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Review

Assessing co-creation in strategic planning for urban energy transitions

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ABSTRACT

Cities all over the world are setting ambitious targets of achieving zero carbon emissions and 100% renewable energy in the near future. Such energy transitions are highly complex societal processes, however, necessitating intensive collaboration among regional and national governments, energy companies and utilities, research institutions, advocacy groups, and local communities. Although there has been a rising interest in collaborative approaches such as co-creation in energy transition studies, existing literature on this topic sometimes lacks theoretical rigour or faces problems in practical application. This poses a challenge in assessing what makes co-creation useful for accelerating energy transitions. The aim of this paper is to critically review co-creation and other selected collaborative approaches across the public sector literature in order to develop an assessment framework for co-creation in strategic planning for energy transitions. Based on this review, we suggest that co-creation can be assessed according to the following criteria: 1) the involvement of actors (state, market, community, and third sector) and their roles in different phases (initiation, design, and implementation) of co-creation; 2) the use of four sets of activities (expectation alignment, social learning, resource acquisition, assessment, and evaluation) to foster transformative power; and 3) the outcomes of co-creation. The latter may include new knowledge, new relationships, and new solutions, as well as increased efficiency and social acceptability of the transition processes. We illustrate the application of this conceptual framework with an example from an ongoing energy transition led by the ProjectZero organization in Sønderborg, Denmark.

1. Introduction

Cities all over the world are transitioning towards zero carbon and 100% renewable energy systems. However, energy systems that are optimal from technical and economic points of view might not always be acceptable to all societal groups involved, or beneficial for the environment in the long term [1–3]. Moreover, social acceptability is likely to differ from one place to another, meaning that it is impossible to offer a universal blueprint for such transitions. As Rutherford and Coutard [4] note, "cities are not secondary entities expected to contribute to one unique national, let alone global, energy transition; they are […] political arenas through which change is invented, implemented, enacted and experienced in always specific and different ways." This means that transition pathways in cities must be continuously created and re-created through collaboration among regional and national governments, energy companies and utilities, research institutions, advocacy groups, and local communities.

While recent years have seen a proliferation of collaborative approaches to energy transitions such as co-creation and co-production, these have often been limited in scope, either focusing on collaboration between specific actors (such as municipalities and universities [5–7] or municipalities and local NGOs [8–12]) or limiting co-creation efforts to a single phase of the transition process (e.g., knowledge creation [13–15]). Numerous practical difficulties have also emerged, including the lack of time and incentives to participate in such projects, the lack of knowledge and skills required to facilitate co-creation, and the resulting tendency to avoid and/or obscure highly controversial issues rather than resolve them through collaborative methods [15–17]. In a recent European Association for the Study of Science and Technology [18] conference session focusing on co-creation, it was acknowledged that not enough is known about the key principles and activities that make co-creation both effective and efficient.

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The aim of this paper is to critically review co-creation and other selected collaborative approaches across the public sector literature in order to develop an assessment framework for co-creation in strategic planning for energy transitions. We illustrate its usefulness with an empirical example from an ongoing process of urban energy transition in the municipality of Sønderborg, Denmark. In doing so, we seek to answer the question,

"How can co-creation in strategic planning for energy transitions be assessed?" The paper is structured as follows: in Section 2, we sketch out the problem in more detail; Section 3 briefly outlines the principles of a critical narrative review and our review methods; Section 4 presents the results of the review and lays out a framework for answering the research question; Section 5 discusses and illustrates the application of this framework with an empirical example; and Section 6 concludes the paper by offering steps for future research.

2. The limits of technocracy and the resurgence of collaborative approaches

2.1. The many faces of technocracy

The social acceptability[1] of renewable energy has been a rising issue since the 1990s, when the sector started attracting increasing capital investments. This has particularly been the case in front-runner countries like Denmark, where the increasing commercialization and industrialization of wind energy stands in stark contrast to the locally operated wind cooperatives of the early years [19,20]. The social acceptability of renewable energy is a complex phenomenon with three major dimensions: the micro-social, the meso-political, and the macro-economic [21]. The micro-social dimension includes the attitudes of local individuals and communities toward the siting and development of specific renewable energy projects. The meso-political dimension comprises the shaping of regulations and policies associated with renewable energy and how major interest groups and the general public react to these changes in policies. The macro-economic dimension is concerned with the competitiveness of renewable energy in the energy market, as well as the relations among renewable energy companies and developers and between the renewable sector and the incumbent fossil fuel industry.

The need to discuss the acceptability of renewable energy in the first place often arises from what has been called "technocratic planning" [22] or "technical-regulatory decision-making" [23]. Traces of this phenomenon can be found across all of the three aforementioned dimensions.

In the micro-social dimension, technocracy refers to opaque and undemocratic planning and development processes with limited participation, public consultation, and information meetings [22,24]. These processes often rely heavily on highly detailed technical "expert" knowledge, while the values, norms, traditions and interests of local people associated with the specific places involved are relegated to a secondary role [25,26].

In the meso-political dimension, renewable energy transitions are commonly envisioned and regulated on a centralized (national) level, at which regulations are shaped by large energy companies lobbying for their own purposes [27,28].

In the macro-economic dimension, typically only a limited number of (large) energy companies have the capacity and capital to initiate large renewable energy projects or are enabled to do so by the regulatory framework [29]. Moreover, incumbent industries tend to use their power to resist change and to cement their positions despite unfavourable market conditions [30,31].

