moreover, there are also differences since the three S-D logic levels are analytical and not ontological (or hierarchically related [55]), while the MLP ones have been interpreted as hierarchical in many applications [34]. This means that, according to S-D logic, the macro- and micro-levels are ways of analyzing the (eco)system and are not separated from it—they are not just influencing but are also reciprocally influenced. Moreover, levels are overlapping, so they share actors and institutional arrangements. For these reasons, we encourage a more systemic view that S-D logic can provide, complementing it with the existent approaches to ETs.

3.2. Proposal of S-D Logic as an Integrative Framework Enriching the Socio-Technical Systems View on ETs

3.2.1. The (Further) Contribution of Institutional Theory to ET

We claim that the definition of service (eco)system phase transition does not contrast but integrates the socio-technical systems' view on ETs. Indeed, although they share common roots, such as complex adaptive systems theory and institutional theory, the usage of those theories has not been widely exploited yet in practical studies dealing with ETs. At the same time, the freshness of the ideas of S-D logic can give a new, further push to their adoption (an original study suggesting the application of institutional theory to ET has been proposed in [56]). For example, Geels et al.'s [57] typology of transition pathways focuses on formal institutions, while S-D logic restates the importance of focusing on all—formal and informal—institutional arrangements of service (eco)systems and their alignment. Foundational to institutional theory is institutional work, the purposive action of actors "aimed at creating, maintaining, and disrupting institutions" ([58], p. 217), which is what actors of the energy service (eco)system should put in place to drive ETs. According to Scott [59], many of the disputes about institutional arrangements among analysts depend on their varying attention to one versus another institutional element. For example, those stressing regulative elements give more attention to rational choice and design, and scholars emphasizing normative elements stress the social embeddedness of political and economic behavior. Generally, in analyzing ETs, the three elements and their interdependencies should be considered. This has been claimed by socio-technical transition studies but is missing in most ET declinations and case studies.

Moreover, deepening the view of technology as a component of systems, in S-D logic, technology is viewed as an institutional phenomenon [7]. Thus, the development of new technologies includes institutional maintenance, disruption, and change, which requires the integration of existing technologies with existing institutional arrangements and results in the development of new value propositions and service innovations [60]. Therefore, technology is not adequately replaced by institutional arrangements but is a tool for achieving institutional change [60]. Finally, it must be highlighted that institutional arrangements to analyze in an ET are not only the ones that characterize the service (eco)system after the transition but also the ones of the "pre-transition" state and, as the three-horizon approach states, there is a transient state between the former two.

3.2.2. The (Further) Contribution of the Complexity Adaptive System Theory to ET

Further looking at institutional arrangements in the provided definition of service (eco)system phase transition [3], the initial stability of the service (eco)system must be dislodged for a transition to happen. Stability must also be re-gained at the end of the process (de-institutionalization and re-institutionalization, where the degree of destruction and construction depends on the degree of institutionalization of the (eco)system, and thus on how many emerging properties contrast and compete [61]). This conceptualization overcomes the view of a transition as a "systemic fight" between niches and regimes [62]. It is aligned with other socio-technical system studies, viewing a transition as "a fluid unfolding of network activities by diverse actors aligned with a particular stream, resulting in a transformed system" [61]. Furthermore, although not informed by institutional theory but by complex systems theory, other definitions of transitions shared the same logic, such as the one based on the metaphor of regime shift [34] or the one related to the dissipative structures [53]. Accordingly, feedback loops—born in cybernetic theory and adopted in the study of complex systems [63]—enable and restrict institutionalization [49] and are recursive processes that can be opportunely orchestrated to provoke or stabilize a service (eco)system change. In particular, feedback loops are needed to explain the diffusion of innovation [49,64] and can be used: at the beginning of a transition to weaken stability by strengthening new emerging properties, increasing the diffusion of new institutional arrangements using positive-reinforcing—feedback loops, and in the final stage of the transition, to re-stabilize the (eco)system, preventing institutional change through negative-balancing—feedback loops.

A straightforward example in the field of ET, which also shows the potentialities of the related illustrative tool (called a causal loop diagram) to express relationships between variables, is reported in Figure 2. In a reinforcing loop, a variation in any variable of the loop is propagated through the loop and reinforces an initial deviation. Thus, in the example, an increase in the financing of small- and medium-scale RE generation solutions can bring about decentralization of the ownership structures, which in turn discourages investments in large-scale conventional generators. Such discouragement further increases the financing for small- and medium-scale RE solutions. It is a reinforcing loop.

