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Information systems-enabled sustainability transformation: A study of an energy self-sufficient village in Germany

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Abstract

Information systems (IS) play an important role in helping organisations attain environmental sustainability targets, and how to use IS for sustainability transformation is attracting research attention. However, extant studies have mainly focused on such transformation of business enterprises, overlooking it of communities. Our study intends to fill this gap by conducting an in-depth case study at Feldheim, a small village in Germany that has successfully built a renewable energy system using IS and achieved energy self-sufficiency. Guided by the belief-action-outcome (BAO) framework, our study unveiled a process model of antecedents, belief and action formation, and outcomes specific to community-based sustainability transformation. The model also reveals three roles that IS assume in such transformation: participation objects, connectivity enablement, and fluctuation mitigation. Our study contributes to the literature on IS-enabled sustainability transformation by extending it from the business enterprise context to the community context. It also provides communities with guidelines for conducting IS-enabled sustainability transformation.

KEYWORDS

belief-action-outcome (BAO) framework, community, environmental sustainability, green IS, sustainability transformation

1 | INTRODUCTION

Although there is an increasing recognition that information systems (IS) contribute to the achieving of sustainable development goals (SDGs), IS studies on this topic are insufficient (Gholami et al., 2016), and more research is needed (Tan & Nielsen, 2021). This study focuses on the environmental aspect of sustainable development, where the focal IS are often known as green IS (Malhotra et al., 2013). A growing literature has examined IS-enabled sustainability transformation, which refers to large-scale IS-enabled organisational change aimed at environmental sustainability targets (Seidel et al., 2013). Existing studies have unveiled the antecedents (Bose & Luo, 2011; Hu et al., 2016), belief and action formation (Hedman & Henningsson, 2016; Loeser et al., 2017; Tan et al., 2015), and outcomes of such transformation (Butler, 2011; Loeser et al., 2017), as well as the roles that IS assume in it (Hanelt et al., 2017; Seidel et al., 2013).

However, existing studies have mainly focused on sustainability transformation of business enterprises, overlooking it of communities. In their editorial comment, Elliot and Webster (2017) stated that most research on using IS to achieve environmental sustainability had been conducted within business firms, and therefore called for research that looks beyond this level of analysis. Similarly, Davison (2018) stated that green IS research appeared to be driven by what is good for business enterprises, and research examining how green IS can benefit communities at the village level was rare. A community context is important because, with the help of IS, a community can make significant contributions to environmental sustainability. Some communities have achieved net-zero carbon emissions and exported clean energy to others by building IS-enabled renewable energy systems (Young & Brans, 2017).

Existing findings derived from the business enterprise context cannot be readily applied to the community context. Although a community context is not necessarily a non-business context, as communities often include business enterprises that play crucial roles in driving their energy transitions (Busch & McCormick, 2014), the organisational change process and the roles of IS in these two contexts are distinct. First, in the business enterprise context, organisational change is often related to the reconfiguration of internal routines and behaviour change of internal employees (e.g., Cooper & Molla, 2017; Loeser et al., 2017). These change actions are less effective in the community context, where sustainability transformation relies on the collective actions of multiple stakeholders and aims for the social and economic development of the entire community. Second, in the business enterprise context, IS are mainly used to reduce energy consumption (e.g., Hanelt et al., 2017; Seidel et al., 2013). In contrast, sustainability transformation of a community involves changes to both energy production and consumption (McCormick & Kåberger, 2007). Thus, the roles of IS in a community go beyond energy consumption and may entail connecting energy production and consumption.

To explore how a community uses IS for sustainability transformation, we conducted a revelatory case study in Feldheim, a small village in Germany that has successfully built an IS-enabled renewable energy system and become the country's first energy self-sufficient settlement. Data analysis was guided by the belief-action-outcome (BAO) framework, which captures different phases and aspects of sustainability transformation and allows researchers to examine the role of IS in each phase (Melville, 2010). Our case study unveiled a process model of antecedents, belief and action formation, and outcomes specific to community-based sustainability transformation. The model also reveals three roles that IS assume in such transformation: participation objects, connectivity enablement, and fluctuation mitigation.

Our study contributes to the literature on IS-enabled sustainability transformation by extending it from the business enterprise context to the community context. It also answers the call of this special issue for relevant research that underscores the role of IS as a source of solutions for achieving SDGs (Tan & Nielsen, 2021). Our findings also have the potential to guide communities to conduct IS-enabled sustainability transformation.

2 | LITERATURE REVIEW

2.1 | BAO framework for IS-enabled sustainability transformation

The BAO framework that Melville (2010) proposed provides a sound lens for examining IS-enabled sustainability transformation. The framework captures three core concepts of sustainability phenomena in the IS literature: belief formation, action formation, and outcomes. These concepts can be examined at the individual, organisational, and societal levels. Since our study focuses on the sustainability transformation of organisations, we examine these three concepts at the organisational level.

Belief formation at the organisational level concerns the formation of an organisation's environmental orientation, which affects its interpretation of sustainability-related risks and opportunities (Loeser et al., 2017). Action formation concerns how beliefs about environmental sustainability are translated into organisational actions. Outcomes are related to how sustainable actions affect organisational and environmental performance. Antecedents are also an important part of the BAO framework. Melville (2010) proposed two structures as antecedents. The social structure refers to cultural or normative patterns that define the expectations of participants, while the organisational structure refers to how tasks are divided and integrated to pursue sustainability targets. Both structures influence an organisation's sustainable orientation and practices.

By integrating these three classes and the antecedents, the BAO framework allows researchers to examine different aspects and phases of sustainability transformation of organisations and to unpack such transformation as a system-level change. This is consistent with Seidel et al.'s (2013) notion of IS-enabled sustainability transformation as transforming the entire organisational work system. The BAO framework can also guide researchers in identifying the roles of IS by paying specific attention to how IS shape beliefs, enable sustainable practices, and improve performance (Melville, 2010). Prior research has also confirmed the effectiveness of this framework in examining IS-enabled sustainability transformation (e.g., Loeser et al., 2017).

In the following sections, we organise existing findings on IS-enabled sustainability transformation according to the core concepts of the BAO framework. Since IS-enabled sustainability transformation is a system-level change, it involves multiple interconnected IS. We adopt Watson et al.'s (2010) classification to identify the IS relevant to our research context. Based on the energy sector, Watson et al. (2010) classified four components of an intelligent energy system: (1) sensor networks consisting of digital devices that monitor environmental conditions and the status of physical items used in energy production; (2) flow networks consisting of connected components that support energy movement; (3) sensitised objects sensing and reporting data about energy consumption; (4) an IS connecting all the components to form an integrated solution.

2.2 | Antecedents and belief formation of IS-enabled sustainability transformation

Regarding the antecedents of IS-enabled sustainability transformation, existing findings fit nicely into both the social and organisational structures (Melville, 2010). Concerning the social structure, Bose and Luo (2011) found that regulatory support and industrial competition influence an organisation's orientation towards sustainability. Hu et al. (2016) extended Bose and Luo's (2011) work by adding the public's environmental awareness, regulatory requirements, industrial norms, and competitors' practices. Concerning the organisational structure, Bose and Luo (2011) identified management support, resource commitment, firm size, and technical readiness as influencing factors. Hu et al. (2016) grouped management support, resource commitment, and technical readiness into a more comprehensive concept of internal readiness and added a new antecedent of customers' and equity holders' attitudes.

