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Nermina Abdurahmanovic

nermina.abdurahmanovic@iee.fraunhofer.de

Fraunhofer Institute for Energy Economics and Energy System Technology

Tarek Anwarzai

Fraunhofer Institute for Energy Economics and Energy System Technology

Anna Cadenbach

Fraunhofer Institute for Energy Economics and Energy System Technology

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Behavioural engagement in district heating systems: An exploratory comparison of provider and end-user perspectives on motivational tariffs and gamification

Nermina Abdurahmanovic[1*], Tarek Anwarzai[1] and Anna Cadenbach[1]

[1*]Fraunhofer Institute for Energy Economics and Energy System Technology IEE, Joseph-Beuys-Straße 8, Kassel, 34117, Germany.

*Corresponding author(s). E-mail(s): nermina.abdurahmanovic@iee.fraunhofer.de;

Abstract

Background: District heating (DH) is important for decarbonising heat supply, but its behavioural dimension remains less studied than technical optimisation. This study explores how motivational tariffs and gamification are perceived by DH providers and end-users. Online surveys included 15 DH providers in Germany and Denmark and 93 end-users in Germany.

Results: Providers saw potential in behavioural engagement but identified technical integration, organisational resources, and implementation effort as key barriers. End-users showed substantial stated willingness to engage when measures were simple, transparent, and linked to visible benefits. Among end-users, 79.6% would participate in a point-based tariff and 84.9% would use a corresponding digital application, whereas only 23.7% expressed a positive attitude towards gamification. Financial incentives were the most frequently preferred reward (95.7%). Providers focused mainly on technical and organisational feasibility, whereas end-users focused on usability and clear personal benefit.

Conclusions: Behavioural engagement in DH requires alignment between provider capabilities and user expectations. Selected gamified features appear most relevant when they support practical feedback and understandable incentives rather than a strongly game-like experience.

Keywords: district heating systems, user-engagement, behaviour change, energy efficiency, motivational tariffs, survey analysis, gamification

Abbreviations

Abbreviation	Definition
DH	District heating
DHS	District heating system
4GDH	Fourth-generation district heating
DSM	Demand-side management
GDPR	General Data Protection Regulation

1 Background

The decarbonisation of the heat sector is one of the major challenges of the energy transition. Space heating and domestic hot water account for a considerable share of final energy demand and greenhouse gas emissions, particularly in the building sector [1]. District heating (DH) is therefore increasingly relevant for integrating renewable heat, waste heat, and sector-coupling technologies into urban heat supply [2].

Considerable progress has been made in improving the technical performance of district heating systems (DHSs), including lower-temperature operation, digital monitoring, control strategies, and network optimisation [3, 4]. However, system performance is not determined by technical components alone. End-users influence heat demand, return temperatures, and the way operational measures are accepted and used [5, 6]. DH can therefore also be understood as a socio-technical system in which technical performance is linked to organisational processes and user interaction [7].

This interaction becomes increasingly relevant as DH systems become more flexible and data-driven. In the electricity sector, demand-side management already uses dynamic pricing, consumption feedback, and digital tools to make energy use more visible and to encourage users to adapt their behaviour [8, 9]. Comparable approaches are less established in DH. Heat consumption is often less visible to users, tariff structures are commonly fixed, and opportunities for direct interaction with system operation remain limited.

Motivational tariffs are one approach to address this gap. They link operationally useful behaviour or performance indicators to financial or non-financial incentives. In DH, existing work has shown how tariff components can be used to encourage improvements in secondary-system performance, for example through incentives related to return temperature or flow [10]. Such approaches are relevant because inefficient customer-side operation can affect the performance of the wider network. At the same time, the effectiveness of a tariff depends on whether customers understand the mechanism, perceive the benefit, and are willing to respond to it.

Gamification provides a related but different approach. It uses elements such as points, progress indicators, challenges, rankings, or rewards to support motivation and engagement. Previous energy research has examined these mechanisms mainly in electricity, smart-grid, and demand-response contexts [11, 12]. Their transfer to DH cannot be assumed. DH is characterised by collective infrastructure, limited user visibility of system operation, and specific technical and regulatory constraints [13]. In this context, game-like elements may be less important than clear feedback, understandable incentives, and information that connects user actions to system operation.

Recent research also shows growing interest in the social and organisational dimensions of heat transitions. Survey-based work in Germany has examined how municipal actors experience and evaluate low-carbon heating options, including DH [14]. Other studies have addressed user acceptance, governance, and organisational challenges in DH [15, 16]. Nevertheless, provider and end-user perspectives are still often examined separately. This is a relevant gap for behavioural engagement because providers determine the technical, organisational, and tariff-related conditions, while end-users decide whether the resulting measures are understandable, acceptable, and worth using.