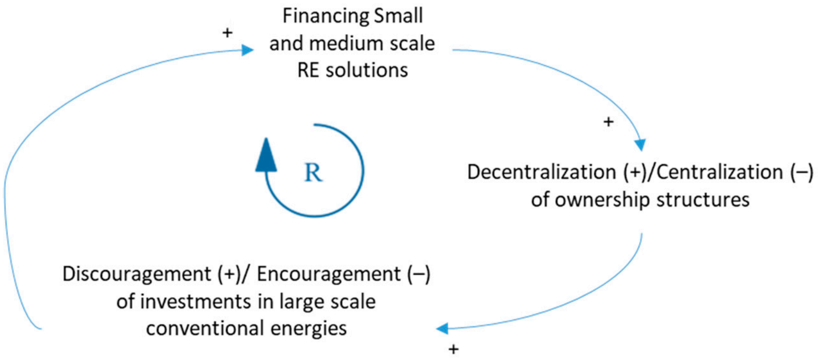
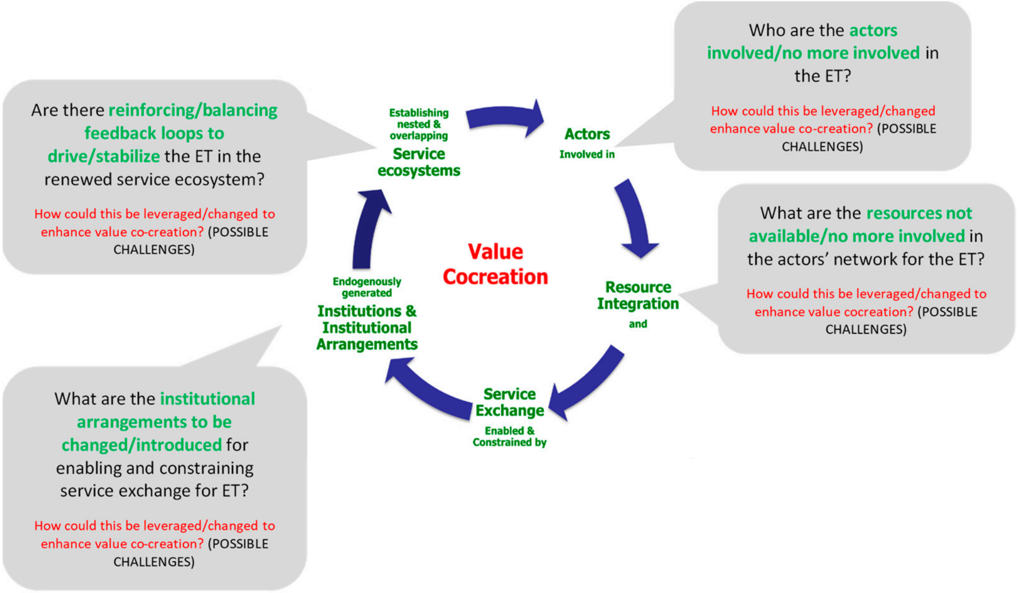


Figure 2. Example of reinforcing feedback loop (R) for ET described in [34]. The example is here represented through a causal loop diagram (a tool belonging to system dynamics [65]). Positive relationships between variables (words) are depicted as arrows with a plus sign on the link. Closed loops are causal feedback loops. When the number of positive links is even, the loop is reinforcing, otherwise, it is balancing.

Stability, or better, the resilience of the ET, indeed, “maintains the direction, speed, and required rate of progress towards a secure, affordable, sustainable, and inclusive energy system even in the face of disruptions” [22]. It is needed, for example, to allow the engagement of investors who desire to work in a predictable environment. Thus, actors’ institutional work should be oriented to establish recursive processes (feedback loops) able to act as de-institutionalizing and re-institutionalizing forces (i.e., able to institutionalize favored institutions and phase out others). The regime shift approach already recognized the importance of feedback loops, and those and further feedback loops should be designed for ETs to happen given the particular context (deriving from the analysis of institutional arrangements in place) in which ET should occur.

3.3. Operationalizing S-D Logic for ET

Based on the content of the first part of this section, this paragraph provides a practical and synthetic list of questions that a researcher should answer when they try to assess an ET and identify the possible challenges an energy (eco)system must undertake (see Figure 3). Remembering that value co-creation and, thus, increase in viability are the objectives of an ET, actors, resources, institutional arrangements, and feedback loops should be analyzed to answer the following question and find possible challenges to be overcome: How could this be leveraged/changed to enhance value co-creation? Some synthetic clarifications are provided concerning resources and institutional arrangements.


Who are the **actors involved/no more involved** in the ET?

How could this be leveraged/changed enhance value co-creation? (POSSIBLE CHALLENGES)

Are there **reinforcing/balancing feedback loops to drive/stabilize** the ET in the renewed service ecosystem?

How could this be leveraged/changed to enhance value co-creation? (POSSIBLE CHALLENGES)

What are the **resources not available/no more involved** in the actors’ network for the ET?

How could this be leveraged/changed to enhance value cocreation? (POSSIBLE CHALLENGES)

What are the **institutional arrangements to be changed/introduced** for enabling and constraining service exchange for ET?

How could this be leveraged/changed to enhance value co-creation? (POSSIBLE CHALLENGES)

Figure 3. Main areas of inquiry when analyzing ET with S-D logic lenses. The questions are related to the narrative [7] of S-D logic (depicted as a blue circle in the center of the picture).

Resources. Resources are those tangible/intangible assets that actors integrate for service-exchange service and value co-creation. By analyzing the actor’s network, two kinds of resources become interesting to enhance value co-creation: (i) not available/not sustainable resources, i.e., those resources that could be not available to actors involved in the ET/not sustainably provisioned to carry on the ET, and (ii) no more involved resources, i.e., those resources that were successfully used before the ET but whose resourceness decreases when the transition occurs. Considerations of those two kinds of resources should be oriented to actions towards an increase in value co-creation. In particular, it should bring attention to: (i) Avoid not available/not sustainable resources. In the former case, include new actors in the network to reach the resources available. (ii) Reconfigure, recycle, or reuse no more involved resources, to leverage value potential.

