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Understanding social innovation in local energy transitions processes: A multi-case study

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ABSTRACT

Social innovation (SI) in local energy transitions is gaining focus in current times but energy transitions have not yet been explicitly analysed in the context of SI. Our objective is to characterize SI in co-created local energy transitions processes through the study of three distinct cases based on energy transitions in localities in Sweden (Skåne and Dalsland) and Denmark (Hjørring). In these localities, municipality actors (MA) are engaged in increasing the adoption of solar PV systems, uptake of EV and biogas cars, and phasing out oil-burners, respectively. We analyse the three cases by following the work of the MAs and through the frame of Transformative Social Innovation (TSI), which consists of four shades; social innovation, system innovation, game-changers, and narratives of change. Subsequently, we use causal loop diagrams to characterize the SI in the oil-burner phase-out case. We see shades of SI and system innovation but there are no 'game changers' or 'narratives of change' yet in any of the cases.

1. Introduction

Rapid energy system transformations are needed in order to avoid dangerous climate change [1,2]. Energy system transitions are considered to be socio-technical transitions because they change technological regimes and the way societal systems are organized [3]. Socio-technical systems comprise of technologies, policies, politics, knowledge and other artefacts.

A sub-set of energy transitions are local energy transitions. Reference [4] explains that local energy transitions have certain different characteristics, which set them apart from general energy transitions, such as differing priorities of the stakeholders, the spatial scales and their associated complexity and ownership of transition.

Ontologically, energy transitions are often viewed through the Schumpeterian [5,6] techno-innovation frameworks, often placing technology at the centre of the transition and transition management [7]. It may be argued that such approaches do not necessarily centre the humans and societies also undergoing the transitions. As a counter to this, the last few decades have seen the emergence of social innovation (SI), and with it, its allied concepts of social enterprise, and social entrepreneurship.

European Commission defines SI as: "social innovations are new ideas that meet social needs, create social relationships and form new collaborations. These innovations can be products, services or models addressing unmet needs more effectively"[8]. This definition puts SI firmly away from marginal improvements to technological innovations involving societal elements as a by-thought, and instead emphasises that societal needs are at the forefront of the innovation.

A more comprehensive definition differentiating SI from technological innovation is proposed by Ref. [9]. Here, SI is characterised by it meeting neglected social needs, and the underlying image of social innovations combine functionalist and transformationalist aspects. Furthermore, they add that the primary impact is the well-being of the beneficiaries of SI, along with the actors involved.

In their seminal systematic review of the concept of SI, Ref. [10]

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proposes three elements to guide the analysis of SI as an innovation process. These three elements are: 1. an emphasis of social interactions between actors and social practices involving perceptions, meanings, values etc., 2. the potential institutionalization of social practices and 3. social practices are the crux of the different stages of innovation. In the above study, the authors posit that social practices and social value is the manifestation of social innovation in the context of the local energy transition.

Reference [11] stresses that the first difference between social and technical innovation lies in the intended result, that is while a technology is at the forefront of the technical innovation, in SI the social practices and processes are at the centre of the transition process. Another defining difference between the two is the immaterial structure of SI, which does not manifest as a technical artefact, but as new social practices. This is critical to understand in fields of practice which are technology-dominated, such as energy transitions. When energy transitions are assessed using a technological innovation lens, the technology underpinning the innovation gets centred and assessed, but when local energy transitions have social innovation, even if the technology is new, the novelty could be the social practices and/processes spurring the transition on, rather that the technology being the reason for the change.

More importantly Ref. [11] points out that two separate theoretical perspectives have guided the inquiry into SI, that is the 'agent-centred perspective' which is the individualistic and behaviourist approach, and the 'structuralist approach', where SI is perceived as an external structural context. This division/separation of perspectives stops one from gaining deeper understanding of SI and the interaction between agent and structural interactions as per the author. The author goes on to state that a form of understanding which integrates the two perspectives could be useful.

When [12] conducted their study of social innovation in community energy, they found that community energy initiatives are strongly focused around democratization of energy and citizen empowerment, and not necessarily around the energy technology at the base of the energy community per se.

Energy transitions have been analysed as socio-technical transitions in many literature in the transitions community [13–15]. The technological artefacts underpinning said transitions naturally place the emphasis on technological innovations. That said, there are numerous works on local energy transitions, where the emphasis has been on analysing actor-centred energy transitions at the local scale (see Ref. [4].). Simultaneously, literature also emphasises the nonlinearities and feedbacks which are present in energy transitions and especially in actor-centred transitions [16,17]. There are clear ontological differences between treating energy transitions as socio-technical and actor-centred transitions and treating them as pure technological transitions, which have implications on how local energy transitions are studied, assessed and eventually replicated [4]. Thus, using techno-innovation frameworks is clearly insufficient to understand social innovation in energy transitions.

Multiple scholars, such as [12,18] point out that the presence of technological innovations should not preclude the presence and analysis of SI in the said local energy transitions. In fact, [19] explicitly points out that even with technological artefacts being involved, the innovation could be social or societal in nature, in the form of new social practices underpinning the innovation, thus being qualified as a social innovation.

Given the nonlinearities and complex feedbacks between the different factors in the transition processes of actor-centred, local energy transitions, they may be analysed and understood using systems thinking and System Dynamics (SD), which have a history of being used to understand energy transition processes (see Refs. [20–23]), but not yet to analyse SI in local energy transitions. Systems thinking helps in understanding SI in a systematic way and may thus give an understanding as to how SI in local energy transitions improves the transitions process, why they do or don't work, among other things.

Thus, in this study we are contributing to solving the gap of social innovation not having been understood or assessed using a systems perspective by combining a social innovation lens with systems thinking to give a better understanding of social innovation in local energy transitions. The research question can be framed as follows: How can SI in co-created local energy transitions be understood?

The research question will be answered by applying a selected framework to a few cases of co-created local energy transitions, albeit happening at similar geographical spaces and propose a conceptual model of how SI is underpinning local energy transitions. A pluri-local multi-case study gives us enough opportunity to link empirical local energy transitions initiatives with the lens of SI.

The rest of the article is organized thus: Section 2 presents the conceptual frameworks used in the studied cases and these used for the analysis in this study; Section 3 presents the methods used; Section 4 presents descriptions and analysis of the cases; Section 5 presents the Causal Loop Diagrams (CLDs) of the Hjørring case; Section 6 presents discussions and, finally, Section 7 the conclusions.

2. Conceptual frameworks

This section presents first the co-creation model that the MAs used to guide their local energy transition projects, and then frameworks used for the analysis in this study, the Transformative Social Innovation (TSI) framework and the linking of TSI with systems thinking and CLDs.

2.1. Co-creation in skåne, Dalsland and Hjørring

As mentioned above, the presented study is based on three real-life local energy transitions cases set in localities in Sweden and Denmark, who embarked on a common project of co-creating energy transitions [24]. It should be stressed that the authors of this study only viewed the project and its activities as outsiders and were not involved in the carrying out of the project. The local energy transition projects were instigated by the municipality actors (MAs), after a public open consultation process. In the localities the three cases are set in this study (Skåne, Dalsland and Hjørring), the MAs belonging to the local public bodies undertook to engage in co-creation of energy transitions. The MAs are public officials attached to public administration bodies whose mandate is to officially carry out activities related to energy within their jurisdiction.