Against this background, this study explores behavioural engagement in DHSs from both perspectives. It compares the views of DH providers and end-users regarding motivational tariffs and gamification and examines where provider capabilities and user expectations converge or diverge. The study is exploratory and does not aim to estimate population-level acceptance or behavioural effects. Instead, it provides empirical insight into the conditions under which behavioural engagement mechanisms may be practically implemented in DH.

Accordingly, the main research question is:

How are behavioural engagement mechanisms perceived and evaluated by DH providers and end-users?

Three sub-questions are considered:

- What opportunities and barriers do DH providers perceive regarding the implementation of motivational tariffs and gamified engagement strategies?
- How do end-users perceive and evaluate motivational tariffs and gamified engagement strategies in DHSs?
- Where do provider perspectives and user expectations converge and diverge regarding behavioural engagement in DHSs?

The contribution of the study is the direct comparison of these two stakeholder perspectives. This makes it possible to distinguish between barriers related to provider-side implementation and conditions that matter to end-users. It also helps clarify the role of gamification within DH: whether users respond to the concept itself or mainly to individual features such as feedback, points, progress tracking, and financial rewards. The results are intended to support the design of engagement mechanisms that are technically feasible for providers and understandable and useful for end-users.

The remainder of the paper is organised as follows. Section 2 introduces the conceptual background and analytical framework. Section 3 describes the study design and analysis. Section 4 presents the survey findings, followed by the discussion in Section 5 and the conclusion in Section 6.

2 Conceptual Background and Analytical Framework

Behavioural engagement in DHSs cannot be understood solely from a technical perspective. Although technical components such as heat generation, distribution networks, and control strategies determine the operational capabilities of a system, their practical performance is also shaped by organisational arrangements, communication, tariff structures, and user behaviour. This section therefore situates behavioural engagement within the broader literature on socio-technical energy systems before introducing the analytical framework that guides the empirical analysis.

2.1 DHSs as socio-technical systems

Research on DH has traditionally focused on technical challenges such as network optimisation, heat generation, hydraulic performance, thermal losses, and control

strategies [17], [18]. These studies have substantially advanced the technical understanding of DHSs and contributed to improving their efficiency and reliability. However, technical performance alone does not determine the overall success of a DH network [13], [19].

Socio-technical systems research argues that infrastructures should not be viewed as purely technical systems but rather as configurations in which technologies, organisations, institutions, and users continuously interact [20]. From this perspective, technical innovations only realise their full potential when they are accompanied by appropriate organisational structures, communication processes, institutional conditions, and user practices. Consequently, system performance emerges from interactions between technical and social components rather than from technological improvements alone [19].

Applying this perspective to DH highlights that providers and end-users fulfil complementary roles. DH providers determine tariff structures, communication strategies, and operational conditions, while end-users influence system performance through their everyday heating practices and their responses to information and incentives. Behavioural engagement therefore cannot be understood as an individual characteristic but should instead be viewed as a relational process embedded within the wider socio-technical context of DH.

Adopting a socio-technical perspective provides an appropriate conceptual basis for the present study because it enables behavioural engagement to be analysed from both provider and end-user perspectives simultaneously. Rather than examining isolated stakeholder preferences, the study focuses on how interactions between both groups shape the opportunities and limitations of behavioural engagement mechanisms.

2.2 Behavioural engagement in energy systems

Behavioural engagement has become an increasingly important topic in energy research as technological innovation alone is often insufficient to achieve intended energy and climate objectives [9], [21]. Across different energy sectors, behavioural engagement refers to approaches that encourage users to actively participate in improving system performance by adapting their behaviour, responding to information, and interacting with energy-related technologies.

In electricity systems, behavioural engagement is commonly associated with demand-side management, dynamic pricing, smart metering, and digital feedback systems [22]. These approaches increase transparency regarding energy consumption and enable users to adjust their behaviour according to system conditions or economic incentives. Previous research ([23], [13]) has shown that providing timely information, personalised feedback, and appropriate incentives can encourage more energy-efficient behaviour and improve overall system operation.

Compared with electricity systems, behavioural engagement remains considerably less developed in DH [24]. Heat consumption is often less visible to end-users, tariff structures are frequently fixed, and opportunities for active participation are comparatively limited. As a result, behavioural engagement within DH extends beyond individual behavioural change and also depends on how providers communicate with users, design tariff structures, and create opportunities for participation.

Consequently, behavioural engagement in DH should be understood as a shared responsibility between providers and end-users. While providers create the institutional and technical conditions that enable participation, end-users ultimately determine whether these opportunities are accepted and translated into everyday behaviour.

2.3 Motivational tariffs and gamification

Among the different approaches to behavioural engagement, motivational tariffs and gamification have attracted increasing attention because both seek to encourage voluntary behavioural change through positive incentives rather than regulatory obligations.