The technocratic approach is particularly dominant in wind power planning. This often has a negative effect on the social acceptability of wind energy and ultimately of energy transitions at large.

2.2. Collaborative approaches

As a response to the limitations of the technocratic approach, the 1990s saw the rise of communicative [32] or collaborative [33–35] planning theory, characterized by the promotion of consensus building through inclusive and deliberative dialogue. However, it soon became evident that the "collaborative turn" tended to overestimate both the capability of planners to facilitate inclusive dialogue [36] and the power of rational argumentation for solving conflicts [37]. This realization paved the way for the rise of alternative collaborative approaches such as co-creation and co-production, which hold a number of advantages in comparison to collaborative planning: 1) instead of relying on a pre-established understanding of participation, they aim to involve citizens and communities in all stages of the planning process; 2) they specifically focus on including disempowered and underprivileged actors and recognize the importance of power struggles; 3) by engaging with the real needs of local people, they broaden the array of what is possible as well as what is actually relevant in planning; 4) they acknowledge the vast opportunities presented by alternative forms of collaboration working outside and sometimes against official planning procedures; and 5) they rely on showing and learning-by-doing rather than on deliberation and dialogue, thereby engaging with the material and tangible results of change [38–40].

Co-creation has become a "buzzword" among scholars and practitioners across various fields, including those working on urban energy transitions [41] but its implementation has encountered a number of practical challenges. These difficulties often relate to the selective inclusion of "frontrunners" (innovative pioneers) and the resulting power disparities, [42–44] which has sparked accusations of "policy design without democracy" [45]. In addition, an emphasis on consensus-building at any cost rather than openly confronting the political and social controversies embedded in transition processes has resulted in narrowing the range of alternative solutions [16]. Often, such attempts at collaboration are used to cover up and downplay the most difficult issues rather than resolve them [17,46–48]. Moreover, doubts have been raised over whether highly complex transition processes can be "managed" at all [49]. More specific problems include the lack of time and incentive to participate, the lack of knowledge and skills required to facilitate co-creation, and the cultural, institutional, organizational, and communicational differences between individuals that can easily become insurmountable barriers [15]. Indeed, a recent EASST [18] conference session on co-creation noted a lack of knowledge among scientists and practitioners on the key principles and activities that are conducive to effective and efficient co-creation processes. All of these difficulties are magnified by the challenge of integrating the social and technological strands of innovation [50,51]. It would not be an exaggeration to conclude that co-creation as implemented to date lacks a meaningful and operational definition [52,53].

Still, the need for collaboration is greater than ever given the recent focus on transitions to 100% renewable "smart" energy systems [54–56]. These are very complex changes characterized by the integration of electricity, thermal, and gas grids with storage technologies in order to identify synergies and achieve optimal solutions for the overall

[1] We prefer the term "acceptability" in place of the more commonly used "acceptance" because we see it as more applicable to empirical evidence. This is because "acceptance" refers to an end-state of a process and treats it as a dichotomous choice between fixed alternatives (i.e., acceptance or the lack thereof), whereas "acceptability" refers to an evolving process of negotiating and finding balance between a number of technological and social choices [21].

Table 1
The classification of the phases of co-creation identified by selected authors.

Authors	Voorberg et al. [60]	Nabatchi et al. [53]	Paskaleva & Cooper [50]	Spagnoli et al. [62]
Identified phases	initiation design implementation	commissioning design delivery assessment	conceptualization and decision-making design and development delivery and use evaluation	analysis design implementation evaluation

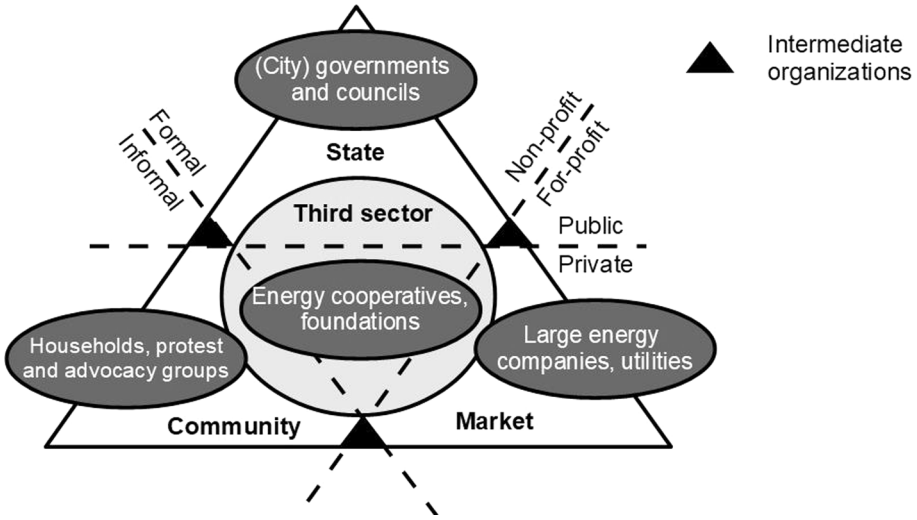

Fig. 1. The classification of actor groups in co-creation and examples from the energy sector at the organizational level (adapted from [69,70]).

Table 2
The classification of activities that foster transformative power in co-creation as identified by selected authors.

