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The role of thermal energy communities in Germany's heating transition

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A rapid decarbonization of the energy sector is key for mitigating climate change and in this transformation a transition to renewable heating is essential. To date, most attention in both research and policy on decarbonization has been on electricity and transport systems, with less interest in the heating system. Half of the EU's final energy consumption is made up by the heating and cooling sector, making this an important sector for reducing fossil fuel consumption. This article addresses the lack of research on decarbonization of heating by answering the question, what barriers and drivers do Thermal Energy Communities (TECs) perceive when trying to enter the market and play a role in the decarbonization of heating in Germany? Eight TECs and four umbrella organizations in Germany have been interviewed about their experiences of initiating and running a TEC. The results show, amongst others, that the political support of municipalities is put forward as an essential driver and important factor for success. However, barriers for municipalities to get involved were often that they lacked expertise, capacity and financial resources. An important driver for TECs was the involvement of local experts and professionals who could support the volunteers often in charge of a TEC. The results show that TECs that included professionals had an advantage in building heating systems, as they could better address their complexity and high initial costs. Another prevalent result was the need for community engagement and citizen mobilization, which is a greater need in heating projects compared to those focusing on electricity, due to community heating systems requiring a substantial number of customers for profitability.

KEYWORDS
energy community, heating, thermal energy community, heating transition, Germany, renewable energy community

1. Introduction

The recent report of the third working group of the Intergovernmental Panel on Climate Change (IPCC) states that rapid decarbonization is needed to reach the target of <1.5°C global warming (IPCC, 2022). In this, the energy sector is a key player and a rapid transition to renewable energy sources is essential. To date, most attention in both research and policy on decarbonization has been on electricity and transport systems, with less interest in the heating system. However, half of the final energy consumption within the European Union (EU) is accounted for by heating and cooling (Thomaßen et al., 2021), making this an important sector for reducing fossil fuel consumption. Increasing the number of renewable district heating grids is one part of the solution (Thomas et al., 2022). Another important part of a transition is citizens' engagement, where citizens actively interact with the energy systems (Wahlund and Palm, 2022). Citizen engagement will be practiced differently, depending on whether collective or individual heating solutions are being chosen (Sovacool et al., 2021). In Germany, important local actors in the transition to renewable electricity are citizen-led community-based initiatives that have significantly contributed to the wider acceptance of renewable energy technology (Fouladvand et al., 2022a). Moreover, on the international level, the EU has given community-based initiatives a central role in the transition to renewable energy [Directive (EU) 2018/2001, 2018; Lowitzsch et al., 2020a]. This demonstrates the importance that these actors have been attributed in the transition to a low-carbon economy (Holstenkamp, 2021).

Despite the prominent position of community renewable energy in international policy on the European level, and its importance for the decarbonization of electricity and uptake of renewables, its role in the decarbonization of heat remains largely under researched (Fouladvand et al., 2020, 2022b). One explanation for this could be the dependence of renewable heating on renewable electricity (Fridgen et al., 2020). Another is the strong focus on the local level, as heat cannot be transported over long distances and must therefore be used close to its source, making research case dependent and less attractive. These challenges differentiate the decarbonization of heating from electricity. Some recent studies have investigated community-based initiatives in the context of heating (Fouladvand et al., 2022b; Papatsounis et al., 2022), but further research specifically targeting heating is necessary (Fouladvand et al., 2022b). Therefore, this article focuses on TECs in Germany. A TEC will here, in line with (Fouladvand et al., 2022b), be seen as a sub-category of energy communities including three main elements: thermal renewable energy technology, stakeholders involved and related institutions. A TEC aims to provide sustainable energy for thermal applications such as space and water heating.

Studying the role of energy communities in the decarbonization of heating in the context of Germany is of particular interest for several reasons. Among the EU member states, Germany has higher greenhouse gas (GHG) emissions per capita than the average (Palm et al., 2020), with 8.18t emission compared to the EU average of 5.93t per capita. In 2021, 84% of Germany's emissions were energy related (Wilke, 2022b), with almost half of all energy being used for heating. While the share of renewable energy for heating and cooling has been increasing consistently over recent years in Germany, it only makes up 15.6% (Wilke, 2021). The predominant usage of gas for heating has led to Germany's high dependence on Russia, which the country is trying to reduce because of Russia's invasion of Ukraine (Holz et al., 2022). Particularly in private households, heating plays an important role, accounting for approximately 70% of all energy needs in Germany, thus making TECs interesting to study (Wilke, 2022a). Moreover, regulations at the European level mandate Germany to provide a framework that facilitates a pathway for community renewable energy initiatives. So far, Germany has failed to translate the EU policy into national policy, missing the opportunity to revive the sector (Holstenkamp, 2021). Providing more insight into the potential of such initiatives for heating could inform the policy design process regarding the future of energy communities.

The role of community-based initiatives in the uptake of renewable energy technology for electricity, and their central role in international energy policy, underline their importance in energy transitions. The initiatives have received noteworthy attention in literature, mostly focusing on renewable electricity while little research has explored their role in the transition to renewable heating. This article addresses this research gap by analyzing the barriers and drivers TECs have experienced when trying to enter the heating market and contributing to the decarbonization of heating in Germany. The main research question is: what barriers and drivers have TECs in Germany experienced in past heating projects?

2. Energy communities—Earlier research and analytical framework

The decarbonization of the energy sector requires a technological as well as socio-economic transition, which has, in part, been driven by initiatives at the local level, where citizens have come together to jointly invest in renewable energy technology (Blasch et al., 2021). The topic has gained extensive attention since the European Commission emphasized the importance of democratizing the energy sector, actively promoting renewable energy communities (EC) as an important vehicle to deliver energy transitions in Europe. The European Commission defines ECs as "collective actions of citizens coming together to participate in the energy system, taking ownership of their energy consumption" (European Commission, 2022). In research, the definition of ECs is unclear to this day, and an abundance of versions exist with minor differences in names, such as community energy (Bauwens and Devine-Wright, 2018; Brummer, 2018; Ehrtmann et al., 2021), community renewable energy (Mirzania et al., 2019; Rahmani et al., 2020), local renewable energy communities (Wagemans et al., 2019), or energy communities (Gjorgievski et al., 2021; Palm, 2021a; Papatsounis et al., 2022). The lack of one clear, universally accepted definition (Bauwens et al., 2022) is not

Abbreviations: EC, Energy communities; TEC, Thermal Energy Communities.

necessarily a bad thing; a vague definition is more inclusive and encourages local versions of ECs to emerge (Palm, 2021b). Within Germany, the most commonly used term, citizen energy (*Bürgerenergie*), is equally vaguely defined. In this article, the aim is not to find or develop a new definition, therefore Seyfang et al's (2013) definition will be used as it fits the context of Germany and the TECs studied: "projects where communities (of place or interest) exhibit a high degree of ownership and control, as well as benefiting collectively from the outcomes" (Seyfang et al., 2013).