Regarding belief formation, studies have identified both top-down and bottom-up approaches. According to Tan et al. (2015), belief formation benefits from senior executives' envisioning activities, which include establishing a convener, identifying issues and stakeholders, and developing consensus across departments. Environmentally concerned individuals can also change organisational values towards sustainability by promoting green IS initiatives that align with the organisational agenda (Hedman & Henningsson, 2016). Tan et al. (2015) extended belief formation beyond organisational boundaries and identified actions that help form collective beliefs with partners, such as establishing formal control.

Regarding the role of IS in belief formation, Butler (2011) unveiled three mechanisms whereby IS translate pressure from the environment into new beliefs: sensemaking, decision making, and knowledge creation. Seidel et al. (2013) further unpacked the role of sensemaking into two affordances. Reflective disclosure refers to the use of IS to make sense of current work practices and assess alternative actions based on sustainability considerations, while information democratisation refers to the circulation of information related to sustainability initiatives and opportunities to participate in those initiatives.

2.3 | Action formation and outcomes of IS-enabled sustainability transformation

Regarding action formation, prior research has shown that a major challenge in IS-enabled sustainability transformation is the lack of sustainable IS knowledge. Thus, a key action for successful transformation is to acquire, assimilate, and utilise such knowledge; assimilating and utilising sustainable IS knowledge also involves changing organisational routines (Cooper & Molla, 2017). In line with this, Loeser et al. (2017) recognised the importance of green IT and green IS practices and identified that their implementation relies on the formulation of a green IS strategy. Through a case study of a focal business enterprise cooperating with partners, Tan et al. (2015) suggested that IS-enabled sustainability transformation requires both internal changes and joint innovations with partners.

Regarding the role of IS in action formation, Seidel et al. (2013) unveiled two sustainable practicing affordances. Output management refers to the use of IS to manage environmentally harmful outputs and to reduce resource consumption, while delocalisation refers to the use of IS to support remote work and to reduce the negative environmental impacts arising from moving resources and people. Hanelt et al. (2017) extended Seidel et al.'s (2013) findings by examining the role of IS in supporting non-IS eco-innovations. Through examining how companies adopt electric vehicles, they revealed two new IS affordances: (1) enhancing existing business processes for efficient deployment of eco-innovations; (2) building new sustainable processes and business models for implementing eco-innovations.

Regarding outcomes, research has found that IS-enabled sustainability transformation can improve organisational performance, for example, by lowering costs, reducing waste, increasing innovation capabilities, enhancing reputation, and improving market competitiveness (Butler, 2011; Loeser et al., 2017). Regarding the role of IS in improving organisational performance, Petrini and Pozzebon (2009) unveiled the role of integrating socio-environmental indicators into a firm's strategy for sustainability, but this role is only based on the use of a specific type of IS (i.e., a business intelligence system). Benitez-Amado and Walczuch (2012) extended the research beyond a specific type of IS by taking an IT capability perspective; they found that IT capability can improve firm performance by building a proactive corporate environmental strategy, which refers to the voluntary implementation of sustainable practices in advance of regulatory requirements.

As aforementioned, although existing research has generated rich findings on how to use IS for sustainability transformation, the findings which are mainly derived from the business enterprise context cannot be applied to the community context. First, existing organisational change is mostly related to actions of a focal organisation. Prior research has not yet explored the collective actions of different organisations, which are essential for sustainability transformation in the community context. Although Tan et al. (2015) looked beyond internal operations and examined the focal organisation's cooperation with partners, the actions they identified cannot guide a community's transformation. For example, Tan et al. (2015) highlighted the importance of establishing formal control over partners during belief formation, but such control is inappropriate in a community, where partners participate voluntarily (Mundaca et al., 2018). Second, existing roles of IS are mainly related to the promotion of organisational behaviours that reduce energy consumption. Prior research has not yet explored the role of IS in orchestrating energy production and consumption, which is essential in the community context. Our study intends to fill this gap by examining how a community uses IS for sustainability transformation.

Given that sustainability transformation of a community and that of a business enterprise have different tasks and expectations regarding IS, the antecedents, belief and action formation, and outcomes of these two types of sustainability transformation will be different, as will be the roles that IS assume in them. Hence, we intend to utilise the BAO framework as a guide to build a process model of IS-enabled sustainability transformation in the community context and then compare the results with the existing findings from the business enterprise context. A process model can unveil different phases and aspects of this community-based sustainability transformation enabled by IS, which remains a black box in the existing IS literature on sustainability transformation.

3 | METHOD

We chose a case study as our research method for two reasons. First, our study intends to explore how a community leverages IS for sustainability transformation. A case study is suitable for answering a 'how' question and generating theoretical findings in a new context (Edmondson & McManus, 2007; Walsham, 2006). Second, a community-based sustainability transformation enabled by IS sits at the nexus of IS, renewable energy, and various stakeholders. A case study method is suitable for exploring such a complex situation (Pan & Tan, 2011). Our study adopted the interpretive paradigm for case study (Klein & Myers, 1999; Walsham, 2006), in accordance with which we viewed IS-enabled sustainability transformation as a form of sociotechnical development consisting of social and technical changes that mutually influence each other (Melville, 2010).

We chose Feldheim as our case setting for four reasons. First, Feldheim has successfully built an IS-enabled renewable energy system and become Germany's first energy self-sufficient settlement. Its transition to renewable energy involved multiple large-scale IS-enabled change projects, such as establishing a wind farm and local energy grids, thus resembling a system-level sustainability transformation (Seidel et al., 2013). Second, Feldheim's transition to renewable energy covered the implementation of all four components of an intelligent energy system, thus offering us rich empirical ground for examining the roles of IS in sustainability transformation that focuses on the energy production and consumption of a community. Third, Feldheim's transition to renewable energy took a community-centric approach. The transition benefited from close collaboration among participants, and its success also contributed to the community's welfare. As such, Feldheim has been portrayed as a role model for the energy transition of small communities (Mundaca et al., 2018). Finally, the Feldheim community provided us with extensive access to all the key stakeholders involved in its transformation.

3.1 | Case setting

Feldheim is a small village located around 80 km south of Berlin, Germany. It is a district of Treuenbrietzen in the state of Brandenburg. Feldheim's transition to renewable energy began in 1993 when a young entrepreneur visited the village (see Figure 1). He was looking for a place to instal four wind turbines and was attracted by Feldheim's geographical conditions. By successfully persuading Feldheim residents to lease him the land, the entrepreneur installed the first four wind turbines in 1995 and later established the energy company Energiequelle. The village is now home to 55 wind turbines with an electrical capacity of over 123 MW. The community consumes a fraction of the energy that is generated around Feldheim; the rest is fed to the public grid.