In scholarly literature, co-creation has been tackled as actions whose objective is to give lasting solutions to the parts of the society that require it, and at the same time, co-creation is just not the production of solution/outcomes but also the process of innovation.

Hence, it is clearly an allied concept of social innovation [25]. According to them co-creation has four aspects, which are:

1. Co-creation's objective is to give lasting solutions to the parts of society that require it; a society which has needs and challenges.
2. Co-creation changes the social relationships between the stakeholders, in that it changes the context in which existing practices used to happen.
3. For co-creation to give solutions that matter and are relevant to the society's needs, relevant stakeholders are involved in the design, implementation or adoption of an innovation for the society.

4. And finally, co-creation is not just the production of innovation but also the process of producing that innovation.

These four aspects show that co-creation and social innovation are connected concepts. The essence of the above description shows that similar to SI, the purpose of co-creation is to give solutions to parts of society that needs it. Furthermore, these solutions come with various stakeholders involved in creating them, and the solutions result in changes in existing social relationships between stakeholders. This is essentially the same as the definition of social innovation.

The MAs extensively used a model by Ref. [26] for improving their understanding of co-creation and as a guide to determine their positioning regarding the co-creation of local energy transitions in their respective localities. Reference [26] typified co-creation in local contexts as four categories based on the level of participation of the MAs and the certainty of the outcome of the co-creation activities. The four categories were placed on two perpendicular, intersecting axes. The horizontal axis is a spectrum with the left extreme being the MAs having a central role in the co-creation, and the right extreme being that citizens and civil society have a central role. The vertical axis is a spectrum with the upper extreme being unpredictable/uncertain outcome and lower extreme being predictable/certain outcome. Subsequently, the four quadrants are named ***Equal co-creation*** (central role of MAs and uncertain outcome), ***Facilitated co-creation*** (central role of civil society and uncertain outcome), ***Managed co-creation*** (central role of MAs and certain outcome) and ***Responsible co-creation*** (central role of civil society and certain outcome).

In the four categories, the MAs placed themselves in the Facilitated co-creation category. While they instigated the co-creation process, the MAs in each of the cases were very clear that they facilitated co-creation and did not direct or manage or coerce the transition against the will of the residents. This is important because they did not see themselves as just being involved in municipality lead interventions but rather that they created new social practices that lead to the energy transitions and created new avenues for transitions processes to take root. In the case of the MAs from Skåne, they remarked that ‘ *… we never tell the people who come to our meetings that they need to buy solar PV panels for their home. But rather we tell them we are here if you need to discuss this with someone, especially someone who doesn't stand to get any money benefit out of it …* ‘.

Similarly, in Dalsland the MAs stated that ‘ *… most of the people in Dalsland did not know about the Bonus Malus (the subsidy and extra tax) system in Sweden, they were initially angry at us for hiding it from them, but then we told them we want to make them talk to us, and see us as a viable partner, and that is free information …* ‘.

The MAs defined co-creation as “municipal and private actors' joint efforts to solve common problems through constructive exchange and application of experience, resources, skills and ideas”. They also defined the five underlying principles of co-creation as being: (1) Transparency; (2) Common learning; (3) Energetic and active commitment; (4) Open and flexible processes; and (5) Dialogue [24].

2.2. Analysis framework: transformative social innovation (TSI) and system thinking/system dynamics

The premise underlying the formulation of the Transformative Social Innovation (TSI) framework, built on sustainability transitions theory, is that the TSI is the process through which SI challenges, alters and/or replaces dominant institutions [16]. Reference [16] also points out that while SI has been prescribed as a panacea, wider and deeper scrutiny is needed as short-sighted solutions for persistent societal problems may exacerbate the problems or lead to negative unintended consequences. Thus, they make the case that SI analysis and praxis should look beyond simple linear causalities and overtly apparent cause and effect paradigms.

The TSI by Ref. [16] is used as a framework to explain the different SI present in the different cases analysed here. The ‘transformative’ in the TSI is taken to mean irreversible, persistent adjustment to societal values, outlooks and behaviours. Reference [16] propose the theory of TSI as something needed to bring about sustained and meaningful change and have explained that they see the TSI as consisting of four different elements, or shades, which have some overlap with each other. These four shades of TSI are the social innovation, the system innovation, the game changers and narratives of change, and define transformative social innovation as resulting from the specific interactions between these four shades. The meaning of these four shades is further explained in Table 1.

Social innovation is the first step in TSI, which is then promulgated through system innovation, game changers and finally embedded societally as narratives of change. Reference [16] defines the social innovation as a change in social relations, involving new ways of doing, organizing etc. The system innovation is the change at the level of societal sub-systems, including institutions, social structures and physical structures. The game-changers are the macro-developments that are perceived to change the playing field, and the narratives of change are the overall discourses on changes that come about, with changes in sets of ideas, concepts etc. It should be noted here that game-changers and narratives of change take time to manifest and to be observable, especially in the fields of practice of social innovation and, thus, while we are using these four shades of TSI in analysing the multiple cases in this study, we can only hypothesize as to what the game-changers and narratives of change are. While we are carrying out an ex-post analysis of social innovation in local energy transitions, the time-scale does not permit us to actually report on any game-changers or narratives of change.

Given the objective of our study, which is understanding SI in local energy transitions, the TSI is a useful framework given its delineation of the different shades of SI and to further the understanding of the dynamics underpinning local energy transitions and the dynamics brought about due to the SI in the transitions processes. Thus, the three cases of local energy transitions are analysed through the frame of TSI.

An extension of the TSI through coupling with systems thinking and system dynamics (SD) could be appropriate since 1. TSI is built on socio-technical transitions theory and systems thinking is a suitable method to understand socio-technical transitions; 2. combining systems thinking with TSI may lead to understanding the possible roles of SI in local energy transitions, the possible benefits of SI in local energy transitions and how SI impacts local energy transitions, and it also may provide potential ways in which SI can be used to effect local energy transitions; and 3. this coupling also enables exploring how the combination of these two frames or methods, TSI and systems thinking (CLDs) may contribute to the understanding of SI in local energy transitions.

Reference [27] defines systems thinking as the ability to see the world as a complex system, in which we understand that ‘you can't just do one thing’ and that ‘everything is connected to everything else’.[1] System Dynamics (SD) is an approach to understanding the nonlinear behaviour of systems over time using stocks, flows, internal feedback loops and time delays [28].

The primary reason for using systems thinking methodology is

[1] Systems thinking, and system dynamics are extensively written about in Ref. [27].

Table 1
Brief description of the four shades of the TSI framework, adapted from Ref. [16].