Authors	Paskaleva et al. [63]	Wolfram [9]	Mah [82]	Hölscher et al. [73]
Identified activities	arena modelling enlistment and enrolment	redefinition of place and roles	reconfiguration of relationships and institutions	enabling and anchoring novelty creation
	dialogue for vision-building	alignment of visions and expectations	alignment of interests and actions in visions	strategic alignment and mediating
	networking	networking and learning resource acquisition	networking access to structural resources	monitoring and learning

energy system. Extensive collaboration on all levels is necessary to co-ordinate the component transitions towards smart energy systems in different sectors. Therefore, we argue that co-creation holds promise for advancing these transitions, but only if the shortcomings in the existing literature are adequately addressed. In this paper, we take a first step towards filling these gaps.

3. Review type and methods

3.1. Critical narrative review

The argument developed in this paper relies on a critical narrative literature review. We opted for this type of review for two reasons. First, it allows us to draw on a more diverse set of sources, including literature on co-creation, co-production, co-design, open innovation, grassroots innovation, and social innovation. Second, it enables us to move beyond a formal description of the literature towards including a degree of conceptual innovation, resulting in a new theoretical framework [57]. The main disadvantage of a critical narrative review is the relative lack of formal criteria for the literature search and for the synthesis and analysis of the material, which might make it vulnerable to an overly subjective interpretation by the authors. The result of a critical review is therefore only a starting point for further theoretical and empirical evaluation [57].

3.2. Delineating the literature and defining co-creation

The literature was selected for this review according to three criteria: 1) a focus on collaborative approaches in the public sector[2]; 2) relevance for strategic energy planning and/or energy transitions; and 3) applicability of the ideas in an urban context. The following databases were used for the literature search: ScienceDirect, Taylor & Francis, SAGE, Google Scholar and DTU Findit. In order to uncover a wide range of literature on collaborative approaches, we used keywords that both explicitly and implicitly refer to collaboration. The specific search terms were combined from two sets of keywords: 1) “collaboration”, “co-creation”, “co-production”, “co-design”, “open innovation”, “grassroots innovation”, “social innovation”; 2) “urban energy transition”, “urban energy transformation”, “urban energy planning”. The final selection of articles from those identified through the database search was made

[2] It should be noted that "co-creation" is a term that initially emerged in the private sector. It has only recently been adopted by the public sector, where it has gained a somewhat different connotation [67]. As energy transitions are high-level political processes that are usually coordinated by the public sector and necessarily involve a wide range of actors from all sectors of society, we feel it is more appropriate to apply the definition of co-creation more typical of the public sector to the context of energy transitions. For this reason, we have chosen not to include literature on co-creation in the private sector and instead rely solely on literature on co-creation in the public sector.

based on the screening of abstracts.

To systematize the literature, we relied on the widely-used definition of co-production[3] established by Nabatchi et al. [53]: "a wide variety of *activities* that can occur in any *phase* of the public service cycle and in which state *actors* and lay actors work together to produce *benefits*" (italics added)[4]. We propose that co-creation, in the context of the public policy process, follows certain phases, includes certain actors and activities, and leads to certain benefits (which we refer to as the process' goals and outcomes). We used these categories as building blocks to arrange and analyze the literature and to create a new conceptual framework for answering our research question.

3.3. Empirical example: ProjectZero in Sønderborg, Denmark

In order to show the usefulness of our proposed conceptual framework, we applied it to an empirical example from an ongoing energy transition led by the ProjectZero organization in the municipality of Sønderborg, Denmark. The application of this framework to the Sønderborg case is not meant to represent an in-depth case study, but rather to serve as an illustrative example of how the framework can be applied in further empirical studies, and/or used to guide practice. The data for the example was collected from secondary literature [58,59], the ProjectZero website and associated documents, and the authors' own knowledge about ProjectZero.

4. Literature review

4.1. Classification of phases

The co-creation process is commonly divided into three or four key phases. For example, Voorberg et al. [60] divide the process into the co-initiation, co-design, and co-implementation phase, while Nabatchi et al. [53] describe the similar co-commissioning, co-design, and co-delivery phases, while adding a fourth phase, co-assessment. The urban environment provides an especially fitting testing ground for co-creation, by allowing the combination of real-life spaces with test conditions in "living labs" [61–63], "city labs," [64] or "urban transition labs" [65]. The collaborative innovation processes in these spaces largely follow the previously identified phases. For instance, Paskaleva [66] identifies five phases in co-creation processes in these contexts: co-conceptualization, co-decision-making, co-design, co-delivery, and co-use. In other studies, Paskaleva et al. [63] have referred to "co-development" instead of "co-decision-making," or have included both and also added co-evaluation [50]. The overall logic of the cycle remains the same. Spagnoli et al. [62] likewise divide the process into the co-analysis, co-design, co-implementation, and co-evaluation phases. Similar phases, although not defined as explicitly, can be identified in empirical research surrounding transition processes [13–15]. The various phases are summarized in Table 1, below.

Nabatchi et al. [53] claim that co-implementation and co-delivery are more consistent with traditional approaches to co-creation, whereas in practice co-initiation and co-design appear to be less common. As a result, co-implementation and co-delivery have been researched most extensively, while co-design and co-initiation have received considerably less attention in academia [60]. The lack of emphasis on inclusion in the initiation phase is especially at odds with the results of recent studies which demonstrate that "putting more emphasis on stakeholder engagement in the early stage of service development is one key element to setting up effective stakeholder innovation networks" [63]. Similarly, Torfing et al. [67] have noted that "there is much to gain from the involvement of citizens and private stakeholders in all aspects of the process and […] that this is the ultimate goal of co-creation."