Institutional arrangements. An issue that should not be neglected is the awareness of market actors regarding the possible service to render and exchange based on the resources made available through the ET. This is a marketing problem that should be analyzed case by case. However, one general takeaway from S-D logic is that there is no perception of potential benefit from value co-creation nor upstream of the resourceness and potential service to offer if no related institutional arrangement is "shaping" such perceptions for actors. Thus, actors' institutional work (actions to maintain, create, or disrupt institutions) is the way to build such institutional arrangements, enabling and constraining service exchange and value co-creation.

4. Adopting S-D Logic as an Integrative Framework to Assess ET in Italy: Individuation of Some Challenges

4.1. Main Considerations Applying the Socio-Technical System Analysis

Italy has a scarcity of traditional resources and is one of Europe's countries most dependent on fossil fuels. ET is not only technically feasible, given the abundance of some REs (such as wind and sun), but also a great opportunity since Italy has a natural, agricultural, and biodiversity ecosystem of inestimable value; therefore, it is much exposed to climatic risks given its geographical configuration [66]. Since it was the first European country to be affected by the COVID-19 epidemic in 2020, it has also been the country most financed (together with Spain) by the European Union (funds NextGeneration EU) to accelerate the achievement of European and Global objectives related, among others, to sustainability. Considering the complementary fund Reac EU, thus, Italy has a budget of 60 billion euros for a "green revolution and ecological transition" to be spent by 2026 [67]. Moreover, the significant increase in energy costs due to the Russia–Ukraine war of 2022 has further accentuated the awareness of the need to achieve an ET in the long run. However, fast alternative solutions to fossils are being evaluated to cope with the issue in a short period. Given these facts, under the socio-technical system lenses, the Italian landscape is accommodative and pushing towards an ET. Thus, in Italy, the ET has taken the shape of a broader "ecological transition" and a ministry has been instituted to manage it. In particular, the mission has become "RE, hydrogen, grid, and sustainable mobility" (Mission 2 of PNRR [67]). Based on those governmental initiatives, multiple niche innovations are being financed as new technological solutions for increasing the adoption of distributed generation-based RE by energy consumers—challenged by high energy costs—to become independent.

In the meantime, at the regime level, the availability of public funds and incentives on REs and the decrease of support for fossil solutions are pushing incumbents to reconfigure their roles in the system and become the first movers of the transition, as well as to not be held back and overcome by new emerging niches. Overall, it seems that all general conditions are favorable for an ET to occur, even if it is too early to say which type of transition pathway [31], with the specific exclusion of the substitution type, the Italian energy (eco)system will undertake. Deeper socio-technical system analyses could address "innovation processes, business strategies, social acceptance, cultural discourses, and political struggles" [30] but they are out of the scope of the current study. In the following section, instead, we exemplify how S-D logic can offer a wider integrative framework through which considerations about actors, resources, institutional arrangements, and feedback loops can also be derived, providing further valuable elements to socio-technical and other systems-based ET assessments. Then, a matching with quantitative models (as attempted in [21]) could add cost-effective feasibility.

4.2. Further Considerations Based on the S-D Logic Integrative Framework

These and the following considerations are derived from extensive research based on journal articles and grey research (reports from advisory companies, policy statements, etc.), coded and discussed by the co-authors through the application of S-D logic.

We build on the list of key stakeholders of energy systems from the World Economic Forum [1], considering as actors at least: energy companies (utilities, REs developers, services companies, technology and equipment providers), industrial, residential, and commercial prosumers, policymakers, international organizations, financial sector entities, cities, civil society, and workers for energy systems. In Table 4, some potential challenges for the Italian ET related to actors and actors' networks are highlighted based on S-D logic. Similar considerations can be made based on resources, as in Table 5. Table 6 shows an analysis of the dimensions that characterize the Italian ET (the PESTEL analysis sub-environments have been adopted). Interestingly, governmental support policies are the main drivers of the Italian ET to come, and most of them have been designed in 2021 and are going to be implemented in the near future, yielding the first outcomes in a few years. A focus on institutional arrangement-related challenges is provided in Table 7. Finally, we highlight that, Italian governmental measures put—or should put—in place reinforcing/balancing loops to support ETs. Challenges related to that are presented in Table 8.

Table 4. Challenges related to actors and actors' networks.

Challenge ID	Description
1. Actor's network	The Italian actor's network is still undeveloped due to a lack of shared resources, such as infrastructures (such as smart grids) or new technologies, which will be potentiated thanks to PNRR. There are, however, some experimentations of energy communities that have been implemented not just for technical purposes but also to identify best practices for actors' relationships [68]. Furthermore, a few associations and organizations have emerged to represent the instances of multiple sets of stakeholders, such as, at the European level, the European Youth Energy Network [69]. At the moment, thus, the weakness of the "ET actors' network" makes the overall potential for value co-creation relatively restrained, and could result in a lack of sharing of purposes and results.
2. New actors, actors' roles	Facilitated by experimentations, such as the ones of energy communities, new actors are emerging with the role of aggregators and other intermediaries acting as service providers. Furthermore, looking at the multiplicity of actors' roles deriving from the ET, the shift underway in energy access is resulting in electricity consumers becoming prosumers, i.e., consumers who are also producers of (renewable) energy and who use that energy more intelligently and efficiently. In other words, citizens are starting to become less dependent on energy companies. Blockchain technology [70] can be used to enable Peer-to-Peer (P2P) transactions in a decentralized way, without the need for a central authority [71,72]. Additionally, the design of new distributed architectures and methods able to cope with the issue of scalability in smart grids and microgrids [73] consisting of several distributed energy resources is fundamental.
3. Actors' new role and service	Both new actors and actors assuming new roles, such as residential, industrial, and commercial prosumers, are still not fully aware of the possibilities made available by the new role and service that they can provide/exchange. However, some funds (Investment 3.3 [74]) are being dedicated to achieving awareness of the role and behavior of individuals in the transition, such as the publication of a platform to share educational materials and the involvement of influencers.