Emerging ECs are seen to have multiple benefits and are often discussed in the context of both energy democracy and citizen empowerment (Wuebben et al., 2020; Wahlund and Palm, 2022). ECs have the potential to contribute to increased energy literacy among citizens, helping individuals learn about the interrelationships between energy and sustainability (Wahlund and Palm, 2022). The importance of ECs for local communities and economies has been stressed in earlier research. An argument in favor of ECs is the acceptance among citizens for renewables and energy transitions in general (Hoppe et al., 2015; Morris and Jungjohann, 2016; Gui and Macgill, 2018; Wagemans et al., 2019). Citizen acceptance is especially important as progress of the energy transition can be significantly slowed down by citizen opposition (Zoellner et al., 2008; Cohen et al., 2014). Studies have found that active participation in the energy transition has been expressed as an important social motivation for EC membership (Hanke and Lowitzsch, 2020; Tricarico, 2021). Coy et al. (2021) showed that ECs can foster engagement in the energy system and turn passive consumers into active ones. When people feel empowered they engage more and feel responsible for their consumption (Dóci, 2021). Earlier studies have also emphasized the many benefits that accrue to individual EC members (Bomberg and Mcewen, 2012; Koirala et al., 2016). Individual citizens can face less risk when joining an EC than when investing in an individual energy solution, such as a rooftop photovoltaic installation. Furthermore, ECs can increase the welfare of low-income households and contribute to the collective distribution of benefits (Koirala et al., 2016; Hanke and Lowitzsch, 2020). Studies show that citizens are prepared to pay more for locally generated power (Koch and Christ, 2018). Building trust among citizens was another important driver discussed in earlier research (e.g. Six et al., 2015; Kalkbrenner and Roosen, 2016; Hill and Connelly, 2018; Koirala et al., 2018).

In relation to the potential for TECs to emerge, Punt et al. (2022) stated that institutional relatedness can benefit such a development. Institutional relatedness means that organizational forms are more likely to emerge if similar forms of organizations already exist in a region. Therefore, the existence of ECs in the electricity sector has the potential to contribute to the emergence of TEC actors for renewable heating. The two sectors are also coupled due to the fact that some ECs produce both heat and electricity and a differentiation between them is, in those cases, not relevant or possible (Tarhan, 2015).

ECs are also facing many challenges. In theory, ECs are open and include all citizens but in practice this has historically not been the case. In Germany, more than 70% of energy cooperative members have been male, with relatively higher education and income (Hanke and Lowitzsch, 2020). This is not unique for Germany and a similar situation exists in many other countries (Lazoroska et al., 2021). People with lower income have been especially underrepresented; to join an EC it is necessary to access financing and many people lack savings (Hanke and Lowitzsch, 2020). Financial resources are therefore often cited as a main barrier to participation (Bomberg and Mcewen, 2012; Koch and Christ, 2018; Koirala et al., 2018; Rahmani et al., 2020). ECs have also contributed to injustice since the organizational form has not suited people living in apartments or renting their homes. In addition, the need for expertise has proven to be an excluding factor for vulnerable communities and lower-income families (Inês et al., 2020). Other challenges for ECs to emerge are the reliance on volunteers and the risk of free-riding when members join without contributing to EC activities (Dóci, 2021). Citizens working on a voluntary basis often lack the necessary expertise in legal frameworks or technical aspects, as well as the time and resources required to develop it (Brummer, 2018). Future ECs are likely to be increasingly dependent on partnerships with commercial actors, something that is already starting to happen (Nolden et al., 2020; Blasch et al., 2021; Kojonsaari and Palm, 2021). Another possible path would be for ECs to hire staff or provide a salary to members who previously worked on voluntary basis (Herbes et al., 2017; Horstink et al., 2020).

2.1. Analytical framework to analyze barriers and drivers experienced by TECs

Earlier research investigated the role of technical and institutional conditions in the formation of TECs (Van Summeren et al., 2021; Fouladvand et al., 2022b), institutional relatedness (Punt et al., 2022) institutional entrepreneurship (Mahzouni, 2019), energy communities role in governance (Wagemans et al., 2019; Schmid et al., 2020) in a multi-level perspective (Dóci et al., 2015), the role of energy community actors in different contexts (Özgül et al., 2020) and business models (Cielo et al., 2021). Earlier research showed that energy community initiatives are embedded in their local context and therefore differ in legal forms and initial development Fouladvand et al. (2022a), which specifically reviewed TECs, concluded that TECs should be studied as "distinctive socio-technical entities with their own unique characteristics." (p. 9). In this article we apply Hicks and Ison's (2018) framework,