Shade	Description
Social Innovation	Social Innovation is conceptualized as changes in established social relations, social practices, and new ways of doing things and organizing in societies. The 'social' in Social Innovation reflects that the object of innovation is fundamentally a social phenomenon.
System Innovation	System Innovation is conceptualized as a process of structural change at the level of societal (sub)-systems with functional and/or spatial delineations. Here, societal systems transformation can be structural transformations affecting patterns, physical infrastructure, policies etc.
Game-changers	Game-changers are conceptualized as macro-phenomena (events, trends and developments) that change the 'game' of societal interaction (the rules, fields and players). These game-changers lay down new rules of societal transactions and create changes in the society.
Narratives of Change	Narratives of Change are conceptualized as sets of ideas, concepts, metaphors, discourses or storylines about change and innovation. These narratives may be on the changes occurring or having occurred at the societal level such as the narrative of change on the 'social economy'. The narratives of change could also be brought forth by social innovation initiatives to counter existing framings and discourses.

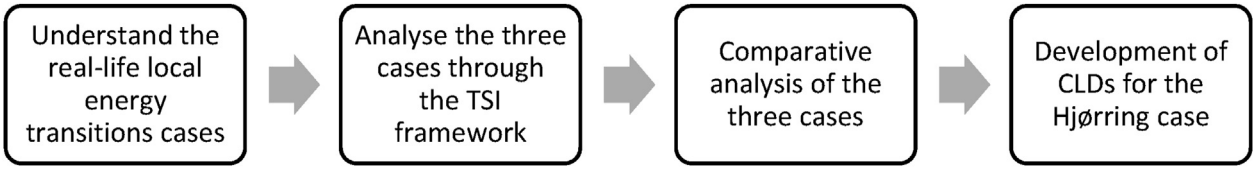

Fig. 1. The method flow undertaken in this study.

that often when looking at socio-technical transitions, which local energy transitions are often described as, the cause and effect are not directly apparent to the observer, and the cause and effect do not have a linear relationship. Repeated experiments show that the human mind is not capable of comprehending and/or estimating real-life non-linear relationships or the delays between causes and effects [27].

Systems thinking provides a method for systematically looking at the causal relationships between the different factors (and variables) in a local energy transition (see Ref. [17,29,30]). It also provides an ideal method to analyse and understand the hard-to-gather feedbacks between social innovation in local energy transitions and the process of transitions.

The reasons for using CLD within the domain of systems thinking is that CLD is a useful tool to elicit the mental models about certain real-life processes, and in understanding the feedbacks between different factors [31,32,33]. The CLDs are an important tool for representing the feedback structure of systems. A CLD consists of variables connected by arrows denoting the causal influence among the variables. A causal link can have a positive or negative polarity. A positive polarity implies that an increase in one variable results in the increase in the connected variable. Conversely, a negative polarity implies that increase in one variable results in the decrease in the connected variable. Likewise, loops can also be positive or negative. Positive loops are called reinforcing loops and negative loops are called balancing loops.

3. Methods

This section presents the methodology adopted and implemented in this study. The authors conducted 'follow research'[2] (research from the outside) of the three real-life local energy transitions cases, analyse the cases through the TSI framework and, subsequently, carried out a comparative analysis of the three cases. Following this, an in-depth analysis of one of the cases was done by extending the TSI with causal loop diagrams (CLDs), part of the System Dynamics method (belonging to the systems thinking domain). A pictorial depiction of the method flow is given in Fig. 1.

[2] Authors have coined the term 'follow research' as translated from the Danish term adopted by the project administration 'følgeforskning'.

3.1. Understanding the real-life local energy transitions cases

The term follow research indicates that we followed the project activities of the MAs and formed theories from what we found out. The 'follow research' of the three cases was conducted by following the reporting of the different actions taken by the different actors in the real-life local energy transitions cases. In the three cases, municipality actors (MAs) were engaged in co-creating local energy transitions in different ways.

The MAs are officers working in the public sector at the municipality level who are in-charge of energy and related environmental actions in the local area. These officers are funded by the municipality budget and in some cases by external funding from other EU projects as well. Their expertise is on implementing energy projects. In the three real-life transition cases, the MAs were working on these specific projects, among some others.

In the three cases, the MAs acted as co-creation facilitators, engaging in actions which they deigned to be co-creation of the local energy transitions with residents. These co-creation activities ranged from information meetings with residents as willing participants of the energy transitions, exhibitions and events, and other novel engagement activities. The intention behind these activities was to find solutions to common problems of energy provision/clean energy access together.

We conducted semi-structured in-depth interviews of the MAs and participated in the workshops and study-visits organized as part of the undertaking of the project. We read and analysed the bi-monthly written status reports of the three different projects (which are the cases in this study), the activity reports of the projects, the transcripts of the focus-groups the MAs carried out among the residents of the locality, the data from the questionnaire survey the MAs carried out among residents and the bi-yearly detailed status reports. We also understood the ethos of co-creation that the MAs accepted from their knowledge reports and project plans.

We also spent many hours, on multiple occasions, talking to and getting the MAs to reflect on their co-creation activities, and asking questions about their experience in the local energy transitions projects. In total, we had three separate interviews with each group of MAs of each case. These interviews lasted an average of one hour. All interviews except one were conducted face-to-face. A voice recording device was used to record the interviews, with the

explicit permission of all parties involved.

We developed the questions based on our perspective and understanding of local energy transitions and co-creation lead local energy transitions. The answers to the questions posed were then categorized to explore the four shades of TSI.

The textual analysis of the multiple written works which were generated as part of the project, the textual analysis of the focus-group transcripts and questionnaire survey and the answers to the in-depth questions posed to the MAs was the primary method of understanding the local energy transitions case.

3.2. Analysing the cases through the transformative social innovation (TSI) framework

Following the follow research, first an inductive analysis of the data and information collected, the project documents, the in-depth interviews with the municipality actors, and the reports of the project workshops, was carried out guided by the question of what/how social innovation is driving the co-created local energy transitions. The results of this inductive analysis of the three cases were then analysed using the TSI framework by categorizing the actions and activities undertaken in the four shades of TSI: social innovation, system innovation, game changers and narratives of change.

3.3. Comparative analysis of the three cases

After the TSI analysis using the four shades of the three cases the outcome of the different cases was compared in order to detect similarities and differences.

3.4. Development of the causal loop diagrams (CLDs) for the hjørring case

Given the non-linearity of transitions and of SI processes, and the research objective of this study, using CLDs to complement and extend the TSI framework is a new way of deepening the understanding of social innovation and TSI. Thus, in the fourth step, we extended the TSI framework with CLDs in order to help both researchers and practitioners to understand SI in the context of energy transitions processes, while aiding the analytical understanding of the energy transitions processes impacted by SI.

A conceptual model of the local energy transitions case of Hjørring was constructed using causal loop diagrams (CLDs). The Hjørring case was chosen for this additional analysis because it presented challenges for the MAs and also had in-depth participation of residents in the co-creation activities, but still was challenging in terms of getting the initial participation going. There was also some form of opposition to the co-creation activities, which will be explained in the subsequent sections.