4.2. Actors, roles, and power relations

In the field of energy transitions, co-creation has commonly involved actors from the "triple helix" of industry, government, and academia; this is sometimes extended to a "quadruple," "quintuple," or "n-tuple" helix [68] to include diverse actors from the broad category of "civil society". It is not always clear, however, on what basis these inclusion and exclusion decisions are made. To begin with, there is a wide range of levels of aggregation: categories such as industry and academia refer to specific organizational or institutional forms, while "civil society" comprises a wide spectrum of both formal and informal actors [69]. This can make the concept of civil society too broad for any meaningful operationalization, as it comprises a wide spectrum of both formal and informal actors [69]. The same issue emerges with the concept of "community," which can refer to a community of place (e.g. resident association), a community of interest (e.g. environmental advocacy organization), or a community of practice (e.g. a professional learning group)—any of which can be either formal or informal.

Drawing on the work of Pestoff [70], Avelino and Wittmayer [69] have proposed a "multi-actor perspective" that aims to overcome these problems by classifying actors as either formal or informal, private or public, and for-profit or non-profit (see Fig. 1). On the basis of this classification, the authors arrive at four basic actor categories: 1) the state (formal, non-profit, and public); 2) the market (formal, for-profit, and private); 3) the community (informal, non-profit, and private); and 4) the third sector (formal, non-profit, and private). In between these four categories lie a variety of combined organizational forms; for example, public-private partnerships and state-owned companies involving state and market actors. This classification helps to address the problem of aggregation by more easily distinguishing between actors on organizational and individual levels. For example, on the organizational level, "civil society" is divided into formal energy cooperatives, foundations, advocacy organizations, and associations belonging to the third sector, and families, households, and communities belonging to the community sphere. Similarly, on the individual level, the third sector is made up of activists, volunteers, and benefactors while the community sphere includes actors such as family members, neighbours, friends, and residents [69].

In energy transitions, as in other public policy processes, different actor groups tend to be associated with different roles [44]. For example, governments usually take on the role of initiating and coordinating the transition process, while large energy companies and advocacy organizations often take on the role of lobbying for and/or advising on policies, and other actors generally have the role of giving feedback or comments (or simply being informed) when called upon. Thus actors may be

[3] There has been some confusion about whether the terms "co-creation" and "co-production" refer to the same concept. In a systematic review of both co-creation and co-production in the public sector literature, Voorberg et al. [60] identify a large overlap in how the terms have been operationalized, thus arguing that they are *de facto* interchangeable concepts referring to the collaboration of citizens and governments in public service delivery processes. However, in the context of the energy sector, "co-production" might also refer to physical energy production. We therefore opt for the term "co-creation," as its meaning is less ambivalent in the energy sector.

[4] We acknowledge that this definition is perhaps too simplistic and may not capture the essence of co-creation in comparison to other forms of participation and collaboration. For the purpose of arranging and analyzing a literature review, the clear and concise nature of this definition is more useful than a more detailed conceptualization would be. However, in the event that a more precise definition is needed, we suggest Torfing et al.'s [67]: "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it."

assigned to roles in the process by others, take on and enact roles without specific intention, or purposefully take on roles and use them as resources to pursue their own goals. However, roles can also be seen as boundary objects between actors, the intermediary and temporary results of interactions that are constantly being constructed, deconstructed, and reconstructed in collaboration [71].

The balance between different roles often influences (and is influenced by) the power disparities between actors. Power can be defined as the capacity of actors to mobilize resources to achieve a goal. Avelino [72] argues that in the context of energy transitions, power can be a reinforcing, innovative, or transformative force. Reinforcing power concerns the capacity to retain and reproduce existing practices and structures, while innovative and transformative power refer to the capacity to create new resources and to develop new practices and structures. These innovations and transformations might entail new physical infrastructure (e.g. a renewed "smart" electricity grid to allow for increased integration of renewable energy), new social structures (e.g. renewed jurisdiction to allow for increased citizen participation in the electricity market), or new practices (e.g. decreased domestic energy use), all of which are vital for successful energy transitions.

Because roles constitute a type of resource, it follows that roles can be mobilized by actors to establish power to either reinforce or transform existing practices and structures, thus hindering or enhancing transitions towards 100% renewable energy. If roles are rigid, the transition process often results in a stalemate (see Section 2.1). However, based on existing literature, we propose that co-creation might produce the potential to reconstruct these entrenched roles, transcend existing power relations, and develop what has been called "transformative capacity" [73–76]. The implicit assumption is that co-creation might result in qualitatively new solutions which are significantly different from the ones that would have been achieved by conventional participation methods more commonly used in public policy processes. However, this is not something that happens simply by gathering a bunch of different people "around the table". Quite the contrary; it depends on a number of activities and preconditions that help foster the development of transformative capacity through empowerment, i.e., the process through which actors gain transformative power [72].

4.3. Activities that foster transformative power

Research on empowerment and the development of transformative capacity has grown steadily over the past decade. Empirical studies often focus on urban initiatives (partially) controlled and coordinated by local communities and/or research institutions under the label of "urban social innovation" [10,77] or "urban grassroots innovation" [9,78,79]. The valuable insights from these studies shed light on the specific activities and preconditions that are needed to nurture transformative power. Some have demonstrated the usefulness of "strategic niche management" [80,81] that rests on 1) the articulation and alignment of visions and expectations; 2) networking; and 3) social learning[5] [9,10]. Similar findings are mirrored by a number of studies. For example, Paskaleva et al. [63] have emphasized constructive dialogue and networking as key activities in urban co-creation processes because they help to establish shared visions and scenarios. Mah's [82] comparison of urban community energy initiatives in China and South Korea highlights the alignment of actors' interests and actions in shared visions and networking for the reconfiguration of relationships within and between emerging and incumbent actors. In addition, Mah [82] and Wolfram [9,10] both claim that resource acquisition is an important lever for tackling existing institutional inertia Hölscher et al. [73] have stressed knowledge creation, continuous learning and monitoring, and strategic alignment and mediation between actors as conducive to capacity development. Monitoring and evaluation are also mentioned by Paskaleva & Cooper [50] who describe them as a separate phase of co-creation and as a continuous activity. The various activities described in the literature as vital to transformative power are summarized in Table 2.