Table 5. Challenges related to resources.

Challenge ID	Description
1. Not available/not sustainable resources: Rare-earth elements	Considering the not available/not sustainable resources discussed in Section 3.3 (i), it is interesting to notice that, although every kind of RE could theoretically have an environmental impact that is lower than the one of the currently used conventional resources, specific evaluations should be carried out to select the lowest impacting RE in each given context. In this sense, not just the REs should be available in the geographical area target of the ET, but also all the complementary technologies and technical solutions, including the raw materials needed to develop those solutions. As commonly agreed, one of the most important policies for a true transition towards sustainability is ensuring that the RE-based generation systems (i.e., photovoltaic and wind generation solutions [75]) and batteries for electric vehicles [76] are produced sustainably, that is by using renewable energy during their production phase and as much as possible by recycling the materials at the end of the product lifecycle. Thus, the impact of processes and technologies needed should be considered. An exemplar case is constituted by rare-earth elements of Chinese monopoly (with consequent geopolitical tensions). Such factors have high environmental impacts and dangerous consequences on health due to the mining process. Furthermore, their demand is estimated to grow around seven times by 2040 [77]. Italian governmental policies have identified a list of key Res to exploit which is quite aligned with the ones of the other European countries. However, given that the related technologies are, in some instances, still under development, periodic re-evaluations should be carried out to assess the availability of the resulting needed materials.
2. Circular strategies to reduce materials' demand	The issue of Challenge 1 is also captured by the concerns expressed by the European Commission [78] on critical raw materials for strategic technologies. It has been restated in [79], suggesting developing circular strategies [80] to reduce materials' demand, starting from the introduction of the material perspective in energy system design. Unfortunately, although PNRR includes incentives for a circular economy, it does not consider specific initiatives for rare-earth elements and critical metals [77].

Table 5. *Cont.*

Challenge ID	Description
3. Not available resources: improving low-carbon supply chains	Dealing, more in general, with resources not available in the Italian ecosystem, reflections should also be oriented to evaluate expansions of the actor's network. In this case, a focus should also be put on improving low-carbon supply chains oriented to reduce risks, enhance resilience, and maintain Europe's global influence built on trade relationships [81]. This should be performed in opposition to the rhetoric of autonomy, self-sufficiency, and sovereignty of countries spread during the pandemic, which would only switch exposure from a global supply chain risk to disruptive events in Europe.
4. No more involved resources: reconfigure, recycle, and reuse	Focusing on no more involved resources deriving from the ET, there should be investments to reconfigure, recycle, or reuse past plants, stocking areas, and workers' knowledge, to avoid accumulating wastes, spoilt sites, workers' frustration, etc. Dealing with tangible resources, given the European bet on green hydrogen that should cover 25% of energy consumption by 2050, a fundamental reconversion is related to natural gas infrastructures to transport hydrogen [82]. Other reconversions are related to some dismissed industrial areas localized in strategic positions (Investment 3.1) that will become hydrogen valleys.
5. No more involved resources: re-locate workers	On the side of intangible resources, the forthcoming ET, as in every other country, will bring about the need to re-locate many workers previously involved in traditional energy production. This objective is aligned with "reskill and upskill" flagship Europe programs. However, in the PNRR, those initiatives seem to be related to schools and universities, also through the promotion of massive open online courses and important but general labor policies (Ref. M5C1 [74]). Thus, the specific issue in connection to ET will be an essential challenge to manage.

Table 6. ET dimensions and the Italian case (current situation).

Dimension of ET	The Italian Case
P—Political **L—Legal**	Recently launched governmental support policies (incentives, funds, tax reduction, etc.) for the future: -Alignment with EU policies for the release of faster permissions for planning, construction, and operations of plants based on REs [83] -Energetic requalification of buildings -Electrification of consumption -REs usage, with self-consumption (as with a super bonus of 110% for the installation of photovoltaic or storage systems, and activation of distance self-consumption) -RE communities [68] -Distributed generation (decentralized mix of production capacities) -Automation building for energy saving -Smart grid and micro-grid infrastructures -Electric vehicles, highly efficient buildings with heat pumps, high-efficiency photovoltaic, marine power -District heating -Hydrogen boiler -Elimination of incentives that currently deepen or perpetuate gas consumption [81] -A differentiated mix of energy sources (solar thermal, green hydrogen—also for industrial feedstock and energy storage [81]—and bio-methane) to further reduce the dependence on gas -Extraction of raw material (nickel, lithium, etc.) for the production of RE-based solutions (i.e., batteries, wind turbines, etc.) -Carbon capture, utilization, and storage technologies (an interesting study on the topic is provided by Rodrigues et al. [84]) -The creation of an internal market of new technological solutions -New RE-related business and occupation -Cybersecurity of infrastructures (for resilient grids) and cybersecurity of communications between digital solutions -Research and development of new technologies Institutional misalignment between European Green Deal and some Italian support policies [85,86]: -The persistence of incentives to fossil fuel boilers ("sussidi ambientalmente dannosi") -Postponement of incentives to sustainable mobility
E—Economical	Circular economy for reducing the cost of raw materials. Need for energy market reform (local markets and integration with the centralized market, since integrated regional markets can buffer fluctuating renewable resources across larger regions) Revenue position of plants located in strategic areas for participating in the dispatching market High (and increasing) cost of fossil-based energy High cost of technological solutions