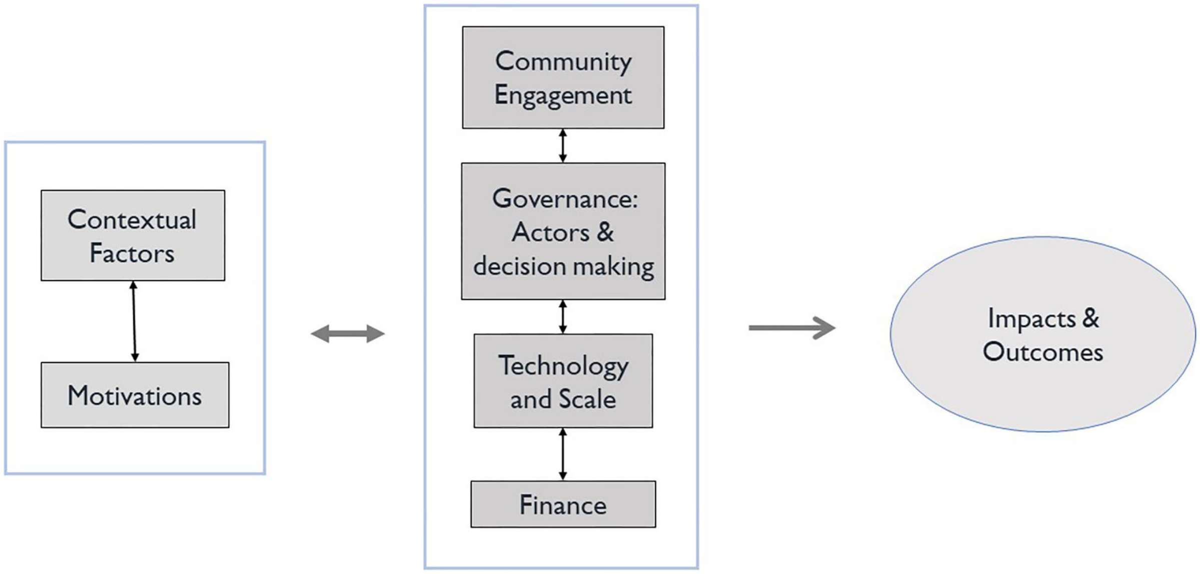

FIGURE 1
Framework developed by Hicks and Ison (2018).

which is a development of a model of Walker and Devine-Wright (2008). Other frameworks that have been used to analyze energy communities are for example polycentric governance (Jordan et al., 2018; van Der Grijp et al., 2019), the Institutional Analysis and Design framework (Fouladvand et al., 2022b) and a socio-ecological system framework (Acosta et al., 2018). Hicks and Ison's framework was chosen for this research as it includes elements identified as important for ECs to emerge from earlier research, how these elements interplay and influence impacts and outcomes. The framework is used to analyze how TECs evolve based on the contextual factors and motivations which interplay with the four key dimensions of a TEC: community engagement, governance (including actors and decision making), technology and scale, and finance (see Figure 1). Encompassing the interplay of the most important elements, the framework offers a solid basis to analyze different aspects of TECs. The framework has been used in other studies, e.g. Verde and Rossetto (2020) who studied the future of energy communities in the EU. The framework uses a holistic approach and does not further specify the technology used. It covers all important aspects of TECs while leaving room to be applied in a variety of different contexts. Furthermore, investigating the key elements of TEC initiatives as outlined in the framework, can facilitate future comparisons with other cases. For these reasons the framework will be used to guide the analysis.

The contextual factors in Hicks and Ison's framework are further divided into four subcategories: physical, technology, institutional, and community factors. The *physical factor* concerns the physical properties of the location and several studies have for example reflected upon the geographical differences that exist between energy community diffusion within Europe (Candelise and Ruggieri, 2020; Ruggiero et al., 2021). The *technology factor* focuses on the technology chosen for the TEC project, which in this case is most likely to be some form of communal heating source, such as a district heating (Papatsounis et al., 2022). Lowitzsch et al. (2020b) discussed how physical factors and technology are interlinked. They show that urban centers need tailored solutions that fit dense areas such as e.g. combined heat and power and district energy, solar PV, and on small or no wind power generation (Bracco et al., 2018). Rural settings which are less spatially dense and have more space can promote different technological solutions such as a combination of PVs and wind (Lowitzsch et al., 2020b). The *institutional factor* refers to the wider regulatory and policy environment in which the TEC initiatives are embedded, the structural aspects of the energy market, potential subsidy schemes for renewable energy technologies or TECs, and general institutions in the energy sector or other relevant fields (Kooij et al., 2018; Palm, 2021a; Ruggiero et al., 2021). A main barrier for TEC initiatives is a centralized market design and regulation of existing energy systems (Brummer, 2018; Koirala et al., 2018; Kooij et al., 2018; Warbroek et al., 2018). Brummer (2018) for example found the existence of a regime in the United Kingdom discriminating against small community-driven initiatives and benefitting big energy companies. Kooij et al. (2018) noticed that decentralized organized energy infrastructure with a small medium enterprise economy enabled energy communities to emerge. The *community factor* encompasses the history and local culture of the community, as well as the skills and information available, the networks of actors, how they are connected to each other and enable the community to function (Blasch et al., 2021).

Hicks and Ison (2018) further categorized the motivations as social, technical, environmental, economic and political/policy. To a significant extent, these overlap with what has been widely analyzed and discussed in previous research, therefore motivations will only be addressed briefly in this article.

Four key elements allow the investigation of the internal processes of TEC initiatives and how these influence the outcome. The four elements are choice of actors, decision-making, technology and scale, finance and community engagement. The choice of actors concerns the people within a project that form the community. They make decisions, govern the project and engage the community. The decision-making element is concerned with who holds the power and how decisions are made. Technology and scale are connected to the target group of the TEC initiative, how widely spread the TEC intends to become, and the choice of technology. The key element of finance concerns how financial benefit will be distributed; whether it will be merely distributed to the members of the TEC, the wider community, or external, non-local investors. Community engagement describes the level of engagement in the development and operation of community members in a project (Hicks and Ison, 2018). The material of the TECs in Germany will be analyzed by applying Hicks and Ison's framework to identify the central barriers and drivers at play that either hinder or enable TECs to emerge. This will form the base for discussing the potential of TECs to contribute to a heating transition in Germany.

2.2. Energy communities in Germany

ECs have a long history in Germany, dating back to the first electricity distribution cooperatives formed in the late 19th century to build the necessary infrastructure for electrification (Holstenkamp, 2015). Due to a favorable policy environment, the number of ECs started to increase in the early 2000s. The Renewable Energy Sources Act (EEG) in 2000, in combination with other regulatory and financial incentives, made the installation of renewables like wind and solar suddenly economically viable, assisting the uptake of renewables in Germany (Palm et al., 2020). After the nuclear accident of Fukushima in 2011, Germany decided to further invest into alternative energy sources. Around this time, the term "citizen energy cooperatives" (*Bürgerenergiegenossenschaften*) emerged and these are now the most common legal structure among ECs in Germany, together with limited liability companies (Holstenkamp, 2021). Shifts to more market-based instruments as well as a focus on larger projects have disadvantaged ECs in recent years, leading to the sector's stagnation. While citizens are still owners of a large share of the installed renewables, their share has been decreasing (Holstenkamp, 2021).