The variables in a CLD are often determined by the context and situation that is to be depicted or analysed. Thus, we used prior acquired knowledge, our experience in studying the project cases, analysis of the interviews with the MAs, and also our intuition in determining the variables of the CLDs. The modelling of the CLDs did not happen in isolation. We obtained input from the MAs associated with the case in terms of what variables were relevant to the model. We also determined the polarity of the relationships between the variables through theoretical learning and reality.

We modelled only the Hjørring case to highlight the methodological benefits of using CLD along with the analysis through the TSI framework. This analysis, of an energy transitions process using CLDs, builds on the work done in Refs. [29,34].

The process of building the CLD was a multi-stage iterative processes as detailed in Ref. [29]; which was also spurred on by the trust and transparency which was built up during the project, between us and the MAs. It was important to understand the processes that were being put into motion by the MAs, and this real-world practice was translated into variables and feedback loops in the CLD.

4. Case descriptions and TSI analysis

This section presents brief case descriptions and the CLD constructed to represent local energy transitions cases and the social innovations in them. Ref. [24] presents the overall description of the project and the real-life cases that the authors follow. The current article only analyses three cases out of the four Ref. [24] details.

4.1. Solar PV diffusion in skåne

Skåne is a county in southern Sweden home to Sweden's third largest urban agglomeration (Malmö). The Skåne county has the highest solar electricity potential in Sweden, due to its southern geographical location. Despite that, recent studies show that the utilized potential is less than 10% of the total possible technical potential. Given this, the MAs of the Skåne county administrative board's Energy Office *(Energikonteret)* were attempting to co-create the diffusion of household solar PV panels in Skåne.

The municipality co-creation actions are centred around providing information related support to the potential households who are looking to invest and are curious about solar PV panels. For this, they conduct information meetings and invite members of households who have already installed solar PV panels. These information meetings were also a venue in providing cost and benefit details of having a solar PV panel installed in a household in southern Sweden, along with details such as how much of savings to expect. Energy advisors (EAs) attached to the Skåne county (and the encompassing municipalities) also participated in these information meetings. They were engaged in giving advice regarding the sizing and location of the solar PV panels among other energy advice.

In information meetings arranged by the MAs, the MAs also encouraged the participants to form study circles, such that these circles would act as ready repositories of information for households interested in installing solar PV panels at their homes in the future.

While discussing the project and the co-creation activities with the MAs, they noted that in Skåne, Sweden, the public have elevated and unrealistic expectations of solar PV panels; *"They (the potential solar PV owner) expect their entire house's electricity needs to be met by the solar PV panel, which is impractical and unrealistic at current times. So, we somehow have to bring their unrealistic expectations down without dampening their enthusiasm."*

In this way, the MAs, through the information they give reduce the gap between the expectations and reality, thus also increasing the likelihood of a household investing in a solar PV panel. The co-creation actions of the MAs increase the information availability and thus increases the likelihood of a potential household deciding to buy a solar PV panel. The transition dynamics of this is discussed in length by Ref. [29].

According to the MAs, the biggest barrier to the diffusion of solar PV in Skåne is the upfront investment cost, despite the government subsidies; *"Currently, the payback period is around 10 years in Skåne, if this can come down to seven years, that is the sweet spot. For 100 000 kroners (Swedish currency), it is difficult for people to think beyond 10 years"*.

This is also in line with findings in the literature [35,36]. Currently, the cost barrier is not being reduced by any dedicated co-

creation activities but there are several possible innovative solutions, which may be characterized as social innovation, such as co-ownership of solar panels among multiple households or communities etc. The neighbourhood Djupadal provides an example of a group of neighbours having expressed interest in installing co-owned solar PV panels. One MA said this of the possible co-owned solar PV panels; *"We are keeping our fingers crossed about Djupadal, but we are not pushing for it, we want whoever is joining to come together by themselves"*.

4.1.1. The analysis of the solar PV case using the TSI frame

As co-creation partners in the project, the potential households' relationship with the MAs has changed, with the MAs being sources of information regarding the technical and cost details of the solar PV technology. At the same time, the MAs are also facilitators of information flow and support the transition, with the fora they provide for the establishment of the study circles. Thus, the method of information transfer and the role of the MAs in the local energy transition points towards social innovation in this case.

The consumers, as a result of the diffusion of solar PV, became active prosumers and the nature of their relationship with the utilities changed. The co-creation activities and the intended outcome of solar PV diffusion in the households did impact on the system innovation of self-generation, with micro-production of electricity. This had the possibility of impacting the price and variability of electricity and impacting the households' electricity consumption patterns. Thus, system innovation in the solar PV diffusion case is the feeding in of electricity and the utilities' willingness to purchase the fed-in electricity.

A sustained trend of grid connected, decentralised electricity generation through solar PV panels would eventually 'change the game' of the grid and electricity supply, and thus also impact upon local electricity security and grid stability. At the same time, the way the potential households view and interact with MAs can radically change also in other areas of energy use/energy services and need not be limited to the field of electricity/self-generation. This aspect of SI could be a 'game-changer' as well but was not observed during the time the follow research was conducted.

In the case of Skåne, a plausible narrative of change was the proliferation of co-owned solar PV among the households and the sharing and security of electricity among self-organized communities or neighbourhoods, beyond the profit motive.

In terms of the shades of TSI, while social innovation and system innovation were present, we did not yet find any 'game-changers' and 'narratives of change' as of December 2018.

4.2. AFVs uptake in dalsland

Dalsland *kommunalförbund* is a collection of five municipalities, namely Åmal, Mellerud, Bengtsfors, Dals-Ed and Färgelanda, in the county of South-Western Sweden. The MAs belonging to the Dalsland Environment and Energy unit *(Miljö-och energiförbund)* were carrying out activities to increase the uptake of electric and biogas cars in Dalsland. In 2017, there were approximately 25 000 cars in Dalsland, and less than 2% were electric and biogas cars. The goal of the project in Dalsland in co-creating the transition to biogas and electric vehicles (EVs) was to increase the number of EVs and biogas cars to at least 10% of the total cars in Dalsland by 2020.

The transition dynamics from fossil fuel cars to alternative fuel vehicles[3] (AFVs) were driven by the likelihood of people buying an AFV and hindered by the uncertainty they perceive in AFVs.

The MAs co-creation activities were designed to increase the likelihood of people choosing AFVs and to reduce the uncertainty. The MAs conducted information meetings and seminars where they involved owners of EVs to present their experiences and give pertinent information to prospective buyers of EVs.

This directly increased the availability of information about EVs, which led to increasing the likelihood of a person buying an EV. The likelihood of buying EVs was reduced if the uncertainty regarding the EVs was high. The uncertainty about the EVs was a manifestation of the lack of availability of charging infrastructure and technical know-how etc. The uncertainty of EVs was reduced by the availability of charging stations, which was achieved by the MAs working with utility actors to install charging stations. The MAs also had meetings and discussions with both garages and car retailers to offer technical services to EVs and to have EVs available for being bought by the general public.