Table 6. *Cont.*

Dimension of ET	The Italian Case
S—Social	Growing public concern for sustainability-related issues Due to the change in energy governance, the need for (policies, plans, and projects): -Ethical ET (not marginalizing the less fortunate, affordable for all, also ensuring that the costs and benefits of the transition are shared fairly among users) -Awareness of the role and behavior of each individual in the transition (at the moment, the initiatives and funds are mainly focused on consumers) -Security and access to energy, given that energy security governance is decentralizing (electricity consumers are becoming prosumers) -Fast relocation of workers -Cultural transition based on the concept of sobriety to reduce energy and resources usage
T—Technological	Underdeveloped energy system infrastructures A few developed novel technological solutions (see in the P&L raw the political actions to support the new technologies to identify them)
E—Environmental	First initiatives to sustain a circular economy (to reduce the environmental impact of new technological solutions) Need for promotion of "systemic tools" to reduce environmental impact, such as: -Lifecycle assessment -Analysis of the expected monetary value of the impact of technological solutions on the environment and society (from risk management)

Table 7. Challenges related to institutional arrangements.

Challenge ID	Description
1. Institutional work in energy communities/smart cities	This first analysis of the Italian ET dimensions allows to identify the primary formal and informal institutional arrangements in place in the Italian energy service (eco)system. It is prodromal to the analysis of service, service exchange, and value in the (eco)system. Then, institutional work could be performed by actors to try to make accepted new or changed institutional arrangements, changing, in turn, the value perceptions of other actors, with a further enhancement of the potential for value co-creation, making the transition more and more effective for the overall (eco)system. An example is related to the increasing benefit perceived by citizens in RE-based self-production of energy, which was initially supported by incentives for photovoltaic units, but is also currently sustained in a growing concern for sustainability enabled by public discourses. Such self-production will need to be further supported by other initiatives, such as the establishment of energy communities, in which multiple actors, from citizens to aggregators, can be enabled by smart grids, devices, micro RE-based energy plants, and new policies (all different kinds of shared institutional arrangements) to co-create value. In particular, early experimentations of energy communities in Italy have been useful not only to test technological solutions (value for the innovators and the citizens' samples) but also to start creating an awareness of future consumer empowerment (value for the society, increase in the viability of the service (eco)system). Indeed, citizens involved in energy communities, being able to produce energy from their local RE-based plants, learned how to take on the role of prosumer and share the energy produced within the community, also providing additional service inside the community and to systems' operators. Those initiatives constitute a testbed for the overall collectivity to envision future potential value co-creation deriving from such a kind of involvement and develop, in turn, policies and procedures to benefit. Such an approach can be extended to smart cities [87,88], that use information from various fields in real-time, and exploit both tangible (e.g., transport infrastructure, energy, and natural resources) and intangible (human capital, education, and knowledge, and corporate intellectual capital) resources, involving the enhancement, attraction, and retention of qualified human capital. The development or empowerment of smart cities in Italy—and in other countries—should also be based on an economy of aggregation, where metropolises, through the creation of a network of small and large cities, could become hubs of exchange with adjacent areas, creating a critical mass for new investments in smart technologies.
2. Lack of institutional work: gigafactory for the production of electrolyzers for green hydrogen	Given the importance of shared institutional arrangements to enhance the potential for value co-creation, multiple studies have suggested that companies, such as utilities, engage in conversations with regulators, market entrants, and citizen associations to identify new mutually beneficial business models (institutional work for new institutional arrangements). A simple example can be an agreement on which market entrants leverage utility infrastructure to serve their customers, while fairly compensating the utility [89]. Other initiatives can be related to cybersecurity, which is needed both for infrastructures (for resilient grids) and for communications between digital solutions [90]. Those shared institutional arrangements are fundamental to assuring security and reliability or energy service ecosystems, enhancing actors' willingness to participate in new service exchange and value co-creation. Thinking about initiatives related to the lack of institutional work for enabling service and service exchange not already envisioned in the (eco)system, an example is an Italian debate about the construction of a gigafactory for the production of electrolyzers for green hydrogen, which both European and Italian funds should finance. One of the most recent concerns is the absence of a market for those products that, according to some specialists, should be identified by the government [91]. Although it might be argued that it is too early to start with marketing actions, or that it is not up to the government to design whole supply chains, it is also true that possible consequences of planning actions should be evaluated before investing. In this example, measures to achieve public awareness and agreement on the themes of green hydrogen support the future creation of a market for electrolyzers. Furthermore, incentives for the adoption of the technology could be planned to be launched synchronically with the completion of the gigafactory project.