3. Materials and methods

This paper explores the potential of TECs to contribute to the transition to lower emission heating. A qualitative approach was chosen to explore the complex set of factors surrounding a TEC (Creswell and Creswell, 2017). This aligns well with the significance that Hicks and Ison (2018) attributed to the context in which TEC initiatives emerge and develop. In total, 12 interviews were conducted with representatives from different TEC-related organizations, eight of which were directly involved with or part of a TEC and four were representatives of umbrella organizations for ECs at the state or federal level. A more detailed description of the interview partners can be found in Tables 1, 2.

The initial choice of interview partners was based on TEC heating projects identified through online research, as well as popular examples of energy cooperatives and climate communities. When contacting the representatives of TEC initiatives, as well as the umbrella organizations, it became evident that the topic of heating did not play an important role at the state or federal level for many organizations. Many of the umbrella organizations replied saying they had no expertise or did not work on the topic and therefore denied an interview. Sometimes contact emails were even left unanswered or the request for an interview simply declined due to the lack of capacity and resources. This was most common with bigger umbrella organizations, such as the German cooperative and Raiffeisen association. In the end we enlisted eight TECs at different stages of their heating projects, some already completed, some in planning stage, and others making progress in transitioning toward renewable heating. Most of the TECs had assumed the legal structure of a renewable energy cooperative. The interviewees of the umbrella organizations were advisors to heating cooperatives or political representatives of TECs at the state or federal level.

The TECs were asked questions regarding the circumstances of their heating project and the TEC, particularly with reference to the drivers and barriers experienced in both the planning and implementation phases, as well as which actors were involved. The interview partners directly involved in TEC initiatives were asked about possible opponents, what they would recommend to other TEC projects, and what they would have done differently. The interview ended with a question on what potential they saw for TECs in the transition to renewable heating in general. The umbrella organizations were asked more general questions about which type of TEC initiative they represented, the relevance of renewable heating in their work, and which actors they worked closest with. More specifically, we asked about drivers and obstacles in

TABLE 1 Interviewed actors from TEC initiatives.

#	TEC	Technology	Context	Scale	Legal structure
1	Baitzer Heizer	Heating grid based on woodchip, solar thermal for warm water (summer)	Cooperative was founded to supply the village Baitz with affordable, renewable heating.	Ca. 40 members	Cooperative
2	Nahwärme Burggrumbach	Heating grid based on two biogas plants	Cooperative was founded to supply a residential area with renewable heat. A local gas provider was planning to build a grid, but it was not economically viable in the end.	49 members	Cooperative
3	Energiegenossenschaft Helmetal	Solar PV, wind turbines, first geothermal heating grid in the state of Thüringen	Cooperative was founded to carry out a wind project; due to long duration, solar PV projects implemented. In 2017, they constructed a development area for new houses with a geothermal plant.	More than 50 members	Cooperative
4	Energiegenossenschaft Kappel	Biogas plant, wind turbines, geothermal heating grid	The village wanted to gain independence from oil and gas supplier countries. The cooperative was founded after the biogas plant and the wind park were built, to construct the local heating grid and make use of the biogas plant's lost heat.	70 members	Cooperative
5	Bürger-Energie-Genossenschaft	Wind, solar PV and local heating grids	Founded in 2013 with the goal to support and expand renewable energy generation in its region.	Eight employees, ca. 370 members	Cooperative
6	Eifel Energiengenossenschaft eegon	Solar and wind projects, one heating grid	Founded in 2009, the cooperative owns 12 solar PV projects, contributed to several wind turbines and owns one, contributed to a solar PV park, started an e-car sharing scheme, and planned, built and runs a heating grid for a village in Aartal.	830 members, three employees	Cooperative
7	Rhein-Hunsrück-Kreis	Solar PV, wind projects, heating grids	Implementing a climate protection concept, with the aim to lower its greenhouse gas emissions, which mainly come from private households (oil for heating). Goal to lower the costs for energy imports and keep the money in the region.	N/A, citizens of the district	Cooperatives, municipalities and others
8	Klimakommune Saerbeck	Bioenergy park with solar PV, wind turbines and biogas plants, small heating grids for local municipal buildings	In 2009, the municipality won the competition "climate community of the future". The goal, to become CO2 neutral by 2030, will be achieved by a transition toward renewable electricity (achieved), and renewable heating and transport (in progress). The climate community is pushing and advocating for climate education.	7,000 citizens of the municipality	Statuary body (municipality) and association represented by the Mayor

planning and implementation that they or their members were experiencing.

The interviews were transcribed, and an inductive analysis was conducted based on Hicks and Ison's (2018) framework. We chose not to compare the different TECs in this paper but rather to focus on barriers and drivers presented on an aggregated level in the interviews.

4. Results

Below, the results from the interview study are presented following the structure of the Hicks and Ison (2018) framework described above, starting with contextual factors.

4.1. Contextual factors

The physical and technological factors were not emphasized as an important factor by the interviewees, but their responses were centered around institutional and community factors. In general, the TECs expressed a feeling of strong support when introducing their initiatives. The reasons *why* the TECs felt welcomed in the local market differed, however. TEC #5 pointed toward their projects being unattractive to other market actors, while TEC #1 saw their project as special since it was the first of its kind in their region: "*This is set as an example here and everyone supported it.*" (TEC #1). However, others, for example, had to face traditional heating providers who tried to disrupt their projects (TEC #7).

The institutional context for the TECs was dependent on the state they were located in. Some reported great support from the company providing the energy, where the company

TABLE 2 The interviewed umbrella organizations (UO).

#	Organization	Context	Properties of members
9	Genossenschafts-verband Bayern	Service provider for consultations in legal and economic issues, audits, education and representation of Bavarian cooperatives	Purely cooperatives from Bavaria, among which are energy cooperatives
10	Genossenschafts-verband Baden- Württemberg	Service provider for consultations in legal and economic issues, audits, education and representation of cooperatives in Baden-Württemberg	Purely cooperatives in Baden-Württemberg, among which are energy cooperatives
11	Bürgerenergie Bayern	Representation of the economic, political, and societal interests of EC initiatives in Bavaria	A variety of EC initiatives in Bavaria as well as actors from business and the public sector
12	Bündnis Bürgerenergie	Platform to strengthen the EC movement, voice for and advocacy of EC initiatives at the federal level	A variety of EC initiatives, private individuals and businesses for citizen energy, such as municipal companies, banks and project developers

contributed with technical and administrative understanding as well as subsidies (TEC #3). Others pointed out:

> "The problem for us is only related to the implementation. We lack support from the municipalities concerning the expertise that is needed about the heating systems and also in relation to commercial experience on how to finance the project. You cannot leave it up to the citizens to initiate something like this privately" (TEC #1).