Feldheim's energy transition did not stop at harvesting the wind (see Figure 2). In 2008, the agricultural cooperative and Energiequelle formed a partnership and built a biogas plant. The plant converts manure, maize, and wholegrain cereal produced by the cooperative into heat and electricity. Energiequelle also built a solar farm in

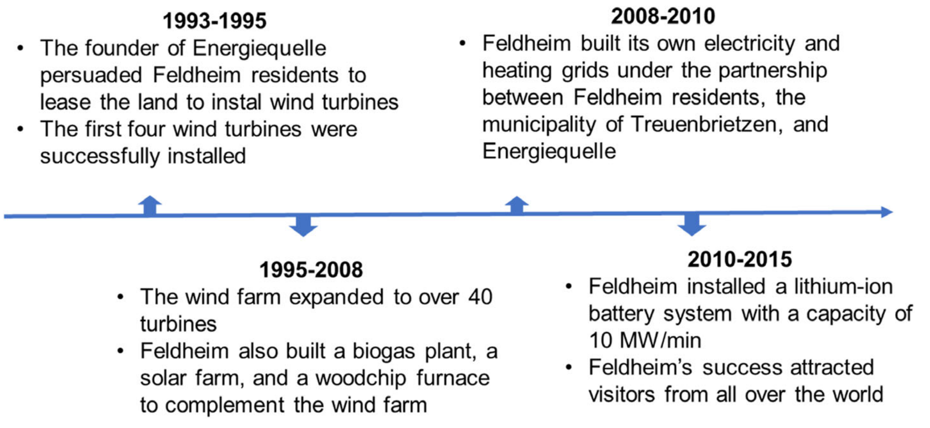

FIGURE 1 Timeline of Feldheim's transition to renewable energy.

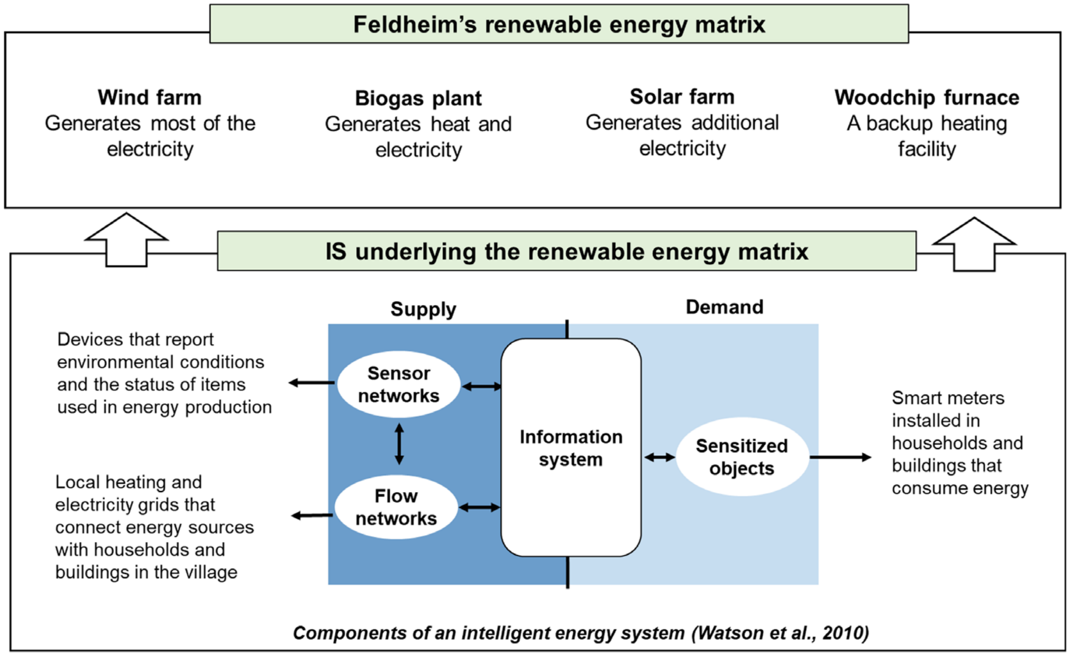

FIGURE 2 Feldheim's renewable energy matrix and its underlying IS.

cooperation with the village to generate more electricity. When there is no wind or the wind turbines are scheduled for maintenance, electricity from the biogas plant and solar farm becomes crucial. A woodchip furnace was also built to provide heat on frigid days when other sources fail. Two infrastructural elements critical for Feldheim's energy self-sufficiency are the local electricity and heating grids, which connect energy sources with households, farms, administrative buildings, and other facilities in the village. These grids are collectively owned by Feldheim residents, the municipality of Treuenbrietzen, and Energiequelle. In 2015, a lithium-ion battery system with a capacity of 10 MW/min was installed in Feldheim with the intention of balancing fluctuations in energy production and consumption. Feldheim's success in building a self-sufficient energy system based on renewable sources has inspired many people and attracted visitors worldwide. To host these visitors and share knowledge with them, the community established the 'Neue Energien Forum Feldheim' (New Energies Forum in Feldheim).

Feldheim's transition to renewable energy benefited from implementing all four components of an intelligent energy system (Watson et al., 2010). First, the sensor networks consist of devices that report environmental conditions and the status of items used in energy production. An example is the dashboards that report the status of energy production facilities. Second, the flow networks comprise the electricity and heating grids, which connect energy production facilities with households and buildings in Feldheim. Third, the sensitised objects comprise smart meters installed in households and buildings, which report energy consumption data. Finally, an information system connects all these components and integrates supply and demand data.

3.2 | Data collection

Our research team visited Feldheim and conducted semi-structured interviews with key members involved in its energy transition. Informants included Feldheim residents, government officials of the district, and Energiequelle executives (see Table 1). We also interviewed experts who followed Feldheim's energy transition closely and members of a voluntary group that promoted renewable energy in the region. These interviews offered us an external perspective and contextual information on Feldheim's energy transition. Each interview session lasted, on average, for 50 min.

TABLE 1 Data sources.

Source of data	Type of data	Use in analysis
Interviews	Five residents at Feldheim	To understand why residents joined the renewable energy projects, what actions they took, and how they used IS
	Three employees from the New Energies Forum in Feldheim	To understand the design of the renewable energy matrix and the underlying IS components
	Two government officials: the Mayor of Treuenbrietzen and the Climate Protection Planner of the district	To understand the regulatory challenges and support in Feldheim's renewable energy transition
	Two executives from Energiequelle: the CEO and the spokesman	To understand Energiequelle's motivations, challenges, and strategies and how it leveraged IS during Feldheim's energy transition
	Two experts who followed Feldheim's energy transition	To understand the success factors of Feldheim's energy transition from an external perspective
	Five members of a voluntary group that promoted renewable energy in the region	To gain contextual information about the renewable energy industry in the region and additional views on Feldheim's energy transition
Archives	Documents released by Energiequelle and the New Energies Forum in Feldheim	To gather information about the milestones of Feldheim's transition and the design of the energy matrix
	News articles on Feldheim's renewable energy transition	To gather external accounts of Feldheim's renewable energy transition
	Academic articles featuring the Feldheim case (e.g., Grosse et al., 2019; Mundaca et al., 2018; Young & Brans, 2017)	To gather external analyses of Feldheim's renewable energy transition

We also collected archival data. We gathered documents released by Energiequelle and the New Energies Forum in Feldheim, such as the presentation on Feldheim's energy self-sufficiency journey and the design of the renewable energy matrix. Since Feldheim's success in the renewable energy transition has attracted media attention, we also gathered news articles published by media organisations. These articles provided us with external accounts of Feldheim's renewable energy transition. We also collected several academic articles analysing Feldheim's energy transition. Although these articles provided us with relevant information for our research, they mainly examined the case from an energy policy perspective rather than from an IS perspective.

3.3 | Data analysis

We analysed the data by following the grounded theory methodology proposed by Gioia et al. (2013). We first conducted first-order analysis, where we read the transcripts of the interviews thoroughly and coded the data relevant to our research question. We used in-vivo codes (i.e., terms used by informants) whenever possible (Gioia et al., 2013). A set of first-order concepts then emerged (see Figure 3).