Table 7. *Cont.*

Challenge ID	Description
3. Sharing institutions: standards	Actors should understand their potential resources, service to render, and their belonging to a network of other actors that can enable service exchange. In such a way, actors could leverage the network to build new practices, agreements, and contracts, to allow such revolution (new institutional arrangements aligned with the existing ones, to foster change). Standards could, in this case, support the communication of each actor's potentialities and current outcomes of each actor in the circularity. For example, the institution of a logo for zero-emission RE plants, such as the Green Label for green production, or the environmental and social scorecards to assess the overall optimization of plants and devices' operations promoted by several companies, can be shared not just with customers but also with financial organizations to obtain funds, as in Enel Green Power's plants. The diffusion of those initiatives should be supported to foster the sharing of institutional arrangements, which favor resource integration and the resulting value co-creation.
4. Technical issues and future social impacts	ET can be oriented toward distributed generation, but there are also incentives and initiatives devoted to centralized RE-based maxi-plants (such as the photovoltaic one in Africa), which further pose issues related to cyber-attack vulnerability, which means a loss of viability of the energy service (eco)system. It is worth noting that those two opposite approaches to the ET—one bringing to energy "democratization", the other to "energy capitalism"—clearly have a significant political impact on society, also involving future generations. Those technical issues and future social consequences should be carefully considered based on system thinking when designing bids and specific measures starting from the PNRR, bearing in mind that successful initiatives are those that enhance the overall (eco)system viability.

Table 8. Challenges related to feedback loops.

Challenge ID	Description
1. Reinforcing loops (public funds) and mis-consideration of ethical and security issues	It is interesting to notice that utility companies that envision the urgency of ET and have capital and knowledge to shape the system are currently operating as incumbents and are trying to drive the ET as first movers to avoid being overcome by it. Eventual reinforcing loops due to concessions of public funds mainly to consolidated groups with demonstrated expertise in the field could accentuate this dynamic. However, this could also bring about mis-considerations of ethical ET (not marginalizing less fortunate, affordable for all), security and access to energy, lack of democratization of energy production, and not pushing towards a just ET [92].
2. Counterbalance between reinforcing (public funds) and balancing (duration of incentives) loops	Incentives cannot be everlasting, so they should be scheduled in a way to communicate trustability to potential beneficiaries and enough to trigger investments in complementary technologies (if not directly financed) without affecting other potential investments.
3. Counterbalance between reinforcing (public funds) and balancing (control of resources) loops	Resources are not infinite. The increasing request for resources to produce and operate RE-based technological solutions can increase prices because resources are limited. This can be partly solved by the sharing economy—magnifying the concept of service by sharing instead of owning products to get benefits while increasing their utilization rates—and the circular economy—to reuse/recycle materials. Both those mechanisms must be supported to be operative by fostering actors' self-organization for the emergence of platforms, standards, and supply chains.
4. Counterbalance between reinforcing (public funds) and balancing (control of emissions) loops	Lifecycle analyses should be continuously performed to evaluate the CO2 emissions of each ET's intervention. For example, producers' attempts to provide cheaper components realized in an unsustainable way should be prevented. Indeed, an important principle for sustaining ET is that used energy (for both production and operations) should derive from a sustainable mix of energy sources, which contemplates a high percentage of REs.
5. Counterbalance between reinforcing (public funds) and balancing (control of wastes) loops	The reduction of energy waste should always be targeted. Some measures, such as the promotion of health pumps, increase the demand for electrified consumption. Those measures should be opportunely associated with policies to support the energetic requalification of buildings. Otherwise, the heath pumps' operations would not be efficient, and energy would be wasted.
6. Counterbalance between reinforcing and balancing loops: electric vehicles	A lifecycle assessment study [93] has shown that electric vehicles used in Europe—operating for at least 200,000 km—would have an environmental impact lower than conventional vehicles only if produced—together with their batteries—using RE sources mainly coming from Europe. Thus, first of all, public incentives toward ET in Italy should foster the production of batteries and vehicles locally, with a consequent reduction of the environmental impact of electric vehicles' production phase. The following increase in the diffusion of electric vehicles would decrease unit incentives for local production due to vast numbers of new producers and a higher volume of production (incentives cannot be everlasting, balancing feedback loops). Then, imports and higher environmental impact could slowly increase. Thus, control of the environmental impact should be continuously performed for an effective ET, and incentives should be cyclical and oriented to finance the adoption of local RE sources for the production of batteries and electric vehicles when there is a new expected significant reduction of environmental impact. However, many of those issues, such as the increase in consumption, will be made more straightforward to manage in Italy than in other countries thanks to smart grids and energy communities. Indeed, the former technically allows network stability, energy production, and consumption balancing also through energy storage in a smart way, and the latter supports actors' resource integration and service exchanges enabled by the grid. They will operate as (dissipative) structures stabilizing the transitioned service (eco)system.

5. Conclusions

The climate crisis and the development of new technologies are increasingly pushing an ET toward de-carbonization around the world. A systems perspective on the topic is mandatory to consider not only environmental, technical, and economic issues but also social and political ones. Accordingly, socio-technical transition and other systems' frameworks have been extensively used to investigate transitions.

From a theoretical point of view, in this paper, we contributed to the discussion on ETs by enriching current frameworks with a value co-creation and service (eco)system perspective deriving from service-dominant logic as an integrative framework to assess ETs. Indeed, we have shown that S-D logic is a meta-theoretical framework that is accommodative of socio-technical transition studies and other systems' studies on ETs. It adds to the latter the overcoming of the distinction between producers and consumers, suggesting looking at the perceived benefits (value) that actors can envision in their interactions, and the service that they can exchange to achieve such value through value co-creation. Recent advancements in phase transitions [13] help in identifying de-institutionalizing and re-institutionalizing mechanisms needed for effective and viable ETs to occur. Indeed, focusing on the overall service (eco)system undertaking an ET, compared to currently adopted frameworks, it can further unfold the challenges for the (eco)system viability. Indeed, it is fundamental to pay attention to the destabilization and decline of existing fossil fuel regimes before designing and supporting the institutionalization of policies, technological solutions, and related practices. Those specific actions will determine the ET pathways undertaken in each energy system.