An obvious barrier was the high initial costs and the TECs stated that improved regulatory and financial support was needed if TECs were to flourish (TEC #8). Several of the interviewed TECs called for the municipality's support to mitigate the financial barrier (TEC #1; #3 and #4). The umbrella organization UO #9 suggested subsidies for the initial consulting through project developers or other experts, who could support in assessing whether the project would be feasible financially or not.

The interviewees stressed the importance of a high level of support from local politicians in heating projects. According to TEC#5 unsupportive local politicians or municipalities could severely endanger the success of a project or prevent its implementation in the first place. Establishing a district heating network requires a minimum number of connections and as the contract must be signed before the heating system is being constructed, the politicians could give the project the legitimacy needed to motivate people to sign (TEC #8). TEC #5 stated, however, that at the same time *"the first opponents are actually always the politicians",* often simply due to their personal opinions.

Preferential treatment of TEC actors in the legislation was suggested, since TECs experienced heavy regulations as a barrier. A general notion was that there was a need for a better understanding and a clear definition of TEC, since, according to the respondents, the term had been misused in the past. At the same time, different standards needed to be applied due to the complexity of heating projects, so there were no clear-cut regulatory solutions presented by the interviewees. Additionally, the frequent changes to legislation were mentioned as difficult to keep up with. TEC #3 said, for example, *"the underlying conditions are continually changing, and a volunteer cannot manage this".* The heating market is complex, and the regulatory framework became often a barrier rather than a driver. Another barrier mentioned was the mismatch between communication from the federal level and the regional or local level.

One barrier related to the community factor was the TECs' high reliance on voluntary work (UO #9). All interviewees emphasized the importance of getting "the right people" on board for the initiative. These were identified as local politicians to support the project and motivate citizens, young people to achieve a different dynamic, and experts to provide the necessary skills. Overall, the requirement for involving the right people demonstrates the complex and high demands of heating projects. One umbrella organization (#10) emphasized the importance of them acting as mediators between TEC, the municipal utility companies, and the climate protection agencies, facilitating the work for the TEC. In terms of technical understanding, several interviewees attributed municipal utilities a potential advantage due to their more professional structures and existing expertise (TEC #1; UO #9, #12). This collaboration was important to ease the administrative burden of the volunteers in a TEC, as they often lacked technical understanding. Another important collaboration was with the citizens (because heat needs to be consumed locally), which was mentioned as crucial by all.

4.2. Motivational factors

To a large degree, the motivations of TEC initiatives overlapped with those found in earlier research. The TECs were motivated by carrying out the energy transition together with the citizens. One stated that their main driver was that if they did not carry out the project in the area there would be no district heating (#3) and another said that the availability of a heating source, a biogas plant producing electricity, is what motivated them (TEC #2). Some were motivated by finding and testing new business models and innovative ideas. For most, profit was not a main driver, but their aim was to breakeven financially in a project. TEC #5 stated that the purpose of a citizen energy cooperative was to:

> "do the things that are somehow innovative or that are not so financially safe, which scare off the big players" (TEC #5).

The local network and high degree of voluntary work of members could contribute to reduce the project's costs (TEC #4). For the TECs, the locally added value was of high importance, given their dedication to a citizen-led energy transition. Apart from economic advantages for the local community, TECs said they could potentially create a stronger bond within the community and between its members. The project was said to bring both social and financial values. One TEC said that:

> The local network and high degree of voluntary work of members can help reduce the project's costs. /../ It creates a friendship, a camaraderie, a feeling of togetherness that you do not have otherwise" (TEC #4).

TEC #7 emphasized the strong dynamic of cooperatives as a motivator "*because the idealism is in there*" TEC #5 even went so far as to say that:

> "we want to implement the energy transition and we do so together with the citizens. We are also convinced /.../ that this can only be achieved if the citizens are involved" (TEC#5).

The current situation of high energy prices and geopolitical conflicts had increased the interest and motivation to carry out a renewable heating project, according to the TECs. Table 3 shows an overview of the motivational factors mentioned by the interview partners.

TABLE 3 Overview of motivational factors.

Main motivation for the heating project	Interview partner
Look for new business models	TEC #5, #6; UO #12
Carry out the heating transition with the citizens	TEC #5, #8
Implement innovative concepts	TEC #3, #5; UO #11
Independence from fossil fuels and lower prices for heating	TEC #1, #2, #4, #7; UO #12
Local interest and trust	TEC #4, #5, UO #12
Locally added values	TEC #4, #8
High energy prices and societal pressures (climate movements or political reasons)	UO #9, #10, #12

4.3. Community engagement

Heating grid projects required a closer collaboration between TECs and citizens, and higher levels of community engagement compared with other energy community projects such as solar photovoltaics or wind turbines, according to our interviewees,. Citizens needed to be engaged early to guarantee the minimum number of connections required to make the grid profitable.

> "a member is not only a member but also a customer /.../ These interfaces or contact points from the member to the cooperative are significantly higher [compared to] a pure electricity or wind cooperative" (UO #10).

Convincing citizens to commit to a grid connection could be easy if it was "done correctly", as the grid's synergy effects made it cheaper than individual heating solutions in the long run (UO #10). TEC members were most often customers as well, demonstrating the importance of close connections. This combination of membership and customer facilitated to eliminate fears and doubts about community-owned heating and established the trust and transparency that heating projects required to be successful (TEC #5). Successful TECs instilled a certain pride within the community, not least because members often did much of the work voluntarily to save money (TEC #4; UO #12).

> "We are proud, really /.../ And now that the heating oil price is so expensive. /.../ I hear from other people from other communities, 'yes, you obviously did the right thing back then'," (TEC #4)

The collaboration brought members of a community closer together, while at the same time offering an advantage to local businesses (TEC #4). However, this depended on the structural form and local context, as TECs only focused on their members and could risk marginalizing those who chose not to join (UO #11). Citizen involvement in heating projects is, however, crucial, regardless of TEC membership or not as it can prevent citizen opposition toward projects and facilitate follow-up projects (UO #10).