We then conducted second-order analysis, where we sought similarities and differences among the 1st-order concepts and reduced them to a smaller set of more abstract, theoretical themes. These themes were further grouped into aggregate dimensions. While the first-order analysis focused on the informant perspective, the second-order analysis focused on taking a higher-level perspective needed for informed theorising. To inform the theorisation, we referred to the BAO framework and the sustainability transformation literature organised by the BAO framework. Following Gioia et al.'s (2013) suggestion, we paid particular attention to themes that did not have adequate referents in the existing literature; in our case, they are themes specific to the community context.

Based on the first- and second-order analyses, we constructed a data structure that linked the first-order concepts, second-order themes, and aggregate dimensions. This data structure demonstrated the data-to-theory connections and prepared the ground for the theorising process, which captured the dynamic relationships among the second-order themes and transformed the data structure into a theoretical model that answered the research question. The resulting model is a four-phase process model that consists of antecedents, belief and action formation, and outcomes specific to community-based sustainability transformation and the three roles that IS assume in the transformation.

4 | FINDINGS

4.1 | Antecedents of Feldheim's IS-enabled sustainability transformation

Antecedents stimulating Feldheim's IS-enabled sustainability transformation included embedded entrepreneurship, residents' desire for change, and institutional support.

4.1.1 | Embedded entrepreneurship

The founder and CEO of Energiequelle was a critical player in Feldheim's energy transition. His entrepreneurial activities not only drew on community resources but also brought positive changes to the community, thus resembling the notion of embedded entrepreneurship (McKeever et al., 2015). The entrepreneur exploited local physical resources in running his business. During his first visit to Feldheim, he noticed its favourable geographical conditions for building wind turbines. The village sits in a windy area with a large tract of farmland, and the farmland is a good

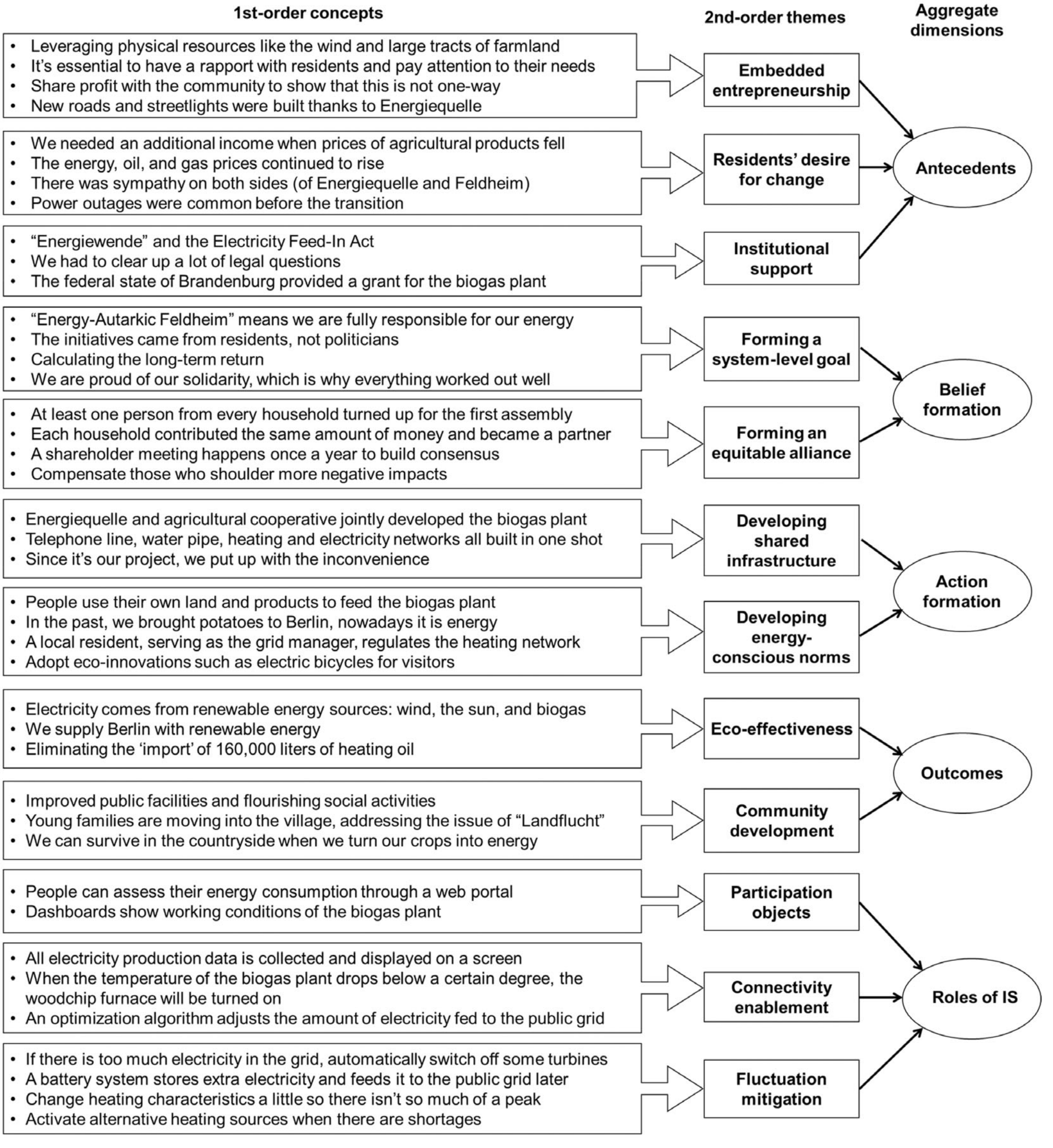

FIGURE 3 Data structure.

distance from the settlement, making the construction of wind turbines less intrusive to people's lives. The entrepreneur drew on social resources by building social bonds with residents, believing that, as an energy producer based in the community, it was essential to have a rapport with residents and pay attention to their needs.

The entrepreneur also initiated projects that brought economic and social benefits to the community. In his words, 'We share profit with the community to show that this is not one-way'. The energy company that he founded guaranteed that the electricity prices that Feldheim residents paid would be significantly lower than the market rate. The company also invested resources in renovating public facilities in the village. According to a resident who had stayed in the village for many years,

> The streetlights and roads were renovated. We also expanded the playground for children. None of this could happen if we didn't have Energiequelle in Feldheim.

The two external experts who followed Feldheim's energy transition also acknowledged the positive impacts brought by Energiequelle. According to them, a critical success factor of Feldheim's energy transition is the presence of an entrepreneur who is willing to invest, take charge of complicated projects, and share returns with participants.

4.1.2 | Residents' desire for change

Without residents' support, the renewable energy projects proposed by Energiequelle would not have occurred, or at least not so smoothly. The two primary factors that drove residents' desire for change were declining incomes from agricultural products and rising energy bills. In the 1990s, the prices of agricultural products, such as crops and milk, declined. This significantly reduced the profits of the agricultural cooperative, which was the village's largest business and the primary source of income for many families. At the same time, energy prices also rose, and the rising energy bills further reduced the profits from agricultural products and increased residents' living expenses. Hence, residents were looking for an additional source of income and a cheaper source of energy. Renewable energy projects became desirable in that they could fulfil both demands.

As the CEO of Energiequelle recalled, when he first presented the notion of installing wind turbines, the villagers, though unfamiliar with the concept of renewable energy, were very curious about the project. The head of the village corroborated this, stating that 'There was sympathy on both sides'. Recalling residents' desire for change during the construction of the heating network, she explained,

> There was no compulsion, and nearly everyone was convinced. At that time, energy, oil, and gas prices were very high. So many didn't need to think twice [to join].

