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Thermal energy communities: what, why and how to formulate complex collective action for the thermal energy transition in Europe

Javanshir Fouladvand
Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, The Netherlands
E-mail: javanshir.fouladvand.work@gmail.com and j.fouladvand@uu.nl

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What makes energy communities peculiar energy systems is their collective and decentralised nature for energy generation and consumption [1]. 'Energy community' is an overarching term used to represent initiatives that aim to generate, distribute and consume renewable energy collectively for all locally involved participants [2]. Although there are various definitions for energy communities in the literature (e.g. the ones presented in [3]), in a broad sense, energy communities are defined as individual households in a neighbourhood who invest in renewable energy technologies (RETs) jointly and generate the energy they consume (with energy saving measures) [4]. Such collective energy systems are gaining momentum in the real-world [5], particularly in Europe, as the number of established energy communities is increasing [6]. As summarised in [7–9], the main reasons for this momentum of the energy communities are:

- (Inter)National targets and incentives to increase the share of renewable energy generation and consumption, specifically for the built environment and among individual households;
- Improvements in the technical and institutional system design of decentralised renewable energy systems (mainly due to developments in decentralised renewable energy systems);
- Recognising the importance of stakeholders' participation in the decision-making processes (mainly due to new governance arrangements for decentralised renewable energy systems);
- Attempts of different stakeholders to conserve energy in the residential area, especially policy-makers and individuals.

Although the number of energy communities is increasing, most established ones focus only on renewable electricity technologies [6]. This is also reflected in the academic literature, as recent literature on the establishment and governance of community energy systems is dominated by the research on RETs in general (e.g. [9]) or studies on specific renewable electricity technologies, namely solar photovoltaic (solar photovoltaic systems (solar PV)) and wind turbines (e.g. [10]). However, thermal energy systems, which are used for the purpose of heating, cooling, bathing, showering and cooking [11], are largely understudied within the context of energy communities [12]. This contrasts with the importance of thermal energy at the community level within European countries, as these systems cover approximately 60%–75% of the non-transport-related energy consumption among households [13]. This is problematic, as to foster the local energy transition (and the energy-secure transition as a whole), it is essential also to include energy communities with thermal energy applications [14].

Why to establish thermal energy communities (TECs) is essential to understand their impacts, possibly increasing the motives for establishing such collective energy systems and eventually fastening the energy transition. Most importantly, TEC initiatives could drastically reduce individual households' natural gas consumption and CO_2 emissions [15]. Studies such as [16] demonstrated the possibility for households to reduce their CO_2 emissions by 50%, on average, by participating in TEC initiatives. Therefore, such energy systems reduce the reliance on fossil fuels imports and consumption for the built environment, which is approximately 30% of total national energy consumption. Therefore, TEC initiatives could play a crucial role in local and national energy independence.

Along with environmental and energy independence impact, TEC initiatives have considerable economic influence. Along with economic influence on the local level (e.g. creating jobs) and national level

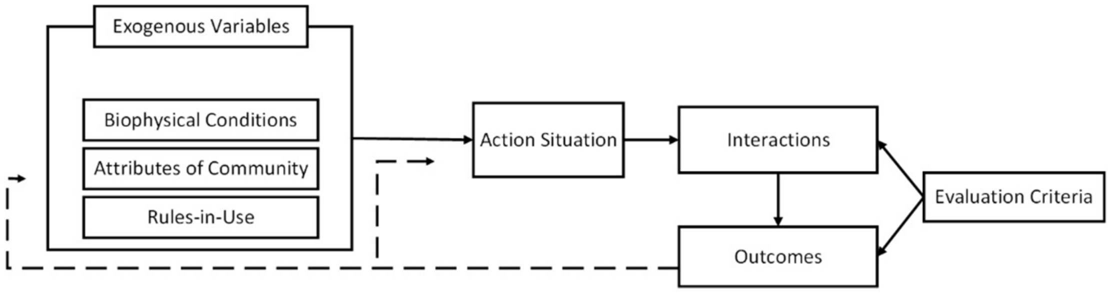

Figure 1. The IAD framework [25] John Wiley & Sons. © 2011 Policy Studies Organization.