4.4. Governance: Actors and decision making

Local authorities, municipal utilities, and local companies, as well as political or societal representatives from local associations, were mentioned as important collaborative actors by the interviewees. The cooperation between TECs and municipalities was mentioned as particularly important since local politicians might act as key figures to mobilize citizens and gain acceptance within the community. Their involvement could facilitate motivating citizens to connect to the grid, as well as providing the required expertise:

> "If we did not have [the Mayor], it would be impossible to carry out this project because people are very sceptical" (TEC #5).

All umbrella organizations emphasized that ideally there should be some form of cooperation between the municipality and the cooperative (UO #9-12). This, however, required a professional structure, which could clash with the high reliance on voluntary work in some TECs (TEC #1; #2; #4). Close collaboration with local experts could prevent this, having them as members or simply leaving the technical implementation and planning to other actors (UO #12). One umbrella organization even emphasized that the workload and complexity of heating projects was too high for TEC initiatives. Therefore, municipal utilities should manage heating projects, with TEC actors playing a secondary role (UO #11). This umbrella organization also commented:

> "For me, a cooperative is typically not the main actor of energy supply, it cannot and should not be, because such an important issue cannot be on voluntary shoulders" (UO #11).

In line with UO #11, UO #12 warned that heating grids required a more professional structure than was currently in place in many TECs, due to the high technical complexity and planning effort needed. Several TECs agreed with this, as the workload in heating projects was significant for members working voluntarily, especially within smaller TECs (TEC #1; #2; #4). The heavy reliance on voluntary work often meant that the expert knowledge had to be developed first: "*What is often unclear is who has to do what and how*" (UO #9). TEC #7 recommended relieving the burden on the members doing voluntary work through professional structures or municipal actors taking over. Another TEC commented:

> *"The bigger it gets, the more expensive it becomes, and then I think you are better off with the municipal actors" (TEC #4).*

4.5. Technology and scale

When talking about the technology and scale, the discussion circled around technology and local characterization, due to the inability to transport heat over long distances. As has been discussed above, the technical complexity of heating projects was a big issue and it was mentioned that:

> "without technical support, a small cooperative will not be able to accomplish these projects" (TEC #3).

Access to local experts and technical competence was essential to carrying out the project successfully, but experts were not easily accessed, because:

> "there are only a few engineers we know here in Germany who can carry out these projects" (TEC #1).

A heating project had to be done in collaboration. Local actors were seen as crucial to realizing synergies, such as combining construction work when laying cables and infrastructure for the grid (TEC #2). Some emphasized that heating grids must be built efficiently from the start and can only be expanded under certain conditions. TECs usually plan the grid and the heating capacity for a certain number of people, to ensure economic efficiency and profitability. For cost efficiency, smaller TECs needed to be as efficient as possible in their planning and usually only planned to connect those who were TEC members at the planning stage. This approach made later connections dependent on efficiency gains through renovations or energetic refurbishment (UO #9). Interviewees had different opinions on how big an obstacle this was. Some were more easy-going, admitting that connecting people to the grid retrospectively was challenging, but:

> "We also have to consider that in the following years, due to energy efficiency in buildings, such as insulation, new windows, the heat consumption may decrease. Then we will have free capacity to connect one or two more houses" (TEC #1).

TEC #5 pointed out that "*it depends on how much work you do beforehand and how much risk you take*" whether or not additional connections could be made after the grid construction was completed. This TEC always planned larger capacity grids than the number of people who wanted to connect initially. Based on earlier experiences, they assumed that people would decide to connect at a later stage which had been the case in earlier projects. If the new customer/member paid the costs of the construction from their house to the grid, a later connection was not only possible but also reasonable according to them (TEC #5).

In sum, the capacity of the grid seemed to depend on the local context in combination with the openness to risk or risk adversity of the actor planning the grid.

4.6. Finance

Subsidies are crucial in carrying out heating projects and all interviewed TECs (#1 to #8) received some form of financial subsidies and emphasized that without these the project could not have been carried out. Many of the projects relied on national or regional funding schemes. The TECs boards were the ones responsible for calculating how much subsidy needed to cover a heating project and this is in some countries part of the TEC board's training. It was however unclear if our TECs had gone through such training. TEC #1 meant that the municipalities should support them with knowledge on how to finance a heating project and was critical to the lack of support from municipal actors. Particularly the smaller TECs, those who saved money by relying on volunteers, would have liked more support from their municipality (TEC #1; #3). Due to the high level of voluntary work and cooperatives not aiming to achieve profit, heating could be provided at a lower price than through private actors (TEC #1, #2, #4). The actual costs were, however, a barrier in the funding phase of a project since people did not want to commit before knowing what costs they could expect. A big problem was:

> "we cannot tell [potential members] how much it will cost [...] The more people participate, the cheaper it will get. So, if you participate now, I can promise you that it will be a bit cheaper, but right now I cannot say an exact price" (TEC #4).

Heating projects come with a high financial risk, due to their complexity in planning and the dependency on the grid once it is constructed (UO #9). One TEC had tried to carry out heating projects before but failed due to coupling their price with the oil price, which then fell (TEC #6). Financial support at the beginning to calculate and plan the grid could help overcoming such initial barriers (UO #10). Banks might not be familiar with the legal structure of the TEC or not trust the business plan, posing another obstacle to financing (UO #11). The goal of reducing heating demand further also put the business model at risk of being unprofitable in the future (UO #11).

Umbrella organization #11 raised the aspect of equality, since mostly richer citizens could afford to invest in TEC and then later profit from them. If a municipal utility made the same investment, the profit could be reallocated to communal institutions, which would benefit more citizens. Other interviewees argued, however, that municipal utilities equally have to realize a profit and that the TECs purposefully kept their membership fees low so anyone could join. Another benefit of TECs acknowledged by UO #11 was that with the option to finance their projects through their members, TECs were ascribed more flexibility to invest in innovative projects, which traditional actors like municipal companies might avoid.

Instead of paying a dividend that must be taxed, cooperatives commonly lowered the heating price retrospectively and paid money back at the end of the year. Others collected the revenue of their heating project together with their more profitable projects in solar PV and wind, paying a small interest rate to members at the end of the year (TEC #3).