Another factor that drove residents' desire for change was the need for a stable energy supply. The old electricity system often failed to deliver stable energy, and power outages were common. The situation was improved after installing the wind farm and the local electricity grid. Even when there was planned maintenance, the outages did not last long, and Energiequelle always informed residents beforehand. Energy stability was further improved after installing the biogas plant and the solar farm, which complemented the wind farm.

4.1.3 | Institutional support

Despite the mutual interests of Energiequelle and Feldheim residents, the community's renewable energy transition could not have been a success without the government's institutional support. At the national level, Feldheim's transition occurred in the context of 'Energiewende' (energy transition), Germany's long-term energy policy aimed at promoting renewable energy and phasing out nuclear power. In line with this policy, acts supporting renewable energy were introduced. For example, the Electricity Feed-In Act, offering a feed-in tariff to renewable energy producers, was an important financial incentive for Feldheim's energy transition.

At the regional level, the municipality of Treuenbrietzen played an important role. The Mayor of Treuenbrietzen was the champion of Feldheim's energy transition. He worked closely with Feldheim residents and Energiequelle to help them acquire financial and legislative support from the government. In terms of financial support, the community successfully acquired several government grants, including a grant from the federal state of Brandenburg covering 50% of the cost of the biogas plant.

Legislative support was equally important, if not more so. Building a self-sufficient energy system in a community required the clearing up of many legislative questions because the existing regulations did not consider the particular case of Feldheim. For example, in the case of developing the local electricity grid, the existing law did not specify whether a local grid owned by the village complied with regulations. Thus, a particular application was submitted for approval. The community engaged policymakers proactively. The mayor often invited politicians to visit Feldheim, and during such visits, he demonstrated the value of Feldheim's renewable energy system and explained why Feldheim's model should be promoted. As the mayor recalled,

> We had to clear up a lot of legal questions because, at that time, many laws didn't consider this situation. If they [policymakers] ever would have put their thumbs down, we now would have an electricity network without being allowed to use it.

4.2 | Belief formation

Belief formation during Feldheim's IS-enabled sustainability transformation consisted of two main actions: forming a system-level goal and forming an equitable alliance.

4.2.1 | Forming a system-level goal

Although residents, Energiequelle, and the town of Treuenbrietzen participated in Feldheim's energy transition with different goals, they shared a goal at the system level (Gulati et al., 2012). That was 'Energy-Autarkic Feldheim', meaning that the village would be fully responsible for its energy supply. This goal guided all the renewable energy projects in Feldheim. Because there were no external sources to rely on, the community designed its renewable energy matrix to be self-sufficient. The biogas plant and the solar farm were installed to ensure that the village had electricity when the wind farm stopped working. The woodchip furnace was built to ensure the village had heat when the biogas plant failed to function. The deployment of local heating and electricity grids gave the community control over its energy circulation.

Residents were fully committed to this system-level goal, which was an important success factor of Feldheim's energy transition. As the Mayor of Treuenbrietzen commented, 'The initiatives came from residents, not politicians'. Residents' commitment was not built overnight. In the beginning, many residents had concerns. Some worried about the noise from the wind turbines, while others worried about the devaluation of the farmland. To address these concerns, Energiequelle and the municipality of Treuenbrietzen spent much effort communicating with the residents. According to the Climate Protection Planner, who was responsible for writing a climate strategy for the district, frequent communication was crucial in unveiling and addressing the real concerns of residents. Showing benefits was also important in building residents' commitment. Compared to addressing concerns, showing benefits was more straightforward. For example, during the development of the local heating network, the CEO of Energiequelle hosted a consultation session where he presented the forecast of the long-term benefits for residents. As a resident who attended the session recalled,

> The CEO and his deputies had the calculations ready. They worked out how many of us to join for the project to be worthwhile and what is the long-term return for participants. That gave us a very clear idea.

Solidarity was also an important reason why a shared goal could be formed at Feldheim. According to the spokesperson of Feldheim,

> Solidarity is very important, which is why everything worked out so well. We had visitors from other places who said they were interested in doing the same, but that could not work in their places because there will always be half of the village supporting it and the other half against it.

4.2.2 | Forming an equitable alliance

Although the system-level goal of Energy-Autarkic Feldheim influenced the community's sustainability orientation and its perception of the risks and benefits of the sustainable energy projects, the goal needed to be translated into something concrete to sustain its influence. To this end, the participants formed an alliance. Because participants shared the decision rights equally, it was an equitable alliance.

This equitable alliance was initiated by open discussions. Before a decision to launch any project was made, the village would hold assemblies for all residents to attend. These assemblies allowed residents to learn about the new project, raise questions, and discuss important issues. These assemblies also ensured that the decisions made reflected the collective interest of the whole community instead of the interest of a few individuals. Recalling the assemblies for the development of the local energy networks, one resident stated,

> During the first assembly, there was a tent erected for this event…and at least one person from every household turned up…In the final assembly, people came together, and the signing happened.

The equitable alliance was built on joint ventures where residents were partners. In the biogas plant project, Energiequelle and the agricultural cooperative formed a joint venture. Then, representatives of the cooperative were involved in all the decision-making processes. A new company, Feldheim Energie, was formed to develop the local energy grids. The company was collectively owned by residents, the municipality of Treuenbrietzen, and Energiequelle. Nearly all the households participated. Each household contributed the same amount of money and became a partner of the company. As partners, residents participated in the decision-making processes. As a resident who was actively involved in the decision-making processes elaborated,

> For changes, a consensus has to be reached. A shareholder's meeting happens once a year to deliberate. Because we are an association, we are in the same boat.

Finally, the equitable alliance was sustained by compensating those who shouldered more negative impacts. Take the wind farm as an example. Despite the reasonable distance between the wind farm and the settlement, the farm still caused some annoyance due to noise, shadows, and obstructed views. Since families were located in different parts of the village, some were affected more than others. The village built a consensus that households shouldering more negative impacts would benefit first from its social development. In this case, households closer to the wind farm were the first to be connected to the new roads and linked to the energy grids.

4.3 | Action formation

During Feldheim's IS-enabled sustainability transformation, action formation consisted of two actions: developing shared infrastructure and developing energy-conscious norms.

4.3.1 | Developing shared infrastructure

The community developed energy facilities collectively. For example, the biogas plant resulted from the joint venture between Energiequelle and the agricultural cooperative. After installing the biogas plant, heat was about to be transferred to pig farms and administrative buildings. Feldheim residents recognised the potential of connecting heat to their households. Then, the notion of building a heating network emerged. At the same time, the community was also planning to instal a local electricity grid. Their original plan was to purchase or lease the grid from the existing electricity provider that served the region, but the electricity provider refused to sell or lease the grid. Feldheim then decided to build the local electricity grid themselves, together with the heating grid. The community took a bold approach, additionally including the installation of telephone lines and water pipes, since they also required digging trenches. According to the head of Feldheim,

> We had Telekom to lay the telephone lines. We got new drinking water pipes, a new district heating network, and an electricity network. All was done at the same time. That was a challenge. But [in the end] everything worked out fine.

Although it made economic sense to construct all these networks at the same time, the complexity of the project created many disruptions. Wide trenches were dug in the village, which made it inconvenient for people to walk around. However, since it was the joint venture that operated this construction, residents deemed it 'their own project' and put up with the inconvenience.