The personal utility an EV represents to an EV owner is also important in increasing the likelihood of a person buying an EV. The personal utility increases with a positive perception of the EV and also with the word-of-mouth. The word-of-mouth is created by the information meetings and the activities of the MAs, and the word-of-mouth also leads to a positive perception. Unrelated to this, the profitability of EV over fossil fuel cars is also an important factor in increasing the transition to EVs.

In reality, the transition to EVs is not happening fast enough, but the 12 months from October 2018 to October 2019 saw an increase in the number of EVs sold in Dalsland [37]. Despite the cost of EVs being too high in comparison to the perceived utility of the EV, the co-creation activities of the MAs were having an impact on the transition to EVs.

The MAs conducted information meetings and seminars about biogas cars, and also worked together with the car retailers, in order to encourage them to have biogas cars available for purchase. Another important activity they carried out was liaising with biogas fuel actors to have biogas filling stations in Dalsland, which may induce people to consider buying biogas cars, and also reduce the uncertainty associated with the fuel availability. Similar to the EV transition, the 12 observed months saw an exponential increase in the biogas cars sold in Dalsland, especially in the two municipalities with biogas fuel stations [37,38]. These two biogas fuel stations are a result of the effort put in by the MAs to help the fuel actor get financial help from the Swedish state. The municipality offices in Dalsland have shown interest in investing and buying biogas cars for municipality use, but it is unknown whether this is sufficient to sustain the demand for biogas fuel such that it encourages other individuals to buy biogas cars.

Furthermore, it is also important to understand that the transition dynamics also involves the competition between these two AFVs, that is, the EVs and biogas cars. The dominance of one over the other depends on the relative likelihood of buying one AFV over the other.

4.2.1. The analysis of the AFVs case using the TSI frame

As with the solar PV case, the fundamental nature of the relationship of the MAs to the different stakeholders in these co-creation activities are changed. In addition to liaising with potential biogas fuel actors about possible government funding to establish biogas filling stations, the MAs were instrumental in promoting the installation of EV charging stations in the five municipalities in Dalsland. By organizing information meetings, and during these meetings giving out information about the government subsidy for EVs and biogas cars, they created new channels of information, subsequently also changing their role in the society. Also, through their public procurement policies, the MAs are trying to increase the trialability of the AFVs, which is again a novel aspect.

[3] Here, the common name of alternative fuel vehicles is given to both electric vehicles and biogas cars.

Thus, there were clear indications of social innovation.

The system innovation in this case was mostly the establishment of charging infrastructure for EVs and fuel infrastructure in the form of biogas filling stations in some of the municipalities in Dalsland. Often, the lack of charging or fuelling infrastructure is a barrier to the proliferation of AFVs. Also, in this specific case, the system innovation is a radical departure from the existing fuelling systems and infrastructure (fossil fuel). The system innovation also signals a change in the establishment of retail outlets of EVs and biogas cars, and establishment of peripheral services such as garages.

In the case of the transitions to AFVs, there is direct continuity from social innovation to the system innovation shades. With the co-creation activities of the MAs establishing information channels about AFVs having taken place in parallel to the establishment of charging and fuelling infrastructures, the social innovation shade has co-existed and followed the proliferation of the infrastructural systems in Dalsland, which is the system innovation shade.

There were no observed 'game-changers' in the AFVs case during the time of our follow research. The 'narratives of change' would be the electrification of mobility and the use of biogas extensively for all transport needs but this was not observed in Dalsland, and probably it would take a few years for these 'narratives of change' to emerge, if at all.

4.3. Phasing out oil-burners in hjørring, Denmark

Hjørring municipality, located in Northern Denmark, is home to approximately 65 000 people, with a number of households of approximately 31 000 in 2018 [39]. In 2016 there were still approximately 5 000 household oil-burners in Hjørring, especially in detached houses. The MAs were doing activities to co-create the transition to phase out oil-burners. The objective of this case was to phase out 500 oil-burners from the municipality of Hjørring, that is, phase out 10% of the existing oil-burners, between 2016 to end of 2018.

The MAs acted as information givers and instigators of the conversation regarding oil-burners in the municipality. Identifying and then approaching the different stakeholders for the oil-burner phase out transition process, such as current owners of oil-burners, former owners of oil-burners, the heating, ventilation, air-conditioning technician (VVSer[4]), the retailers and the chimney cleaners was instrumental in helping the oil-burner phase-out and can be used to explain the transition dynamics. The willingness to consider other heating options increases with information about these options, and the social innovation shade of this real-life case does this. The role the MAs are playing in this case is different to their traditional roles (traditionally limited to administrative duties) and signifies a break away from the traditional way of *'doing business'*. The MA had this to stay about the co-creation activities; *"This was a new experience for us, to go to people directly and ask them what do they want to know about home heating, what is important for you. We didn't know what was going to happen, but we had to do it. Somebody had to do it"*.

4.3.1. The analysis of the oil-burner phase-out case using the TSI frame

Social innovation in this case was through the above presented new method of information dissemination regarding new heating methods.

There was no established system innovation in the oil-burner phase-out case in Hjørring yet. One future system innovation could be firm-operated heat-pumps taking on a role similar to that of traditional district-heating grids, that is, households buying the heat from large heat-pump operators rather than owning their own individual heat-pumps.

The MAs tried to inculcate 'game-changer' mentality, attempting to recruit 'middle-men' from residents of Hjørring with oil-burners who would be willing to volunteer to organize the citizen and town-hall meetings with the MAs. This attempt was made so that the MAs could take on a facilitators' role if and when the residents' decided to phase-out their oil-burners while the volunteer residents themselves could act as *change-agents* within the different communities in the neighbourhoods in Hjørring municipality. Unfortunately, none of the residents volunteered to be *change-agents*.

The MA had this to say about the change-agents; *"We asked a lot if anyone wanted to be middle-men, we asked them again and again 'please come and help us to reach other people', but people did not come"*.

While no concrete reasons were given for this, the MAs surmised that lack of time was the main reason. On the other hand, the participation in other social innovation processes, such as the energy advisor (EA)-lead 'Become your own energy advisor' meetings and the ensuing 'Tupperware'[5] parties lead to more people being reached regarding the transition from oil-burners to other heating options and cost and benefit analysis. Also, the recruitment/purchasing of EAs was a departure from traditional municipality action, in the case of Hjørring.

If this transition case can inculcate and lead to the uptake of citizens being actively involved in phasing out oil-burners, and more active interest in energy decisions, this would signify a narrative of change in the Hjørring municipality. This would also change the way household energy decisions are taken since the households would have a better understanding of the cost and other non-cost related factors associated with energy decisions in their homes.

4.4. Comparison of social innovation in the three cases using the TSI framework

In the case of solar PV diffusion of Skåne, the MAs were very clear that they give the needed information, advice and explain about the practicalities of installing a solar PV panel only to residents who ask them for help. Also, they encouraged the involvement in study circles without the participation of themselves. They encouraged the residents to carry on the study circles even after their involvement in solar PV panel discussion was over, in order to foster more interest among prospective installers. The traditional relationship between an MA and the resident were changed during the course of this case. The MAs became a source of information and help with respect to solar PV panels, and they also became facilitators, often facilitating the free exchange of pertinent information. If enough people install solar PV panels, and enough people get together to have co-owned solar PV panels, the way solar electricity is fed into the grid and the pricing structure will have to change. This was not observed in Skåne.