4.7. Impact and outcomes

The TECs were unsurprisingly mostly positive about the outcomes of their projects. Positive impacts mentioned were the locally added value, security of supply, attracting businesses to their region, and carrying out the energy transition together with citizens. All interviewed organizations agreed that a major impact of TECs was the high acceptance of the heating project among the citizens. Particularly, TEC initiatives with heating were seen to have the advantage of a close connection to the citizens, therefore facilitating future projects more easily.

> "What will be important in the future [is] that the energy cooperative turns into a climate cooperative. That we don't only stay in the area of electricity or heat, but also enter car sharing or charging infrastructure" (UO #10).

It was suggested that grids built with high citizen involvement might be of higher quality, due to TECs wanting to avoid frequent repairs (UO #9). Some argued that TEC actors should instead focus on innovative projects in other areas, as the major transition that Germany needs to undergo cannot be done through initiatives mainly based on voluntary work. Due to their high transparency and the participation and decision-making rights of members, the grid connection rates are usually higher within cooperatives than with other actors carrying out such projects. This close member customer engagement could then facilitate follow-up projects more easily than, for example, in wind or solar PV projects, according to one interview partner (UO #10).

UO #11 argued against cooperatives carrying out heating projects in the future though, as in its opinion, municipal actors would be much better suited.

> "The pioneering period is over. Now the big expansion of renewables is finally coming which will be a mixture of private project developers, hopefully a lot of municipalities and public utilities. Always in connection with some kind of citizen participation and this is where the cooperatives have a role to play" (UO #11).

Municipal utilities could offer cheaper access to the grid as no interest rate has to be paid to those connected to the grid, and construction is equally as expensive when done by the cooperative. However, municipal actors could then reallocate their costs on other projects or invest any revenue in initiatives benefitting the entire community, as discussed above. Cooperatives instead would only serve those who decided to become members and not every citizen of the municipality.

4.8. Summary

Figure 2 (see next page) summarizes the key points made by the respondents.

5. Discussion

TECs could potentially play an important role in the very much needed German heating transition. How to heat a home is a personal decision (Palm, 2010; Sovacool et al., 2021) and a sustainable heating transition requires that many individual households make decisions contributing to entering a new pathway. This implies a need for citizen engagement in heating projects, something also mentioned by the interviewed TECs. Local stakeholder involvement was crucial given the complexity of the heating system and that TECs rely heavily on volunteers who are not necessarily experts on heating. However, while some actors such as municipal utility companies engaged and cooperated with TECs, others regarded them as competitors. Another explanation to why the TECs received little explicit support could be that other actors were unfamiliar with the concept (Holstenkamp, 2021).

This study confirms earlier findings about the importance of municipalities being members of a TEC (Zoellner et al., 2008; Musall and Kuik, 2011; Ruggiero et al., 2014; Meister et al., 2020). A municipality can contribute not only financially and with knowledge, but its commitment also increases the level of support from citizens. A finding in this study, not previously discussed, was that local authorities' knowledge of other ongoing or planned projects that require opening the streets, such as repairing existing pipelines, could be essential for the project to become realized due to the synergies that could occur.

The involvement of local politicians was mentioned as important because they could increase citizens' motivation and drive the project forward. Our interview partners suggested that the involvement of local politicians or other representative of the municipalities was even more important in heating projects, since the establishment of a district heating system needed the participation of many, something a municipality had the capacity to achieve. In Germany, the municipality might be even more important, because it can mandate a connection to the grid, eliminating the need to convince every individual to commit to a grid connection (Weiß et al., 2018).

However, a problem was that municipalities often lacked resources, expertise and the capacity to actively engage in heating projects (Weiß et al., 2018). That is why alliances between local stakeholders could be a way forward. Our interviewed TECs stated that they were well equipped for carrying out a heating project and could take a coordinating role if only there was a professional support structure in place. Municipalities usually have broad networks and can enable such a professional structure to emerge. TECs' close engagement with citizens, which is inherent in their organization form, could from their side contribute to building the necessary trust for a heating project (Heras-Saizarbitoria et al., 2018), and they could therefore act as mediators (Wagemans et al., 2019).

The motivations of the interviewed TECs to carry out a heating project strongly overlapped with those found in literature for renewable electricity projects. A major motivation was to realize the energy transition together with the citizens (Seyfang et al., 2013). Another was the drive to carry out innovative and qualitative projects, which would not happen without the TEC (Broska et al., 2022). Other motivations confirmed in this study was to creating locally added value, keeping money in the region (Walker et al., 2010; van Der Schoor et al., 2016) and creating a stronger bond within the community and between the members (Soeiro and Dias, 2020).

The interviewees emphasized the strong need for community engagement and citizen mobilization in heating projects due to the minimum number of connections required for profitability, as well as members being customers, too. These aspects are often raised as integral to TECs in the literature, due to their close connection to their members and the focus on realizing local benefits (Wagemans et al., 2019). This suggests the important contribution that TECs can make to citizen engagement when taking up heating projects. TECs seem to provide space to foster community engagement in heating projects and increase the energy literacy locally. The involvement of TECs in a heating project helped to gain a wider acceptance of the project in the community and was expected to increase the number of people connecting to the grid. However, other studies view this more critically as, depending on the local context, communities could be exclusionary to those who may be unable or unwilling to participate (Walker et al., 2010). One of the interviewees expressed a similar concern. District heating grid owners had a problem with a potential exclusion of members who were not connected from the start. However, while the interviewees agreed upon a later connection