4.3.2 | Developing energy-conscious norms

Residents developed new norms around the production of renewable energy. One example was their integration of agricultural production with energy production. Residents working in the cooperative moved agricultural outputs such as manure, maize, and wholegrain cereal to the biogas plant, which converted them into electricity and heat. The biogas production also produced fertiliser, which was supplied back to the agricultural cooperative, creating a cycle. Due to the declining prices of agricultural products and the rising price of electricity, agricultural production at Feldheim became more and more energy-centric. A new expression arose explaining this change: 'In the past, we brought potatoes to Berlin, nowadays it is energy'. The Climate Protection Planner further elaborated on this,

> It's not like other biogas plants in the country built by investors which buy corn from wherever they can get it. In Feldheim, people use their own land and products to feed the biogas plant and produce their energy.

Residents also built new norms around the consumption of renewable energy. Previously, residents maintained their heating facilities and adjusted heating profiles on their own. After the transition, the heat supply was managed by a grid manager, who was also a local resident. The grid manager monitored the heat consumption of all the entities in Feldheim and regulated the consumption when there was a shortage. The residents adapted to this change and were satisfied with this new resident-managed heating system. The village also adopted new eco-innovations, such as electric bicycles for visitors. A new energy forum was built to host visitors from all over the world. Feldheim has become a popular tourist destination thanks to its renewable energy projects. This emerging tourism business created new jobs and also lifted the spirits of the villagers. As a staff member from the New Energies Forum in Feldheim stated,

> People from all over the world came to us and talked positively about Feldheim…I am very proud to live here.

4.4 | Outcomes

Feldheim's IS-enabled sustainability transformation led to two major outcomes: eco-effectiveness and community development.

4.4.1 | Eco-effectiveness

Feldheim's energy transition did not aim at making the existing energy system more efficient but at transforming the existing energy system. The result was eco-effectiveness, which is concerned with doing the right things rather than doing things right (Chen et al., 2008; Watson et al., 2010). Before its transition, Feldheim, like most German villages, was supplied with electricity produced by conventional sources, such as fossil fuels and nuclear power. After the transition, its electricity came from three renewable sources: wind, the sun, and biogas. Carbon emissions were greatly reduced, and the village also exported renewable energy to nearby cities, such as Berlin. As the Mayor of Treuenbrietzen commented,

> Berlin is incapable of supplying itself with 100% renewable energy. There has to be a relationship with the surroundings [which produce the renewable energy].

Although the woodchip furnace required woodchips, the materials were the by-product of the essential thinning of local forests. It thus did not put pressure on natural resources. Before the transition, the village used to purchase a large amount of heating oil. After installing the biogas plant and local heating network, heating oil was not needed. As a resident who was a member of the agricultural cooperative explained,

> An advantage of the energy transition is that we eliminate the 'import' of 160,000 liters of heating oil…that is a big saving.

4.4.2 | Community development

Before the energy transition, Feldheim, like many German villages, suffered from 'Landflucht', which refers to the mass emigration of villagers to big cities. The successful energy transition helped address this issue in Feldheim. The village now attracts young people. For example, the managers of the agricultural cooperative used to worry that it could not recruit young people and that after the existing employees retired, the business could not continue. The energy transition increased the income of the cooperative, which then started to attract young people; some young employees rose to leadership positions. A resident shared a similar observation from the housing perspective,

> If a house is empty, it will not take long for it to become inhabited again, because young families are moving in. The recent family that moved in always say how content and happy they are.

The energy transition also created new jobs. The village had an unemployment rate of zero, an impressive achievement in the region. Because the community operated its own energy system, the money that residents paid for energy stayed in the village. Consequently, the village had more resources for renovating public facilities. With the additional resources from Energiequelle, new roads, streetlights, and playgrounds were constructed. Social activities also flourished, with many social events occurring throughout the year. These developments were also important factors that attracted and retained young families. A new expression arose among the residents,

> We can survive in the countryside when we turn our crops into energy.

4.5 | The roles of IS

Our study unveils three roles that IS played in Feldheim's sustainability transformation, namely participation objects, connectivity enablement, and fluctuation mitigation, which respond to belief formation, action formation, and outcomes, respectively.

4.5.1 | Participation objects

IS contributed to the formation of a system-level goal and an equitable alliance by serving as participation objects. The focal IS were the smart meters installed to track the energy consumption of households and dashboards installed to monitor the status of energy production facilities. Since residents had no experience or knowledge at the beginning, it was difficult for them to understand the concept of renewable energy. The smart meters and dashboards allowed residents to visualise renewable energy from both consumption and production perspectives, thus enabling better engagement. According to a staff member at the New Energies Forum in Feldheim,

> There are meters installed in households to monitor heat and electricity. People can assess their energy consumption through a web portal.

These two systems also created transparency of energy consumption and production, which helped residents form a sense of being in an equitable alliance. Overall, the smart meters and dashboards enabled residents to turn the invisible concept of renewable energy into something concrete and actively engage with the energy system, thus serving as participation objects (Ryghaug et al., 2018).

4.5.2 | Connectivity enablement

IS contributed to the development of a shared infrastructure by enabling connectivity between different energy sources. An example is the electricity maintenance system, which collected all the electricity production data and displayed it on a screen. Energiequelle used that data to coordinate electricity production among different sources. For heat production, IS ensured that different sources were connected and complemented each other. As a resident from the agricultural cooperative elaborated,

> All the sources are connected and complement each other. When the temperature of the biogas plant drops below a certain degree, the woodchip furnace will be turned on…We have software for that.

IS also enabled connectivity between energy supply and demand. The electricity grid connected the wind farm, biogas plant, and solar farm to households and buildings in the village. The heating grid connected the biogas plant and woodchip furnace to households and buildings in the village. These two grids were managed by IS installed at Energiequelle and the village, respectively. Finally, IS enabled connectivity between Feldheim and the public grid. With data collected from both the supply and demand sides, Energiequelle could use an optimisation algorithm to adjust the production volume and the amount of electricity fed to the public grid.

4.5.3 | Fluctuation mitigation

Energy production from renewable sources fluctuates with environmental conditions, and this fluctuation poses a critical threat to sustainable development outcomes (Fridgen et al., 2016; Piel et al., 2017). IS improved such outcomes in Feldheim by mitigating fluctuation in both the electricity and heating systems. Regarding the electricity system, on windy days, there could be too much energy in the public grid, making it unprofitable to feed electricity to the grid. In that case, the electricity maintenance system automatically switched off some of the wind turbines. After the battery system was installed, the extra electricity could be stored in the battery and later fed to the public grid based on data collected from both the local and public grids.

Regarding the heating system, on extremely cold winter days, the heat production of the biogas plant could be affected, and the facility also needed more heat to maintain its operation. In that case, heat supply dropped while its demand rose. This fluctuation was mitigated at both the supply and demand ends. First, with the help of a remote-control system, the grid manager who lived in the village could regulate the heating characteristics of each household to avoid peak demand. As the CEO of Energiequelle explained,

> He (grid manager) changes the heating characteristics of households a little, so there isn't so much of a peak…There is something like a remote control in each household that he can control via his computer.