To build the background for such integrative frameworks, we also contribute to ET studies by offering a brief literature review on ET frameworks, with a focus on systemic ET frameworks, and a synthesis of the dimensions of analysis of ETs. Based on our findings, we can state that a qualitative systems-based framework can grasp the complexity of energy systems. However, merging with quantitative models, also based on key performance indicators and other measures, can allow the assessment of ETs.

A further contribution lies in the operationalization of S-D logic to ETs, supporting ET practitioners (policymakers, companies, association of citizens, etc.) with a description of the central tenets of S-D logic and the related implications for them to rethink energy systems' dynamics and ETs. To this extent, we also offered four questions to assess ETs based on S-D logic. In comparison to previous frameworks for assessing ETs, we highlighted that attention should be paid to actors, networks, resources, institutional arrangements, and feedback loops. Among the other findings, we emphasized that actors' available resources should also be valorized through the enhancement of actors' awareness of their potential roles and the service that they can render. Moreover, the need to obtain available resources should be leveraged with the overall environmental impact of such involvement. In this sense, we have found that sharing economy, circular economy, and economies of aggregation are powerful logics to reduce wastes, recycle and reuse materials, and increase their utilization rates (the potential service they can render) and richness, thus expanding and enabling service exchanges on new actors' networks. Essential elements of ET are feedback loops, which can reinforce and stabilize ETs. Based on the illustration in the Italian case, we also derived that feedback loops can be used as control mechanisms to assure that initiatives, such as incentives for a technological solution, do not give birth to vicious cycles of unsustainability. However, as constructivism can explain, we pointed out that the effectiveness of applying our integrative framework to assess ETs depends on the knowledge endowment of the actors in charge of the assessment, in terms of actors, actors' networks, resources, and institutional arrangements in place. In other words, it is up to practitioners to analyze their specific contexts and identify what kind of institutional work they should and can put in place to leverage or change those elements to enhance actors' value perception and engagement in value co-creation. To this extent, shared visions and coordinated actions are required based on transdisciplinary analyses [94] and creative, robust, and audacious strategies [95]. This will, in turn, increase the viability of energy service ecosystems towards effective ETs. Furthermore, although decision-makers could adopt our proposal to map current situations and design new strategies, services, or other initiatives to foster ETs by levering de/re-institutionalization practices, they should always take into account that, since they are coping with complex (adaptive) systems, emergent properties [50] may appear that are not aligned with their expectations. In those cases, updates to their "ET assessment maps" and revisions of the initiatives could be based on effectuation theory [96].

Practically, we illustrated the potentialities for assessing an ET through S-D logic by analyzing some aspects and deriving a list of 18 challenges of the current Italian ET. Given that the government support policies are the main drivers of the Italian ET to come and most of them have been designed in 2021 and are going to be implemented in the near future, this has been the best moment to analyze the current situation and identify some challenges to focus on based on our integrative framework to suggest being taken into account by policymakers.

This study paves the way to more profound analyses on the theoretical contribution of S-D logic to ET literature. In particular, future research with S-D logic lenses could address collective actors' sense-making and engagement for ETs, sustainability and negative assessment of value co-creation in ETs, diffusion of new sustainable solutions to foster ETs, market shaping [97] for ETs, or challenging the basic assumptions guiding most of the decision-makers, and neo-animism [98] to overcome unsustainability in ETs. Moreover, other systems and systems thinking principles (for example, anti-fragility) could be included in our integrative frameworks to build further practical guidelines for practitioners to shape ETs. Furthermore, merging with quantitative models is required to pursue quantitative analyses on the efficiency of the effects of actors' envisioned strategies. In-depth applications to case studies are needed to further reveal the potential strengths and weaknesses of such an integrative framework, and practically support ETs' decision-makers.

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Abbreviations

ET	energy transition
MLP	multi-level perspective
PNRR	Piano Nazionale di Ripresa e Resilienza
RE	renewable energy
S-D logic	service-dominant logic

Appendix A

Table A1. Socio-technical systems studies: main approaches.