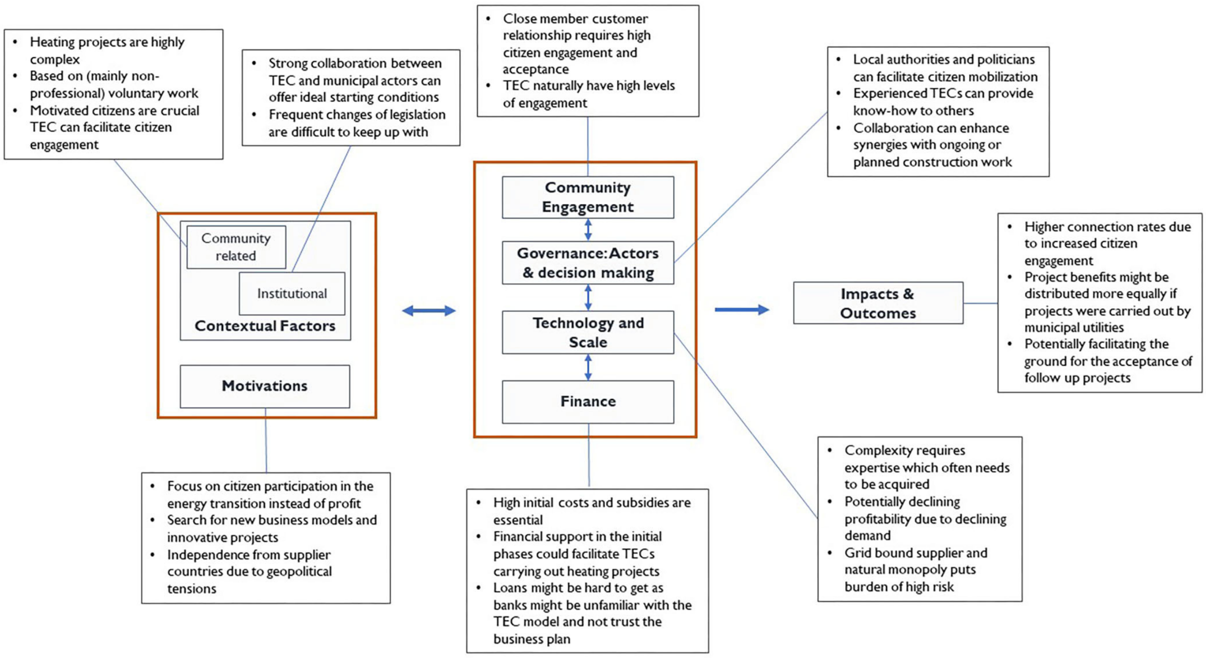

FIGURE 2
Key take-aways from the interviews.

being difficult, attitudes toward the actual barrier it represented differed among them. The issue appears to be related to risk aversion rather than being a technical barrier.

The TECs interviewed reported a high reliance on financial support from government subsidies, the municipality, or banks. This dependence on grants or loans has also been observed in other case studies and seems common to renewable projects in general (Ruggiero et al., 2014; Yildiz et al., 2015). The high initial costs of heating grids further increased the dependency on financial support in the cases studied, suggesting that this is a bigger barrier for TECs carrying out heating projects. The dependence of the final price on the number of participants and the size of the grid further complicated getting people on board.

Research attributes the return of profit as the main reason for investment in EC projects for local citizens (Bauwens, 2019). The decline in new foundations of EC initiatives for solar PV in Germany after a reduction of feed-in tariffs further indicates the certain role of financial incentives (Hewitt et al., 2019). However, EC based on bioenergy has in earlier research been mentioned as being the least profit-oriented of existing ECs (Holstenkamp and Kahla, 2016), and several of our interviewed TECs did not emphasize profit as a main driver for them. Another interesting tension seen in our material, however, was coupled to dividend and low prices. For tax reasons most TECs avoided dividends and reduced the price of heat instead. This benefits the members that are also connected to the grid and customers, but not those who are only investing members. The TECs often mentioned paying a lower price for heating as one of the motivations for the formation of the initiative, indicating that this tension might be structural and represent a problem for future projects based on alliances between local stakeholders.

Generally, the financial risk of renewable heating projects was mentioned as higher than for other renewable energy projects, due to the natural monopoly of district heating providers and the high dependency on the grid's functionality, which has also been seen in earlier studies (Bruns et al., 2012). The interviewees pointed out that banks were unfamiliar with TECs' business model, which sometimes made obtaining bank loans more difficult. This has been previously observed and is a known problem for ECs (Brummer, 2018). The difficulties in calculating a heating project correctly were also discussed. One interesting suggestion from one of the umbrella organizations was to introduce financial support to carry out a feasibility study in the initial phase of a project.

Previously mentioned impacts of ECs demonstrated in literature, such as high citizen engagement (Seyfang et al., 2013), creating a sense of community (Soeiro and Dias, 2020), as well as successfully pushing the energy transition (Klagge and Meister, 2018), were confirmed during our interviews. It also appears that existing electricity focused ECs had a tendency to take up heating projects, confirming Punt et al's (2022) theory of institutional relatedness. Another aspect that underlined Punt et al's (2022) theory were the follow-up projects some interviewed TECs described, for example car sharing, which could be realized much easier due to the close customer member relationships in heating projects.

6. Conclusions and future research

The results from this study imply that TECs can make an important contribution to the needed energy transition. The study confirms earlier research emphasizing the need to understand energy community in their local settings. The contextual factors (physical, technology, institutions and community) will all restrict and enable what is possible to achieve in a TEC. Another conclusion is that citizen engagement is not only a motivation for the TECs but also a requirement to reach a financial breakeven of a heating project. All TECs saw the support from local politicians and local professionals as a main driver and a central success factor. A main barrier was, together with high investment cost, the dependency of volunteers, which often were laymen and lacked necessary expertise about heating technology and EC formation and development.

For local policy makers a recommendation would be to have a collaborative approach and include TECs in their heat planning and projects. TECs can contribute and support a local heating project by engaging citizens and motivating them to join. Furthermore, the workload for citizen workshops or informational campaigns, financial support and general planning workload could be shared, depending on the TEC's members' expertise. A recommendation for the TECs would in similar way be to engage in close collaboration with the municipal utilities and administration. These local actors can provide expertise or funding and mitigate potential opposition among citizens toward the TEC's project. The experiences of the German TECs were that collaboration with local actors in general was beneficial and could contribute to the resources and capacity needed to fulfill the project.

The article contributes with a better understanding of how citizen-led TECs can take an active part in the transition to renewable heating and which drivers and barriers they perceived when entering the heat market in Germany. Further research of the experiences of TECs in other countries, as well as more in-depth studies of policies and other related actors (such as local authorities, politicians, local professionals) can increase clarity on how to accelerate the overall heating transition. Other case studies applying the same framework (or at least the same elements) would benefit a comparison but also comparisons of how TECs experience drivers and enablers to enter a market would be an important contribution to the field. Further suggestions for future research is to investigate the interplay between TECs, municipalities and municipal utilities to determine how each actor, alone and in collaboration, can best contribute to a heating transition. Another suggestion is to further study if TECs are in need of specific policy instruments and how these should be designed.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their oral or written informed consent to participate in this study.

Author contributions

KH designed the study, performed the data collection and data analysis, and wrote sections of the manuscript. JP drafted the article and revised the manuscript. Both authors read and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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