Second, alternative heating sources such as the woodchip furnace and the booster powered by electricity could be activated via the remote control. Activating the woodchip furnace took some time, but activating the electricity-based booster allowed the provision of instant heat. Yet, the booster's timely response came with a price, and heat generated by electricity was the most expensive among all the sources. As such, heat produced by electricity only constituted a small percentage of the total heat consumed in Feldheim, and the electricity-based booster was only used as an emergency component to ensure that households would have sufficient heat on cold days.

5 | DISCUSSION

5.1 | A process model of IS-enabled sustainability transformation of a community

Based on the in-depth case study of Feldheim's energy transition, we derived a process model of IS-enabled sustainability transformation of a community (Figure 4). First, the three antecedents cover all three key stakeholders and complement each other when stimulating belief formation. Second, belief formation consists of forming a system-level goal and forming an equitable alliance. The former influences the community's orientations towards sustainability transformation, while the latter retains and strengthens such influence by translating the abstract goal into a concrete alliance. Third, the new beliefs trigger the actions of developing shared infrastructure and energy-conscious norms. The former action builds the energy system, while the latter integrates the energy system with existing operations. Finally, as a result of these two actions, Feldheim achieves both eco-effectiveness and community development. The former outcome is related to environmental sustainability targets, while the latter is related to the social and economic development of the community.

We also found that IS has a substantial effect in enabling the sustainability transformation of a community. Prior studies on the use of IS at the community level have shown that IS can enable communities to access information at any

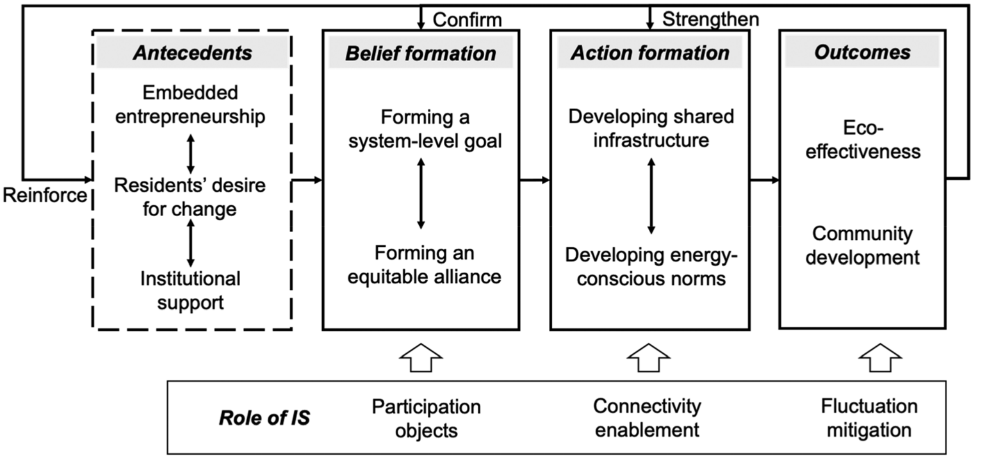

FIGURE 4 A process model of information system-enabled sustainability transformation of a community.

time and from anywhere (Thapa & Sein, 2018), build connectivity between different participants (Ashmore et al., 2017), and respond to changes in the environment (Tim et al., 2021). Our findings are consistent with prior findings. First, IS shape belief formation by serving as participation objects, which allow residents to access relevant information and better engage with the renewable energy systems. Second, IS support sustainable practices by connecting different energy sources and connecting energy production and consumption. Third, IS improve sustainable outcomes by mitigating fluctuation, that is, by adjusting energy production and consumption to respond to the variability of the energy system.

Although each of the three roles of IS may influence multiple phases, there is one role that is prominent in each phase. For example, IS may serve as participation objects and enable connectivity in action formation, but the primary role of IS in this phase is to enable connectivity, which underlies the development of shared infrastructure and energy-conscious norms.

The process model we derived in this study is a recursive one rather than a linear one proposed by Melville (2010). It challenges the linear assumption of prior research by creating a feedback loop. Eco-effectiveness and community development, as the outcomes of the process model, in turn, impact the antecedents, belief formation, and action formation. First, the outcomes reinforce the embedded entrepreneurship, residents' desire for change, and institutional support. For example, successfully implementing the initial wind turbines reduced residents' energy costs and increased their incomes. These benefits increased residents' desire for more changes, such as developing the electricity grid. Moreover, the success of the renewable energy matrix boosted Energiequelle's aspiration to devote more resources to the village and assured the municipality of Treuenbrietzen that its support was necessary. Second, the outcomes also confirm the belief formation. For example, the successful installation of the local energy grids confirmed Feldheim residents' belief that they could become energy self-sufficient. Third, the outcomes also strengthen action formation by providing feedback for the community to allocate more resources to the new actions. For example, the successful installation of the biogas plant motivated residents to move more agricultural outputs into the biogas plant.

5.2 | Comparing IS-enabled sustainability transformation of business enterprises and communities

Our process model extends the existing literature on IS-enabled sustainability transformation from the business enterprise context to the community context. Here, we discuss this extension by comparing these two contexts (see Table 2).

TABLE 2 Information system-enabled sustainability transformation of business enterprises and communities.

	Business enterprises	Communities
Antecedents	Public environmental awareness, regulatory requirements and support, industrial norms and competition, customers' and equity holders' attitudes, management support, resource commitment, and relevant capabilities (Bose & Luo, 2011; Hu et al., 2016)	Interdependent relationships among all stakeholders (energy entrepreneur(s), residents, and government agencies) within a community and their collective desire to change the current situation
Belief formation	*Actions*: envision, reinforce, and extend organisational value and build formal control over suppliers (Hedman & Henningsson, 2016; Tan et al., 2015) *The role of IS*: enable environmental sensemaking, decision making, and knowledge creation (Butler, 2011; Seidel et al., 2013)	*Actions*: form a system-level goal that guides collective actions and form an equitable alliance in which decisions are collectively made *The role of IS*: provide digital interfaces that help participants better engage with renewable energy systems
Action formation	*Actions*: acquire sustainable IS knowledge, reconfigure organisational routines, and jointly innovate with suppliers (Cooper & Molla, 2017; Loeser et al., 2017; Tan et al., 2015) *The role of IS*: enable sustainable practices and facilitate eco-innovation (Hanelt et al., 2017; Seidel et al., 2013)	*Actions*: develop shared infrastructure and energy-conscious norms *The role of IS*: enable connectivity between different energy production facilities and between energy production and consumption
Outcomes	*Outcomes*: reduced costs, increased innovation capabilities, enhanced corporate reputation, and improved market competitiveness (Butler, 2011; Loeser et al., 2017) *The role of IS*: integrate socio-environmental indicators into organisational strategies for sustainability and support proactive environmental practices (Benitez-Amado & Walczuch, 2012; Petrini & Pozzebon, 2009)	*Outcomes*: eco-effectiveness and community development *The role of IS*: mitigate fluctuation in the renewable energy system by adjusting energy production and regulating energy consumption

With regard to antecedents, the existing literature has identified various antecedents, including public environmental awareness, regulatory requirements and support, industrial norms and competition, customers' and equity holders' attitudes, management support, resource commitment, and relevant capabilities (Bose & Luo, 2011; Hu et al., 2016). Our process model extends these findings in two ways. First, existing antecedents are either related to cultural and normative patterns or related to how tasks are divided and integrated within the focal organisation. Our study shows that in a community context, interdependent relationships among all stakeholders and their collective desire to change are the important antecedents. Second, prior research suggests that established companies with more financial resources are more likely to launch sustainability transformation. In a community context, that argument may not hold. In Feldheim's case, the large energy provider serving the region did not participate in Feldheim's transformation. Instead, it was an entrepreneur who spotted the business opportunity and led the transformation. Given that this community-based sustainability transformation aimed to gain energy independence from established energy providers, it was reasonable that the transformation was orchestrated by an entrepreneur rather than the incumbent energy provider.