4.4. Goals and outcomes of co-creation

Questions also remain regarding the goals and outcomes of co-creation, and whether the activities involved in this process actually lead to something new. In their review of co-creation in public service delivery, Voorberg et al. [60] identify effectiveness, efficiency, citizen involvement, and citizen satisfaction as the most popular objectives and outcomes of co-creation.

Effectiveness means that the intended goals are reflected in the delivered outcomes (i.e., "the right things have been done"). More specifically, the outcomes of co-creation commonly include new knowledge about problems and solutions, new relationships or networks between actors and actor groups, and new proposals, solutions or services to address problems [5,60,83]. Efficiency means that the outcomes have been delivered in the optimal manner ("things have been done in the right way"). An optimal solution is usually one that allows for the outcomes to be delivered in the fastest or least expensive way possible. However, it might also include criteria regarding citizen satisfaction or social acceptability in the context of energy transitions. As discussed in Section 2.1 above, social acceptability can in turn be understood as micro-social, meso-political, or macro-economic acceptability, and/or all of these combined. An optimal solution for energy transitions might therefore be imagined as one that results in a cross-sector compromise on acceptable terms for all. It is important to note that this may not necessarily be the fastest or least expensive solution because these have tended to backfire in recent years due to decreasing social acceptability (see Section 2.1).

With regard to citizen involvement, there seems to be a divide between those who argue that citizen involvement through co-creation is a means for enhancing public services (Paskaleva & Cooper [51]) and those who argue that citizen involvement might also be a goal in itself [67]. For example, Voorberg et al. [60] observe that in a number of studies on co-creation, "there seems to be an implicit assumption that involvement of citizens is a virtue in itself, like democracy and transparency, thereby also stressing that co-creation as a process is a goal in itself." They also add that because of this somewhat normative bias, not enough is known about whether citizen involvement (and co-creation) is actually a useful means to improve public services, and if so, in which phases and through which activities it might be most useful.

4.5. Taking stock of the literature

After reviewing the potential phases, actors, activities, goals, and outcomes of co-creation, we can now highlight what we regard as the key takeaways.

The co-creation process is often divided into the main phases of initiation, design, and implementation. In practice, co-creation in public policy processes is currently more common in the latter phase than in the earlier phases.

Co-creation can include actors from the state, market, community, and third sector. We find that this fourfold distinction helps us to better grasp their formal or informal, profit or non-profit, and public or private characteristics and the roles and power commonly associated with them. Public and private sector actors tend to hold

[5] In the context of strategic niche management, a distinction is often made between first- and second-order learning [81]. First-order learning refers to the accumulation of directly applicable facts and know-how and is commonly guided by the question of how a goal can be achieved. Second-order learning refers to a deeper and more reflective shift in perception and is commonly guided by questions of which goals are worth achieving. Both types of learning are usually necessary in transition processes.

central, leading roles in actual co-creation processes and therefore hold more power over the goals and outcomes.

Common activities include: 1) articulation and alignment of expectations with regard to the process and its goals and outcomes; 2) social and experiential learning, including both first-order learning ("how to achieve a goal") and second-order learning ("which goal is worth achieving"); 3) acquisition of resources, including physical and material assets, financial instruments, and knowhow; 4) continuous assessment and/or evaluation of the process, goals, and outcomes based on monitoring and collecting data and/or feedback. These activities might foster transformative power, which can help disrupt entrenched roles and power relations and lead to the development of new structures and institutions.

The goals and outcomes of co-creation can range from increased effectiveness and efficiency to increased social acceptability or simply involvement (Fig. 2). While the involvement of different actors and actor groups in a representative manner is a cornerstone of democracy and therefore also of co-creation as a democratic process, attention should also be paid to whether it actually increases the effectiveness, efficiency, and/or acceptability of the transition process.

As discussed in Section 3.2, establishing relevant categories and distinctions such as these can provide "building blocks" for a new conceptual framework that can guide us in assessing co-creation in strategic planning for energy transitions. Based on the categories we find in the literature, we propose that co-creation can be assessed according to the involvement of state, market, community, and third-sector actors and their roles in the initiation, design, and implementation phases; the use of four sets of activities (expectation alignment, social learning, resource acquisition, assessment and evaluation) to foster transformative power; and the effectiveness, efficiency, and social acceptability of outcomes (see Fig. 3).

Based on this framework, one can assess and/or improve co-creation by asking the following questions:

Which actors have been involved in which phases, and which roles have they taken on?
- How have state, market, community and third sector actors been involved in the initiation, design, and implementation phases?
- To what extent has there been a reconstruction of roles and power relations?

Which activities have been used to foster transformative power?
- How have participants articulated their expectations, and (how) has alignment been reached?
- To what extent has first- and second-order learning taken place?
- How have the necessary resources been acquired?
- To what extent has there been continuous assessment and evaluation?