(e.g. reducing energy subsidies in the long run), TEC initiatives are financially feasible in a 15-20 years investment for individual households, depending on their technical configurations and institutional conditions [1]. For instance, in the current institutional context of the Netherlands TEC initiatives based on less expensive technologies, including combined heat and power based on bioenergy, the payback time could be around 15 years [1]. As a result of the current energy crises and high prices in the energy market, such systems could potentially have shorter payback times. Therefore, TEC initiatives could potentially overcome the financial barriers, as it is one of their establishment's most essential barriers (and motives) [17]. By providing more supportive policies (e.g. higher subsidies and loans), such collective systems could become financially more attractive than consuming fossil fuels (e.g. natural gas), even in a shorter period.

Furthermore, energy communities, and TEC initiatives as their sub-category, could also increase the social cohesion in a neighbourhood and promote collective action further among individuals [17]. Environmental friendly behaviour and collective action promote the establishment of TEC initiatives and vice versa [16]. Therefore, these peculiar energy systems could be seen as social systems for increasing social welfare and awareness (e.g. about the (thermal) energy-secure transition). All these advantages can be translated into increasing communities' energy security and resilience. TEC initiatives could also contribute to individual households' energy security [1] while fostering the energy security of the whole country and region [18].

Contrary to all the advantages, due to the unique characteristics of TEC initiatives, such as thermal renewable energy technologies (e.g. geothermal, bioenergy, heat pump and solar thermal), covering a high consumption share of energy consumption at the community level, different consumption patterns (e.g. due to building occupation and seasonal changes), and huge required investment (e.g. investment on collective district heating), the establishment of such systems is different and more challenging than electricity-based communities [11]. In this context, establishing local heating renewable energy systems, such as TEC initiatives, is challenged by the current institutional context, unique stakeholder interactions, characteristics and behavioural attitudes rather than the technical design and configurations [15].

There is a relatively vast literature on the technical design and configurations of local heating systems, particularly focusing on district heating in Europe. For example, studies such as [19, 20] have studied the technical design and development of district heating in Sweden. Furthermore [21, 22] studied the techno-economic feasibility and developments of district heating in Denmark and the Netherlands. However, such studies do not specifically investigate TEC initiatives, their institutional design and collective action nature. A comprehensive overview of the TEC initiatives literature and case studies is presented in [12, 23]. Furthermore, in the Dutch context, platforms such as 'Buurtwarmte' [24] (in English: Neighbourhood heat; translation by the author) and 'Energie Samen' are helpful initiatives for mapping the TEC initiatives, as they seek to help individuals who want to form their own TEC initiatives.

How to facilitate TEC initiatives establishment is challenging, but some lessons can be learned from the energy community literature as a whole, as elaborated in [12]. However, their unique technical, institutional and behavioural characteristics need to be studied in detail [12]. The institutional analysis and development (IAD) framework (figure 1) can be used to analyse and structure the necessary actions and settings to facilitate TEC initiatives establishment. The IAD framework enables the dynamic analysis of decision-making processes in a system by breaking them down and organising them into simpler, more manageable parts [25].

As presented in figure 1, the action situation is the main component of the IAD framework. The action situation is described as: 'a conceptual space in which actors inform themselves, consider alternative courses of action, make decisions, take action, and experience the consequences of these actions'. In the TEC initiatives' establishment, action situation refers to the decision-making processes of different actors and their responsibilities in such processes. The action situation component leads to patterns of interactions that generate certain outcomes (i.e. TEC initiatives establishment) [25]. These outcomes can be objectively assessed based on evaluation criteria, such as (i) generated renewable thermal energy, (ii) cost, and (iii) time and duration of the establishment. Ultimately, a feedback loop connects the outcome to the exogenous variables and the action situation. What happens in the action situation component (and all the other components) is influenced by exogenous variables, which are classified into three main components: biophysical conditions, community attributes and rules-in-use. Following these three main categories of exogenous variables, recommendations for actions and settings to establish TEC initiatives further can be formulated as:

- **Biophysical conditions (i.e. technical configurations):** Although renewable thermal energy technologies are well-established energy systems, the required technical configurations still need further investigation.
  - Off-grid TEC initiatives are harder to establish and have lower energy security performances than connected-to-grid TEC initiatives. Connection to the natural gas or national electricity grid (for heating purposes such as heat pumps and electric boilers) could potentially contribute to the flourishing of such collective systems.
  - Higher collective energy systems consequently have a higher impact on reducing natural gas consumption and increasing the energy security of a TEC initiative. The geothermal resources (e.g. aquifer thermal energy storage) are the most suitable for establishing TEC initiatives.
  - In addition to collective energy systems, individual renewable thermal energy systems, such as heat pumps and solar thermal collectors, could lead to more comfort and higher energy security within TEC initiatives.
- **Attributes of community (i.e. individual household attributes):** Eventually, as TEC initiatives are based on collective action, household attributes and decision-making processes are the most impactful criteria.
  - By considering current trends in energy policy (e.g. natural gas prices and CO_2 taxes), in the long-term (i.e. longer than ten years), TEC initiatives are financially more attractive than using fossil fuels (i.e. natural gas), while their contribution to the CO_2 emission reduction is considerable.
  - Household investment size (i.e. budget) can be considered the most decisive parameter for the higher collective energy security performances of TEC initiatives.
  - Adopting environmental-friendly behaviour and acting collectively could potentially lead to a more energy-secure performance of TEC initiatives.
  - Although considering all possible criteria in the decision-making process is important, a faster and converged start could lead to the establishment of more successful TEC initiatives.
- **Rules-in-use (i.e. policy interventions):** There is a need to develop rigorous regulations and business models to establish TEC initiatives further.
  - Incentivising energy policies (e.g. available subsidy) is more impactful than prohibiting energy policies (e.g. CO_2 emissions taxes). Providing subsidy schemes and investment loans for facilitating TEC initiatives establishment are among the most impactful policies.
  - Allocating subsidies based on environmental friendliness and economic constraints could potentially lead to the establishment and function of TEC initiatives rather than only focusing on technical configurations or participation rates.
  - For a fast energy-secure transition, energy policies should focus on strategies to increase collective thermal energy generation and distribution within TEC initiatives rather than thermal energy demand reduction strategies.
  - Although increasing fossil fuel prices, particularly natural gas, could lead to increased energy poverty, it could also contribute to establishing TEC initiatives.

In addition to the mentioned recommendations, the TEC initiatives' leadership is one of the most impactful criteria for further establishing TEC initiatives [15]. Community Board, particularly, shows a higher success in establishing a TEC initiative. Therefore, individuals are encouraged to take the lead in establishing their own TEC initiatives. When possible, the municipality leadership could also lead to energy-secure TEC initiatives. The highly informed and trained community boards have a higher chance of establishing TEC initiatives and achieving energy security.

Considering such technical, behavioural and institutional settings could potentially facilitate the establishment of TEC initiatives, fostering the (thermal) energy transition. Along with behavioural attributes and collective action of involved actors, establishing and functioning TEC initiatives heavily relies on the institutional design of such complex systems, which can be seen as both opportunities and barriers for further development. Although the current study provided a structured discussion on TEC initiatives, it does not include integrating the energy sources and energy systems (e.g. electricity and thermal, net-zero, and integrated energy communities). Detailed study of such integrated energy communities could provide further insights into the interactions and dynamics with the national grid. Furthermore, while this study emphasises the collective action nature of TEC initiatives, studying and developing the (innovative and tailored) business models for TEC initiatives could be significantly beneficial.

As mentioned, TEC initiatives could play a crucial role in natural gas consumption reduction and, therefore, the battle for sustainable development. Furthermore, TEC initiatives could be seen as local collective initiatives tackling energy poverty and dependency in Europe. In conclusion, despite all the challenges of establishing TEC initiatives, such collective and decentralised thermal energy systems could be seen as a proper approach to respond to the current ongoing geopolitical energy crises and the energy transition goals, particularly in Europe. As presented, their establishment is highly feasible, and specific actions and settings could facilitate their establishment.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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