Approaches	Details
Technological innovation systems	Technological innovation systems are comprised of technology, actors, networks, and formal and informal institutions. The innovation functions are related to the role of technology in those systems (such as knowledge development and diffusion, private and public entrepreneurial experimentation, creation of legitimacy, etc.) in connection to the context [99]). Furthermore, in those systems, positive or negative feedbacks have been identified, with cumulative causation and institutional tensions, leading to virtuous or vicious cycles, as shown in the Nova Scotia case on renewable energy [29]. The TIS approach has enabled the diffusion of clean energy technologies [100].
Transition Management	Transition Management is a theoretical perspective and a prescriptive governance framework to lead the change toward sustainability. It conceptualizes socio-technical systems as complex adaptive systems [101], thus considering "management as a reflexive and evolutionary governance process . . . rather than one of control or linear coordination" [102]. In other words, not only can change be engineered by human activity, but it cannot be fully controlled. However, it is possible to influence the speed and direction of the structural processes of change by setting coherent policy initiatives (also conducting 'transition experiments' to test alternative energy practices and technologies). In particular, a continuous cycle of establishing and developing a transition arena, creating a long-term vision and transition agenda, initiating and executing transition experiments, and monitoring and evaluating the process should be followed [103]. Transition Management is informed by the multi-level perspective. In a highly cited case study in the Netherlands, the two are integrated to analyze ETs, to understand if the implementation was determining a structural change and if the theoretical approach could be improved. They highlighted four transition dilemmas: long-term goals and commitment versus short-term success, level playing field versus certainty for investors, regime incumbents versus focus on frontrunners, and nurturing niches versus control policies. In this field, the integration between TM (oriented to condition change) with Decision Making under Deep Uncertainty (focused on preparing for a change) has also been proposed [102].
Multi-level perspective	The middle-range theory, called the multi-level perspective (MLP) [31], has become a prominent framework in transition studies [16,104]. It sees transitions as dependent on the interactions between three analytical levels [21]: The regime, the socio-technical system itself, which is a quite stable system, as the dominant energy infrastructure prevailing at a particular time [16]. It is the "semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems " [105]. The niche innovations, novel small-scale socio-technical systems [31], characterized by new business models, technologies, and behaviors, which can encounter a significant opposition to diffusion from the regime. The landscape, independent exogenous spaces characterized by political, economic, and demographic trends that are not affected by regime or niche, but can influence the society's perception and adoption of niches' innovation [16]. For a transition to happen, instead of single drivers, the MLP basic idea is that there must be an alignment of processes within and between the three levels, taking advantage of windows of opportunity [21]. For example, the landscape can destabilize the system and facilitate the breakthrough of niche innovations. Geels et al. [21] mixed MLP with quantitative models, resulting in socio-technical scenarios, which deserve to be discussed here due to overcoming some of the limitations that MLP presents. Indeed, those scenarios took advantage of MLP but also address the co-evolution of multiple dimensions instead of relying on deterministic megatrends enabling change. In this specific case, the authors focused on endogenously enacted [106] change, looking at changes in attitudes and the behavior of actors. Under this view, transition pathways involved not just technologies but also "social groups (with shared beliefs, interests, capabilities) acting in the context of institutions" [21]. Thus, the authors explicitly mentioned that, for the specific case study under analysis, "because the socio-technical storylines focus on endogenous change (related to actors, interactions and cumulative processes), they arguably exclude the MLP's 'landscape' level. Although some storylines referred to extreme weather events, the scenarios did not include (geo) political changes (e.g., Brexit, America First, populism), shocks or crises" [21]. As we will show later, the exogeneity of the landscape level is overcome by the inclusiveness of the S-D logic macro-level.
Strategic Niche Management	Strategic Niche Management is needed to nurture and protect niches until favorable conditions for them to be diffused occur [31].

Table A2. Multi-level perspective: details on case studies and typologies of transitions.

Details On The Multi-Level Perspective	Description
Illustrations and case studies (some)	The MLP has been the most adopted interpretation lens, with multiple case studies on energy transitions. For example, the comparative study on California, New York, and Oregon focused on adopting microgrids (niche innovation), investigating drivers, contexts, processes, policies, institutions, and interactions [107]. It revealed that natural disasters, massive power outages, and climate change concerns characterizing the landscape determine pressures for the adoption of microgrids. Regimes, on the other hand, were characterized by cheap and abundant electricity and a closer market structure. Government support (funding and legislation) was crucial for nurturing the micro-grid niche innovation. In another case, MLP was used to deal with storage technologies (niche innovation) in the German energy transition by analyzing actors, their perspectives, and the transition pathways [108], finding cooperative interactions of the actors at the niche level and suggesting the path to undertake for a successful transition.
Typologies of Transitions	Within socio-technical systems under the lenses of MLP, Geels and Schot [31] proposed a renowned typology of different kinds of process alignment leading to transition pathways—intended as a concatenation of change patterns over time [109]—of the regime (also considering the possibility of shifting from one path to another): (i) substitution (of disruptive niche innovations to the regime supported by landscape pressures), (ii) transformation (due to adaptation of the regime to the landscape pressures in absence of enough developed niche innovations), (iii) reconfiguration (absorption of niches into the regime driving architectural changes), and (iv) dealignment/realignment (instabilities due to landscape pressures not supported by developed niche innovation, with the emergence of new niche innovations and recreation of the new regime around one of them). They explored this typology by analyzing main (generic) actors and interactions. Acknowledging some limitations of such a typology, such as the lack of focus on agency and institutions embedded in the systems, as well as the importance not only of the timing (in the evolution of levels) and the interpretation and mobilization of actors, the authors reformulated the typology [57] in terms of endogenous enactment by explaining the trajectories as event-chains of moves and countermoves of actors shaping the reproduction or change of institutions. However, in making this revision, they were also pushed by an empirical focus on technology more than the overall system (due to electricity generation rather than the entire electricity system, including the power network and the users) and on formal institutional arrangements (rather than also normative and cultural-cognitive ones) [57]. With their reformulation, they associated transition pathways to institutional change, leveraging the classification by Mahoney and Thelen [110]. Thus, in such revision, they explored the typology analyzing (generic) actors, technologies and rules, and institutions. Recognizing that both the typologies have been adopted to analyze transitions, we highlight a limitation concerning the proposed categorization since technology and institutions can be seen as mutually related rather than two separate or sequentially dependent issues [33], as well as captured by service-dominant logic. This limitation, coupled with the specific focus on technology instead of the comprehensive system, and the focus on formal institutions instead of all kinds of institutions, can affect the effectiveness of the typology in catching the dynamics of energy transitions.

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