In the case of AFV diffusion in Dalsland, the MAs acted as catalysts, liaising with the charging station and potential biogas stations operators and garage services providers; and also discussed the transition to AFVs with residents who were interested. In fact, an owner of an EV volunteered to participate and help anyone not sure about buying an EV and gave his time for the information

[4] VVSer is the shortened form of värme-, ventilations-och sanitetsarbete

[5] Tupperware is a type of food-containment device, and in this case was the name given to the get-togethers.

Table 2
The brief overview of the three transition cases using the TSI framework.

Cases	Social innovation	System innovation	Game-changers	Narratives of Change
Solar PV diffusion in Skåne	The method of information dissemination is new, with the establishment of study circles. The MAs also have a new role as facilitators of solar PV diffusion.	The relationship between the residents and the MAs has changed. The residents have access to the MAs and can request help with technical and other doubts over solar PV installation.	No observed game-changers yet.	Narratives of change have not been observed yet.
AFV transition in Dalsland	The method of information dissemination is new with organizing meetings and demonstration meetings. The method of trialability is also changing, with the availability to try EVs and biogas cars.	Clearly, the physical charging stations have brought about a system innovation, with the town centres having charging-while-parking stations.	No observed game-changers yet.	Narratives of change have not been observed yet.
Oil-burner phase-out in Hjørring	The method of information dissemination is new, with town-hall meetings and focus groups.	No system innovation seen yet.	No observed game-changers yet.	Narratives of change have not been observed yet.

meetings.

In the case of phasing out oil-burners in Hjørring, the MAs attempted to recruit residents as 'middle-men' in the project, to organize town-hall meetings which bring to the fore the problems residents with oil-burners face in transitioning to another form of house-heating. This attempt of recruiting residents into the co-creation process was not successful as many people did not feel inclined to volunteer, and the residents who did so could not dedicate their time as other life activities got in their way. Thus, even the planning of town-hall meetings and the involvement of the VVSer and the heat-pump companies had to be done by the MAs.

Table 2 presents the brief analysis of the three cases using the TSI framework. In all three cases social innovation is present and system innovation is present in the solar PV diffusion and AFVs cases (as analysed in the previous sections). However, in all three cases the authors were yet to see game-changers and narratives of change. The game-changers in the future for the solar PV diffusion case may be the exploration of differing feed-in tariffs and structures for co-owned solar PV panels, and institutionalized guaranteed feed-in tariffs. In the AFVs case, a future game-changer would be the installation of biogas filling stations or charging stations in common and public places. While social innovation and system innovation were present, whether narratives of change happen may only be observed as time goes on. Narratives of change are built up over time, with the transition becoming the common-place thing.

In all three cases, social innovation was enacted through the new social practices established with municipality actors facilitating the interested residents'/citizens' efforts to transition to solar PV prosumerism, AFVs or phasing out oil-burners. System innovation manifested itself in different ways, which was a progression from social innovation towards transformative social innovation, in the shades of the TSI framework. In all three cases, it was yet to be seen if this step is going to bring about lasting change in the challenge of achieving sustainable energy transitions. While system innovation changes such as the installation of electric charging facilities and the installation of biogas filling stations are physical and changing the ways of providing energy, whether these system innovations will lead to lasting change is uncertain.

This uncertainty was further compounded in the Hjørring case of oil-burner phase out. There was no indication that the social innovation discussed previously in the Hjørring case was going to lead to system innovation, despite the steps taken by the Danish government, or the efforts taken by MAs, the EA and other concerned citizens. Nonetheless, as previously discussed, not all social innovations lead to expected or anticipated changes, which is a caveat that needs to be borne in the mind of all practitioners involved.

5. The causal loop diagram of the Hjørring case

In order to better understand the Hjørring case, the TSI framework was complemented with a system dynamics analysis using CLDs. This is presented in this section, with a focus on understanding the transition processes, and thus two CLDs are presented; Fig. 2 presents the CLD from the start of the project (November 2016) until November 2017, and Fig. 3 presents the CLD from December 2017 until September 2018. For ease of notation, the authors will denote the CLD in Fig. 2 as the initial CLD and the CLD in Fig. 3 as the final CLD.

In Fig. 2, the initial negative feedback loop is given by the three variables **Households with oil-burners, Willingness to consider other heating options** and **Phasing out oil-burners**. The **Willingness to consider other heating options** is positively linked with **Awareness of other heating options**, **Availability of other heating options** and **Performance of other heating options**.

The **Willingness to consider other heating options** is negatively linked to the **Relative cost of other heating options**. The implication of this is, in simple terms, when the relative cost of other heating options such as heat-pumps increases, the willingness to consider heat-pumps reduces among the residents with oil-burners.

The municipality action, in the initial actions was concentrated on creating awareness of other heating options, which they did through extensive citizen meetings and town-hall meetings. In Fig. 2 this is represented through the variables **Municipality action** positively linking to **Citizen meetings**, which in turn positively links to **Awareness of other heating options**.

Through their focus group meetings, the MAs found out that some earlier versions of heat-pumps had a bad reputation/word of mouth among the residents of Hjørring, and this was stopping them from changing to heat-pumps. But, the present technological status of heat-pumps is better. So, the MAs also communicated with the VVSer in the locality and enlisted their help in spreading awareness of the performance of heat-pumps and benefits that accrue from heat-pumps and other more sustainable heating options. The MAs liaised with the local VVSer to offer technical advice to the participants of the town-hall meetings. This is shown by the positive link from **Municipality action** to **VVSer and service offered**, which has a positive link to **Performance of other heating options**.

Despite all these positive links to influence the phasing out, the biggest barrier, the relative cost of other heating options, was still