Motivational tariffs aim to reward energy-efficient behaviour by linking predefined actions or performance indicators to financial or non-financial benefits [25], [26]. Rather than functioning solely as pricing mechanisms, they can also serve as communication instruments that increase user awareness and strengthen engagement with the energy system. Previous research has primarily examined motivational tariffs in electricity markets and demand response programmes, whereas their application in DH remains limited [27].

Gamification follows a complementary approach by introducing elements commonly associated with games into non-game contexts. Typical examples include reward points, badges, progress indicators, personalised feedback, challenges, and rankings. The objective is not to transform energy management into a game itself but to increase motivation, sustain engagement, and support behavioural learning over longer periods [24], [21].

Although motivational tariffs and gamification represent different mechanisms, both pursue similar objectives. They seek to improve behavioural engagement by increasing transparency, providing feedback, and creating incentives for energy-efficient behaviour [17], [28]. Their successful implementation, however, depends not only on technical feasibility but also on stakeholder acceptance, organisational capabilities, and practical usability. These characteristics make both approaches particularly suitable for examining behavioural engagement from a socio-technical perspective.

2.4 Analytical framework

Based on the literature reviewed above, this study conceptualises behavioural engagement in DHSs as the outcome of interactions between provider capabilities and user expectations rather than as the result of individual behaviour alone. Providers create the organisational, technical, and communicative conditions under which behavioural engagement can occur, while end-users determine whether these opportunities are accepted and translated into everyday practice. The analytical framework developed for this study therefore distinguishes between two complementary perspectives. The provider perspective focuses on organisational readiness, communication strategies, perceived opportunities, and implementation barriers associated with motivational tariffs and gamification. The end-user perspective addresses awareness, acceptance, motivational preferences, communication preferences, and willingness to participate

in behavioural engagement mechanisms. Figure 1 illustrates the analytical framework underpinning this study. Behavioural engagement is positioned at the centre of the framework and emerges through the interaction between provider capabilities and user expectations. Motivational tariffs and gamification represent two complementary mechanisms through which this interaction may be strengthened. The framework sub-

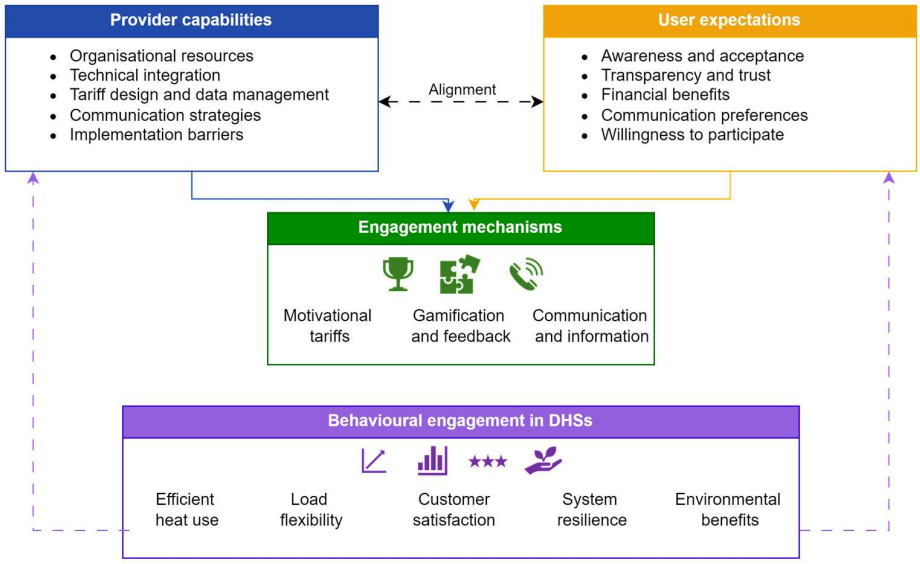


Fig. 1 Analytical framework used to examine behavioural engagement in DHSs. Behavioural engagement is conceptualised as the outcome of interactions between provider capabilities and user expectations, mediated through motivational tariffs, gamification, and communication.

sequently guides the development of the questionnaires presented in Section 3 and provides the basis for the comparative analysis of provider and end-user perspectives reported in Section 4.

3 Methods

This section describes the methodological approach used to address the research questions introduced above. It presents the study design, questionnaire development, participant recruitment and data collection, as well as the procedures used for data analysis. Methodological considerations relevant to the interpretation of the results are discussed at the end of the section.

3.1 Study design

This study employs a cross-sectional survey design to investigate behavioural engagement in DHSs. Building on the analytical framework developed in Section 2, the study compares the perspectives of two stakeholder groups: DH providers and end-users.

The objective is to examine how provider capabilities and user expectations shape the perceived feasibility and acceptance of motivational tariffs and gamification.