Which outcomes have been achieved, and to which extent?
- To what extent has the effectiveness of the transition process been improved?
- To what extent has the efficiency of the transition process been improved?
- To what extent has the social acceptability of the transition process been improved?

We now offer a brief illustration of the application of this framework with an empirical example from an ongoing urban energy transition in Sønderborg, Denmark (see Table 3 for a summary).

5. Assessing co-creation in the example of ProjectZero in Sønderborg, Denmark

5.1. Involvement of actors and their roles

5.1.1. Initiation phase

Sønderborg is a town with a population of around 28,000 and is the administrative centre for the Sønderborg municipality in southern Denmark, which is home to around 77,000 people. The municipality of Sønderborg was formed by the merging of seven smaller municipalities after a national structural reform in 2007 [58]. The municipality is characterized by a distinctive geographical mix of urban and rural areas and by a large agricultural sector as well as a significant high- and clean-tech industry hosting a number of electronics, manufacturing, food processing, and telecommunications companies. The University of

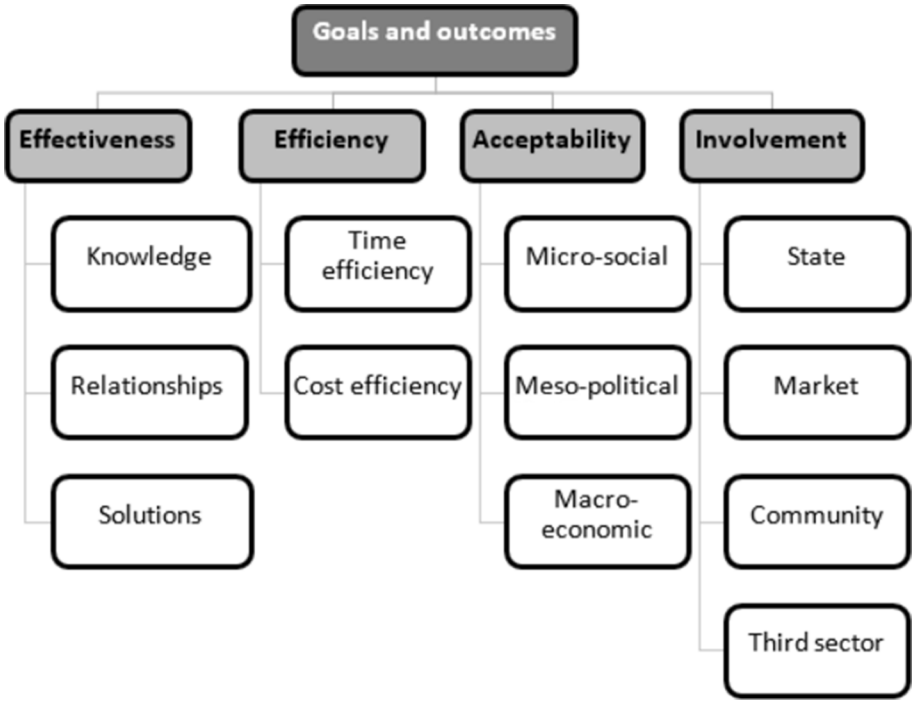

Fig. 2. The classification of the goals and outcomes of co-creation (based on [5,60,83]).

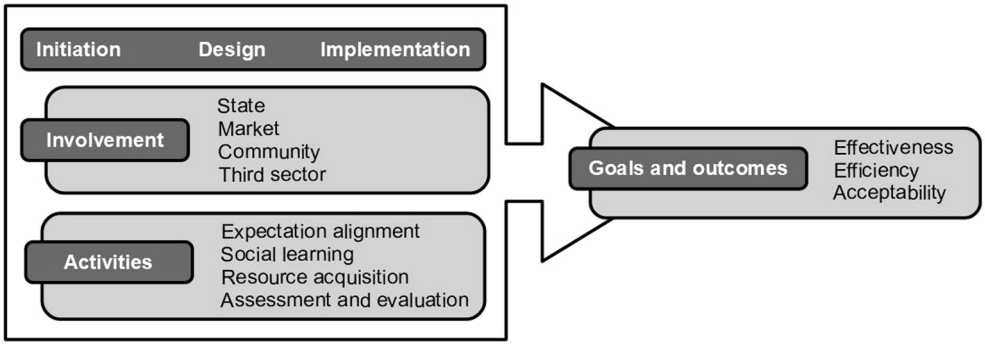

Fig. 3. Framework for assessing co-creation in strategic planning for energy transitions.

Table 3
Assessment of co-creation for energy transition in Sønderborg.

Phases	Initiation	Design	Implementation
Involvement of actors	Public-private partnership	Large energy companies, consulting agencies and universities	Large energy companies, municipality, households
Activities	· Alignment of expectations between the market and state sectors, community mainly involved in the implementation phase · Learning and competence development throughout all phases and between and within all sectors · Stable funding via annual grants from committed companies and municipality · Regular monitoring and evaluation of progress towards targets		
Goals and outcomes	· Major progress in CO_2 emissions reduction, minor setbacks in energy consumption reduction · Relatively high social acceptability of the transition in macro-economic and meso-political dimensions, some problems in micro-social dimension		

Southern Denmark also has a campus in Sønderborg. However, like most rural municipalities in the outskirts of the country, Sønderborg has for the past few decades struggled with emigration and an aging population, and is thus facing the risk of long-term socio-economic decline [59].