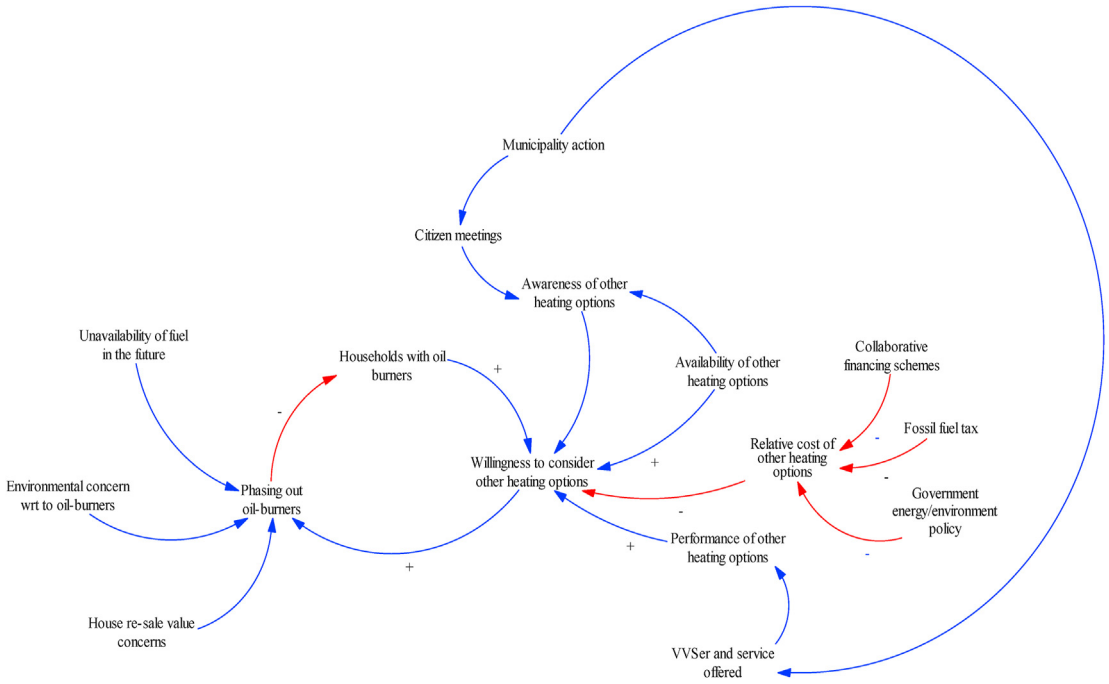

Fig. 2. The initial CLD for the phasing out of oil-burners in Hjørring.

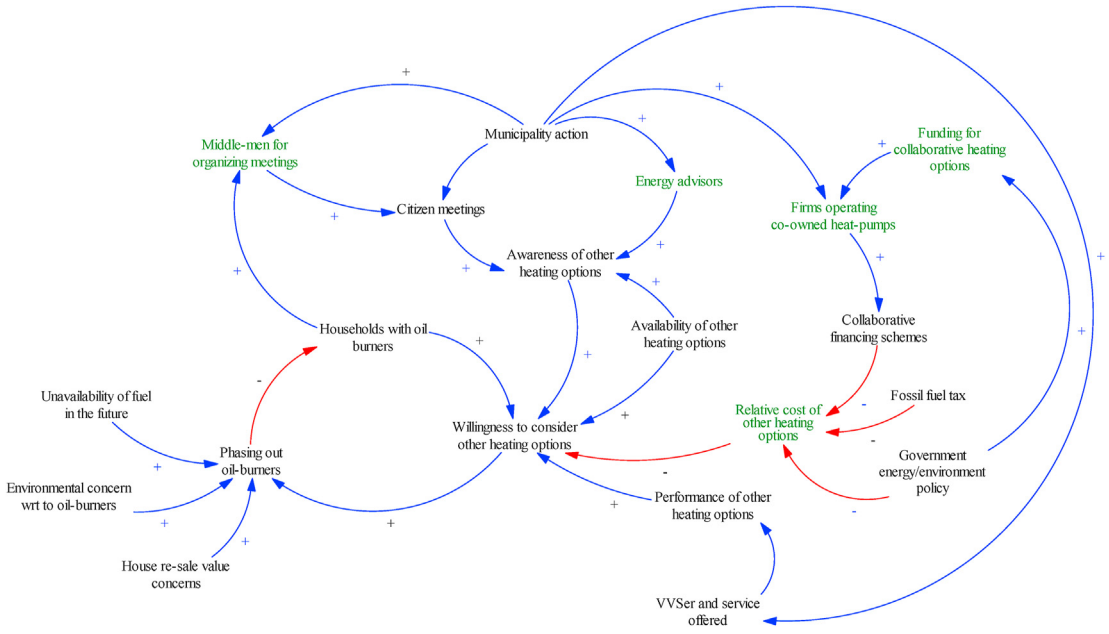

Fig. 3. The final CLD of the local energy transitions process of phasing out oil-burners.

too big to surmount. Some detached houses did not have access to a district-heating grid, and even the ones that could have access to the district heating grid, had to bear the initial cost of laying new pipes. Heat-pumps were also expensive, in the range of 100 000 DKK (Danish Kroners), while the oil-burners were still relatively cheaper. The general **Fossil fuel tax** in Denmark and the Government's energy and environmental policy did not have a discernible effect in making them change from an oil-burner. But, this might change in the future if the ambition of Denmark to be fossil-free comes to fruition. Such a fossil fuel tax, if high enough, can drastically increase the viability of non-fossil free heating methods for houses.

On the other hand, during the focus group meetings, the MAs did discover that housing value, environmental effects of fossil fuel and the possible unavailability of fuel in the future were concerns that would make the residents with oil-burners phase out oil-burners in Hjørring. This is shown through the relevant variables being linked to the **Phasing out oil-burners** variable in Fig. 2.

As mentioned before, Fig. 3 shows the development of the real-life transition project in Hjørring. The newly added variables are given in green coloured text to differentiate them from the variables in the initial CLD in Fig. 2.

In January 2018, the MAs had purchased the services of EAs, to give pertinent advice about changing residents' house-heating methods. The MAs also paid for the services for EAs, so that they may also attend these citizens meetings and create awareness and disseminate information regarding other more sustainable heating options. This is shown by **Municipality action** positively linked with **Energy advisors**, which in turn is positively linked to **Awareness of other heating options**. These EAs visit the homes of oil-burner owners, who if they are availing themselves of such a visit need to invite some other of their neighbours/friends who also have oil-burners. The EAs also advice the citizens to do the calculations regarding the cost of heating their house through both oil-burners and other heating methods, such as heat-pumps etc.

The Danish government has given funding to five heat-pump firms, to each install 350 heat-pumps around Denmark, in order to replace oil-burners in homes [40]. These five firms are full service firms in that the consumer is only buying the heat and the heat-pumps are installed, operated and serviced by these firms, with the household not taking responsibility for any of the technical aspects of the installation or the running of the heat-pump. The MAs have gotten in contact with two of the five firms, inquiring if they plan to start their operations in the Hjørring municipality. The contacted firms have expressed interest. Thus, if these firms were to operate in the municipality, this may lead to a system innovation in the future, in a new ownership/co-ownership model of buying heat from a heat-pump operator, rather than the household personally buying and installing it themselves.

The MAs arranged for information meetings with VVSer participating to answer the questions prospective heat-pump customers will have, regarding the total cost, and changes needed for peripheral system changes etc. The Danish government also gives a tax deduction on the service fee for changes done to the house for house-heating improvements (Danish Tax Authority 2016). This development is represented by the **Government energy/environment policy** positively linking to Funding **for collaborative heating options**, which in turn positively impacts **Firms operating co-owned heat-pumps**, which in turn positively links to **Collaborative financing schemes**, which has a negative effect on the relative cost of the heat-pump.

Furthermore, to initiate interest and action from within the residents, the MAs tried to recruit 'middle-men', that is residents of Hjørring with oil-burners who would be willing to volunteer to organize the citizen and town-hall meetings with the MAs, so that the MAs could take on facilitators' role if and when the residents' decided to phase-out their oil-burners. This is represented by the new variable (in green text) **Middle-men for organizing meetings**, which in turn would lead to increased citizen-meetings.