With regard to belief formation, business enterprises envision, reinforce, and extend organisational value and build formal control over suppliers (Hedman & Henningsson, 2016; Tan et al., 2015). Our process model extends existing findings in two ways. First, it highlights the importance of establishing a system-level goal which guides the collective actions of the community. In the business context, a sustainability transformation goal is also crucial, but that goal corresponds to the goal of the focal organisation rather than the goal of the community. Second, it suggests the need to build an equitable alliance. In the business context, alliances are also needed for sustainability transformation, but such alliances are not equitable in that decisions are primarily made by the focal organisation and then imposed on other participants through formal control (Tan et al., 2015). In the community context, since participants join in sustainability transformation voluntarily (McCormick & Kåberger, 2007), forming an equitable alliance is essential. An equitable alliance also creates a stable set of partners with aligned interests, which is crucial for IS-enabled transformation at the community level (Walsham & Sahay, 1999).

Regarding the role of IS in belief formation, IS enable environmental sensemaking, decision making, and knowledge creation in a business context (Butler, 2011; Seidel et al., 2013). The focal IS for those roles are enterprise collaboration systems and knowledge management systems. Such systems are often absent in a community context, where knowledge sharing occurs in offline gatherings such as the resident assemblies in Feldheim. In a community context, the key IS for belief formation are the digital interfaces of the renewable energy system, such as the smart meters and dashboards. These interfaces enable residents to visualise renewable energy consumption and production and allow for better engagement (Ryghaug et al., 2018).

With regard to action formation, business enterprises acquire sustainable IS knowledge, reconfigure organisational routines, and jointly innovate with suppliers (Cooper & Molla, 2017; Loeser et al., 2017; Tan et al., 2015). These actions aim to transform unsustainable organisational activities into sustainable ones. In a community setting, the main objective is not to improve the existing activity system but to build a new system based on renewable energy. Hence, Feldheim's key actions involved developing a shared IS-based energy infrastructure. Developing energy-conscious norms was also crucial because it integrated the new energy infrastructure with the existing operations.

The role of IS in action formation in business enterprises is also different from that in communities. In business enterprises, IS enable action formation by enabling sustainable practices and facilitating eco-innovation (Hanelt et al., 2017; Seidel et al., 2013). In communities, these actions are relevant but not critical. The most critical role of IS in this phase is to enable connectivity between different energy production facilities and between energy production and consumption. Because of the connectivity that IS enable, the energy infrastructure built in the action formation phase is an integrated solution; an integrated solution is crucial for the transition towards renewable energy (Piel et al., 2017).

Transformation outcomes in business enterprises include reduced costs, increased innovation capabilities, enhanced corporate reputation, and improved market competitiveness (Butler, 2011; Loeser et al., 2017). Market competitiveness is essential for business enterprises but not for communities. Our study extends the existing literature by unveiling the benefits of community development in addition to eco-effectiveness. It shows that sustainability transformation can not only improve environmental sustainability but also serve as a means for community development, addressing issues such as low employment rate and rural exodus. This aspect of community development is not present in the existing literature. Our study highlights that green IS have potential beyond the environmental sustainability goals and can be a solution for improving the social and economic development of a community.

The role of IS in improving transformation outcomes in business enterprises is different from that in communities. In business enterprises, IS improve outcomes by integrating socio-environmental indicators into organisational strategies for sustainability and by supporting proactive environmental practices (Benitez-Amado & Walczuch, 2012; Petrini & Pozzebon, 2009). Although Feldheim's intelligent energy system also helped assess socio-environmental indicators and supported the community's proactive transition towards renewable energy, these two roles were not salient. In a community context, the salient role of IS in improving transformation outcomes is to mitigate fluctuation, which is a major threat to renewable energy systems (Fridgen et al., 2016).

6 | CONCLUSION

6.1 | Theoretical and practical contributions

Our study makes important theoretical contributions. First, it extends the literature on IS-enabled sustainability transformation from the business enterprise context to the community context. By conducting an in-depth case study at Feldheim, the first settlement in Germany to achieve energy self-sufficiency, our study develops a process model of IS-enabled sustainability transformation of a community. The model, which consists of antecedents, belief and action formation, outcomes, and roles of IS that are specific to community-based sustainability transformation, opens the black box of this transformation (Davison, 2018; Elliot & Webster, 2017). By comparing the process model with the existing literature, our study also highlights the differences between IS-enabled sustainability transformation of a business enterprise and that of a community.

Second, our study also answers the three calls of this special issue (Tan & Nielsen, 2021). First, this study unveils mechanisms whereby a community tackles varied and complex sustainability challenges, such as residents' lack of participation (Zhang et al., 2012). Second, this study underscores the role of IS as a solution for attaining SDGs. Our study unveils that IS shape the formation of sustainable beliefs by serving as participation objects, enable sustainable practices by connecting energy production and consumption, and improve sustainable outcomes by mitigating fluctuation in renewable energy systems. Third, we shed light on how IS can help to make a better world (Walsham, 2012). We identify that IS-enabled sustainability transformation of a community can benefit the world by both generating renewable energy and helping the community's social and economic development.

Our study also makes important practical contributions. The process model can guide communities to conduct IS-enabled sustainability transformation. Although community-based energy transition is crucial for the attainment of SDGs, it is difficult to achieve due to the various challenges mentioned above. Hence, the lessons derived from Feldheim's success story are valuable. The antecedents and actions of our model can provide community leaders with a repertoire of resources and actions for sustainability transformation. Meanwhile, the three roles of IS can guide managers to formulate effective green IS strategies and to build an information infrastructure that supports sustainability transformation.

6.2 | Limitations and future research

Because our process model is based on empirical data from Feldheim, it may not demonstrate all the possibilities regarding the process of using IS for community-based sustainability transformation. For example, the relationship between actions and outcomes is linear in Feldheim since the actions of infrastructure development and norm reconfiguration led to desired outcomes. In other communities, however, these actions may not lead to desirable outcomes, and such communities may need to revisit their beliefs. Future research may enrich the model beyond the empirical data from Feldheim (Cloutier & Langley, 2020). It can do so by examining the contingencies that affect transitions between stages.

First, solidarity can be a contingency for the transition from antecedents to belief formation. The Feldheim community was proud of its solidarity, which allowed it to transform the collective desire for change into a shared belief, but in a community where residents have distinct interests and views, a shared belief may not be formed even when the community has a collective desire for change. Second, action plans can be a contingency for the transition from beliefs to actions. Feldheim had concrete plans for renewable energy projects, for example, the plan to deploy the telephone lines, water pipes, and local energy networks simultaneously. In the absence of concrete action plans, the transition from beliefs to actions may not occur. Third, the presence of local maintenance capability can be a contingency for the transition from actions to outcomes. Feldheim's energy grids were maintained by both the energy company and local residents, such as the grid manager and agricultural cooperative employees. Participation of these local residents reduced the maintenance costs. This local maintenance capability may not be available in other communities, and such communities may endure high maintenance costs, which negatively affect the outcomes. Future research may collect empirical data beyond Feldheim and examine the influence of these contingencies on the process model.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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