These issues led Asger Gramkow, a local businessman, to establish a think-tank called Futura Syd with the aim of seeking new opportunities for branding the area, creating new jobs, and maintaining economic growth, as well as uniting the recently merged municipalities. In 2007, Futura Syd published a report titled "ProjectZero: Sønderborg as the first sustainable and CO_2 neutral area in Europe," which described the potential of the area for achieving carbon neutrality based on examples of other urban sustainability projects in China and the USA [59]. A series of meetings with local stakeholders resulted in a shared vision "of creating a CO_2-neutral Sønderborg by 2029, based on sustainable growth and many new green jobs as a result" [84]. ProjectZero is now a public-private partnership between the Sønderborg Municipality, local manufacturing and utility companies, and foundations investing in green solutions [59]. The organization is responsible for promoting the vision, coordinating action, and safeguarding the commitments of actors [58].

5.1.2. Design phase

The realization of the vision is guided by the ProjectZero 2029 Masterplan, created with the input of more than 80 leading energy experts from local companies, consulting agencies, and universities. The main goals of the masterplan are 1) reducing energy consumption by 40% through increased energy efficiency and energy saving; 2) replacing all fossil fuels with 100% renewable energy provided via a smart energy system; and 3) as a result reducing CO_2 emissions to make the area carbon neutral by 2029 [85]. The specific implementation activities are laid out in 5-year implementation plans (referred to as roadmaps). The first roadmap was prepared by six task groups composed primarily of local stakeholders, with the process facilitated by outside consultants. The task groups focused on the CO_2 baseline and prognosis, buildings, manufacturing processes, transport, agriculture, and renewables. The most significant measures, both technical and social, to be taken to reduce CO_2 emissions were reflected in six beacon projects: 1) green district heating, 2) individual heat pumps outside district heating areas, 3) central biogas plants, 4) wind turbines, 5) energy renovation, and 6) business programmes (ZEROshop and ZEROcompany) [86].

5.1.3. Implementation phase

The implementation of the solutions developed in the design phase is based on the principle that all citizens, enterprises, shops, farmers, schools, housing associations, the municipality, and the energy and utility companies are preconditioned key participants in the transition process. This is achieved through a number of community engagement programmes unified under the overarching zero carbon vision. The programmes include the ZEROfamily programme, through which more than 100 families have learned how to save energy and water through behavioural changes and simple technological fixes such as new light bulbs (Fig. 4); the ZEROhome programme, which helps private house owners find the best solutions for energy retrofitting their homes; the ZEROshop and ZEROcompany programmes, which offers local shops and companies technical support and opportunities for promotion if they establish a climate change strategy with the goal of at least 10% carbon reductions within a year; and the TEST an EV project, which encourages the use of electric vehicles in the area [87]. Although community-oriented programmes have been part of ProjectZero from the start, a clear shift of focus towards deeper citizen engagement and stakeholder partnership can be seen between the first and second roadmaps [59].

5.2. Activities that fostered transformative power

5.2.1. Articulation and alignment of expectations

The establishment of ProjectZero required a cross-sector alignment of expectations in the initiation phase, crystallizing in a shared vision between the companies and the municipality. Indeed, the main role of ProjectZero has been to create a political and cultural narrative around the green vision of Sønderborg and to disseminate information on the related energy transition activities. In the design phase, however, ProjectZero refrained from taking on an active role in the articulation and alignment of options and instead assigned this role to the energy consultancies and local companies which developed most of the solutions. As a consequence, the masterplan as well as the first roadmap were highly technical documents and were only later supplemented with more specific citizen engagement strategies. The ProjectZero vision has ultimately proven successful as a major mobilization tool for community engagement; for example, in the aforementioned ZERO programmes.

Fig. 4. A ZEROfamily programme ambassador in Sønderborg. Source: [87].

5.2.2. Social learning

The ProjectZero masterplan states that "learning about climate, energy efficiency and renewable energy sources at all levels from kindergarten to PhD is essential for […] zero carbon growth" [85]. The project's learning strategy focuses on three areas: 1) increasing awareness through the general education system; 2) providing the necessary professional training and re-training through vocational education for the future workforce in the energy industry; and 3) increasing research and development relevant to the necessary technical and social solutions for energy transition in cooperation with universities and companies [86]. In the first focus area, both second-order learning about what the proper response to the climate crisis is as well as first-order learning about how to take action have been encouraged. Furthermore, it is clear that the learning goes well beyond educational institutions. The local government, involved companies, and households are all pioneering solutions in the ZERO programmes that require extensive competence development and require a high degree of experimentation and learning-by-doing.

5.2.3. Resource acquisition

From the start, ProjectZero managed to secure stable and regular funding via annual grants totalling 5,000,000 DKK (ca. €670,000) from three energy companies and the municipality of Sønderborg, as well as continuous financial support from a foundation established by Danfoss, the main employer in the area [58]. The stability of this annual funding and the long-term commitments made by the major actors have been key success factors for ProjectZero. Aside from financial resources, the project has benefitted from Denmark's well-established academic and industrial experience and know-how in renewables and energy planning, and from ambitious policies on the national level and a general public awareness of the need for green energy transitions. Local circumstances such as the pre-existence of an innovation-oriented high-tech industry and the need for a unifying vision for the Sønderborg area after the political reforms of 2007 also contributed to the cause.