The CLDs presented here, in Figs. 2 and 3 show the development and establishment of the novel relationship between the MAs and the citizens of Hjørring, which was developed with the sole purpose of achieving the phase-out of oil-burners. This is indicative of the shade of social innovation in the TSI framework. The **Municipality action** variable indicates the novel social practices which are part of the social innovation process, through which the objective of phasing out oil-burners is to be realized. Similarly, trying to recruit **Middle-men for organizing meetings** was also an attempt at instigating and establishing social practices to enable local energy transitions in Hjørring.

6. Discussions and conclusions

This section presents discussions centred around the place of social innovation in the multi-case study of local energy transitions and on understanding SI in local energy transitions.

6.1. Understanding social innovation in local energy transitions

The study has shown a possible way of how social innovation in local energy transitions may be understood through using the TSI framework and, for one of the three cases, systems thinking through casual loop diagrams (CLDs). In the three cases examined, local energy transitions were attempted through establishing and embedding social practices between the MAs and residents/citizens, as a way of spreading information/knowledge about the energy transitions (Skåne, solar PV case), the technologies underpinning the transitions (all three cases), the peripheral infrastructure (Dalsland, AFVs case). These social innovations at the centre of the local energy transitions have been critically examined using the theoretical lens of TSI. How these social innovations lead to local energy transitions are better understood by representing these social innovations using CLDs.

The CLDs represent the social innovations through the interactions that happened between the different actors in the transitions, through new social practices, and were then carried forward to see what effect these outcomes have on the transitions process. The feedback effects of the social innovations propelled the energy transitions forward. The novelty in this study is two-fold: 1. The application of TSI to SI in local energy transitions and 2. the combination of the theoretical lens of TSI and the CLDs, to further the understanding of the social innovations in local energy transitions. The study extends the concept of emerging social innovations possibly transforming local energy systems by introducing new social practices and social values which help in the overall scheme of achieving a society's sustainability needs. The CLDs also posit a new method of understanding the how SI may transform local energy systems.

6.2. Furthering the understanding of social innovation in local energy transitions

As per [11], the actor-centred and structuralist perspectives of social innovation need to be integrated while being analysed, to get a fuller picture of how social innovation works in practice. This also closely resonates with the process dynamics of social innovation that [41] also emphasize. The process dynamics of social innovation gives a deeper understanding of how initiatives (micro level) drive social change (macro level). In characterizing SI in the three cases in this study, we have tried to bridge the actor-centred perspective with the structuralist perspective. In the Hjørring case, assisted by the CLDs, we go one step further, and characterize the SI processes through the feedbacks that take place due to SI activities, albeit instigated by MAs. Of course, in process dynamics of SI, the role of policy and institutionalization also need to be taken into account. This is clearly demonstrated in the CLDs in Figs. 2 and 3.

The argument could be made that this study has placed undue emphasis on technological innovation, and that the central actor in this transitions study is the technology. We think this reasoning is invalid, if one scrutinises the defining characteristics of social innovation. In all three of these cases, while we are studying local energy transitions, the technology at the base of the transition is not radically new. Rather, the social practices and the actor-interactions are new in the local transitions. We argue that the presence of technological innovation (or not) does not preclude the presence of SI and SI can be instigated and/or started by any particular group of actors.

Social innovation in co-created local energy transitions can take multiple forms, such as possible divergence of traditional ownership models to innovative ownership models and installation and concretization of different services around the transition, such as service offering for electric and biogas cars in garages. Even though

TSI cannot be seen in the cases yet, since game changers and narratives of change take time, the SI analysed does show signs of alternative economic paths for local energy transitions. It also shows that the role of municipalities in Sweden and Denmark are expanding beyond the norm, and the nature of the relationship between the MAs and the citizens are changing as well.

There are caveats to be considered when reconciling and generalizing the empirical and theoretical models of SI in such energy transitions cases. As some literatures show, there may be pushback against the power to the people [42], and the benefits of social innovation may be re-directed from the intended recipients to other undeserving parties. This is discussed at length and is the core of the work of [16]; especially when SI leads to disempowerment of certain parts of society. Understanding such barriers and finding ways of using SI or other methods to overcome these barriers may be necessary in the future.

6.3. Future directions of research

One future avenue of continuing this work is converting the CLDs into simulatable stock and flow diagrams, with cost and diffusion dynamics. This will give the researchers and practitioners an idea of how the transition pathways could change and what factors influence the said transitions, along with the possible measurement of the impact of social innovation in the local energy transitions processes. Hence, in addition to characterizing social innovation, system dynamics models can also be used to quantify the impact of social innovation in energy transitions processes. The authors are currently continuing the work in this way.

Another pertinent point of interest is continuing to observe the outcomes of these cases, even after they are over to investigate the impact of SI in the said municipalities. This will give an indication of the prevalence of 'narratives of change' and also methodologically concretize how SI impacts different transitions, both empirically and theoretically.

7. Conclusions

The objective of this study was to investigate how SI in co-created local energy transitions can be understood. The analysis shows that the actor interactions instigated by the MAs spur on new social practices, which in turn lead to better information to the residents regarding their energy decisions, and catalyses new social relationships and system innovations. New information regarding any problems with local energy transitions processes come to light with the newly established social practices, leading to local energy transition. It is important to understand that this happens at various degrees.

In analysing SI through the TSI frame, it is found that social innovation and system innovation can be seen in the solar PV diffusion and AFVs cases, but, game-changers and narratives of change are not yet present in any of the three cases.

In all three cases of local energy transitions, social innovation has been the process of establishing a novel relationship between municipality actors and willing residents with regards to energy transitions. Similarly, system innovation has been the change in how electricity is prosumed in the diffusion of solar PV in Skåne, and the change in charging and fuelling infrastructure in the transitions to AFVs in Dalsland.

Furthermore, in the case of Hjørring, we have used CLDs to represent the energy transitions and the dynamics driving the transitions. Subsequently, we used the CLDs to complementarily analyse the shades of TSI. Given the nonlinearity of the impact of social innovation and the need for systems thinking emphasized by Ref. [16]; the use of CLDs to extend the analyses of the cases using TSI is a methodological outcome of this study. Through this study, we have proposed extending the TSI frame and its lens of analyses with CLDs, and systems thinking methodology.

Finally, to answer the question of how social innovation can be understood in local energy transitions, the social innovation can be understood as the establishment of relationships and social practices which feedback into the local energy transitions processes. The understanding of social innovation and its impact on local energy transitions processes can be through the critical examination of the social practices between the different actors which are established, which in turn positively feed the transitions process. Such an understanding may have beneficial effects when it comes to answering questions such as where public funding should be focused in terms of affecting change in local energy systems.

CRediT authorship contribution statement

Sujeetha Selvakkumaran: Writing - original draft, Visualization, Conceptualization, Methodology, Validation, Formal analysis. **Erik O. Ahlgren:** Writing - review & editing, Conceptualization, Methodology, Resources, Funding acquisition.

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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