5.2.4. Assessment and evaluation

CO_2 emissions and energy production and consumption in the Sønderborg area are measured and reported annually. The most recent monitoring report from 2019 shows a 44% decrease in emissions since 2007 (Fig. 5), which means that the milestone of a 50% reduction by 2020 is within reach [88]. However, it is worth noting that the method used for calculating CO_2 emissions does not include emissions from non-energy-related activities, or emissions related to the production of imported and exported goods from the area's large agricultural sector or the many industrial, food, and brick companies. Another concern is that the numbers also do not include the emissions from rail, sea, and air transport to and from the municipality, meaning that the goal of carbon neutrality does not apply to these sectors [58]. This problem was recently highlighted by the Danish environmental organization Bevar Jordforbindelsen (Stay Grounded), which claimed that the planned expansion of Sønderborg Airport would undermine the energy transition and lead to increases in emissions that are almost triple the reductions anticipated in the ProjectZero vision [89].

5.3. Goals and outcomes

5.3.1. Effectiveness and efficiency of the transition

The results of annual monitoring indicate that CO_2 emissions and energy consumption in the Sønderborg area have decreased steadily since 2007 and that ProjectZero has been effective in reaching its stated goals. Although the transition process is not expected to be completed until 2029, the reductions in emissions have already been greater than what has been achieved in most other municipalities in Denmark or indeed the rest of the world. The last two monitoring reports have, however, indicated small increases in energy consumption (mostly in industrial processes), which might point to limitations on the success of energy efficiency measures if the rising energy demand of local industries is not curbed [88].

Among the most significant projects contributing to ProjectZero's success to date are: 1) an expansion of the district heating network and replacement of fossil fuels with biomass, solar thermal, and geothermal production at district heating plants; 2) an increase in energy efficiency in industry and households through the replacement of oil furnaces; and 3) an almost threefold increase in local renewable electricity production from wind turbines and solar energy plants [90]. A significant number of new jobs have also been created as a secondary result, primarily in the construction sector due to investments in new energy-efficient buildings and infrastructure by businesses and homeowners. In addition, local economic growth has been boosted through international cooperation and the export of new green business solutions [91].

5.3.2. Social acceptability of the transition

The primary aim of ProjectZero has been to get the local government as well as the large industries in the area to support and commit to the zero carbon transition. The acceptability of the transition in the meso-political and macro-economic dimensions is therefore of paramount importance and has in practice been relatively high: there is a clear continuity in the project set-up and an ongoing expansion of the transition activities. This is distinct from most other Danish municipalities, where energy planning is highly dependent on local politics and elections. The transition has also enjoyed a relatively high degree of acceptability in the micro-social dimension. This has been largely due to the continuous and thorough strategic communication of the ProjectZero vision, the numerous citizen and community engagement programmes, and the promotion of learning opportunities for all. However, there have also been some setbacks; for instance, the development of an

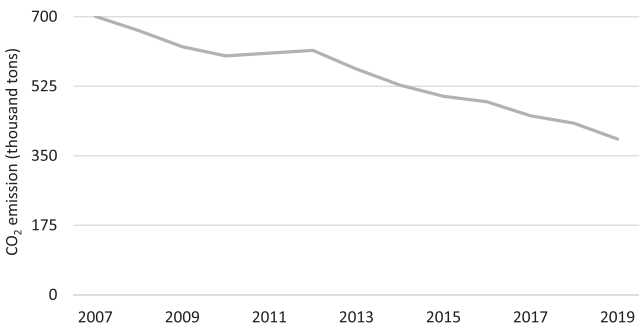

Fig. 5. Total annual carbon dioxide emission in the Sønderborg area. Source: [90].

ambitious coastal wind turbine project in Lillebælt has been stalled for years due to resistance from a neighbouring municipality [58]. Despite this, the wind farm is still included in local development plans and the mayor intends to carry out the project, as it is essential for achieving the 2029 goal.

6. Conclusion

This paper began with the observation that dominant technocratic practices in strategic energy planning often stall zero carbon and 100% renewable energy transitions. However, existing studies of more collaborative approaches to strategic energy planning, such as co-creation, have lacked theoretical rigour. This has made it difficult to assess the conditions under which co-creation is actually useful for accelerating energy transitions, rather than being simply the latest "buzzword." Therefore, we conducted this critical review of co-creation and other similar collaborative approaches in the public sector in order to answer the question, "how can co-creation in strategic planning for energy transitions be assessed?"

Based on this literature review, we developed a conceptual framework for the assessment of strategic co-creation according to the following criteria: 1) the involvement of actors (state, market, community, and third sector) and their roles in the various phases (initiation, design, and implementation) of co-creation; 2) the use of four sets of activities (expectation alignment, social learning, resource acquisition, assessment and evaluation) to foster transformative power; and 3) the outcomes of co-creation (in terms of effectiveness, efficiency, and social acceptability). With an illustrative example from an ongoing energy transition led by the ProjectZero organization in the municipality of Sønderborg, Denmark, we demonstrated how these criteria can be useful for assessing the collaborative transition process. We also suggest that the conceptual framework can be used for planning future collaborative transition initiatives.

Further research could explore in more detail the most useful methods for facilitating co-creation in the initiation, design and implementation phases in the context of the energy transition. Moreover, future studies could explore in more depth whether co-creation can be used on different scales (e.g. international, national, regional), in different energy-related sectors (e.g. electricity, heat, transport) and in different settings and contexts (e.g. in larger cities and metropolitan areas or in older, heavily "locked in" industrial regions). While we have focused on co-creation in strategic energy planning, it would also be highly relevant to analyze the ways in which co-creation plays out in spatial planning (e.g. in processes concerned with the siting and development of wind or solar farms in specific places).

Declaration of Competing Interest

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

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