Behavioural engagement in DHSs emerges through the interaction between providers, who design and implement engagement mechanisms, and end-users, who ultimately decide whether to participate in them. Investigating only one stakeholder group would therefore provide an incomplete understanding of the opportunities and challenges associated with these approaches. A comparative research design was consequently adopted to identify areas of convergence and divergence between provider capabilities and user expectations.

Given the limited empirical evidence on behavioural engagement in DHSs, particularly regarding motivational tariffs and gamification, the study is exploratory in nature. It was designed as a comparison of provider perspectives and end-user expectations rather than as a representative assessment of either population. Rather than testing predefined hypotheses, it aims to identify recurring patterns, implementation barriers, and areas of alignment or divergence between the two stakeholder groups.

3.2 Questionnaire development

Two structured questionnaires were developed, one targeting DH providers and one targeting end-users. Although tailored to the respective stakeholder groups, both questionnaires were designed around the same conceptual dimensions presented in the analytical framework, thereby enabling a direct comparison between provider capabilities and user expectations.

Questionnaire development was informed by previous research [9], [13], [24], [29] on behavioural engagement, demand-side management, tariff design, and gamification in energy systems. Practical experience gained within a national research project further supported the formulation of survey questions and response categories. Prior to distribution, both questionnaires were reviewed by project partners and colleagues to improve clarity, comprehensibility, and consistency.

Both questionnaires combined closed-ended and open-ended questions. Closed-ended items included multiple-choice questions, Likert-scale ratings, and ranking tasks, allowing systematic comparison across respondents. Open-ended questions provided participants with the opportunity to explain their responses and contribute additional perspectives that could not be captured through predefined answer categories.

The provider questionnaire addressed organisational characteristics, existing tariff structures, previous experience with incentive schemes, perceptions of motivational tariffs and gamification, communication strategies, and implementation barriers. The end-user questionnaire focused on awareness of tariff models, energy-related attitudes, willingness to participate in motivational tariff schemes, preferences regarding incentives and gamification elements, communication preferences, and perceived challenges.

3.3 Participants and data collection

Data were collected during 2025 using online questionnaires distributed through several communication channels.

DH providers were recruited through professional networks, direct outreach, and industry contacts. The provider survey yielded 15 valid responses. Twelve participating organisations were located in Germany and three in Denmark. The Danish responses were included to broaden the empirical perspective by incorporating experiences from a country with a long tradition of DH operation; the sample was not designed to enable cross-country comparison.

The end-user survey yielded 93 valid responses. Participants were recruited through municipal communication channels, online platforms, and project-related dissemination activities. Participation in both surveys was voluntary and anonymous. No personal identifying or demographic information was collected.

Table 1 summarises the composition of the study sample.

Table 1 Overview of the study sample.

Stakeholder group	n	Recruitment	Scope
DH providers	15	Professional networks	Germany, Denmark
End-users	93	Municipal and online distribution	Germany

The study complied with the General Data Protection Regulation (GDPR). The survey design and data collection procedure were reviewed and approved by the responsible employee representation body (Works Council).

3.4 Data analysis

The quantitative data were analysed using descriptive statistics. Frequency distributions and percentage shares were calculated to identify recurring response patterns within each stakeholder group. Given the exploratory character of the study and the comparatively small provider sample, the analysis focuses on identifying patterns and describing stakeholder perspectives rather than estimating population-level effects or testing statistical significance. Accordingly, percentages reported for the provider sample should be interpreted descriptively and together with the corresponding absolute response counts. For questions that were presented only to a specific subgroup of providers due to questionnaire branching, percentages were calculated using the number of respondents who received and answered the respective question.

Responses to the open-ended questions were analysed using thematic analysis [30]. The responses were reviewed iteratively and grouped into recurring themes, including transparency, trust, financial incentives, communication, technical feasibility, and organisational complexity. These qualitative findings complement the quantitative results and support their interpretation throughout the Results and Discussion sections.

3.5 Methodological considerations

Several methodological considerations should be taken into account when interpreting the findings.

First, the study is exploratory and the provider sample is comparatively small. The provider-side findings should therefore not be interpreted as statistically representative of the DH sector as a whole but rather as exploratory evidence of recurring response patterns, implementation experiences, and perceived barriers among the participating organisations.

Second, participation was voluntary, introducing the possibility of self-selection bias. Respondents may have been more interested in energy-related topics or more receptive to innovative engagement mechanisms than the wider population.

Third, the study investigates stakeholder perceptions rather than actual behavioural change. Positive attitudes towards motivational tariffs or gamification should therefore not be interpreted as evidence of future participation or sustained behavioural adaptation.

Despite these limitations, the comparative stakeholder design provides valuable insight into behavioural engagement in DHSs. By considering provider capabilities and user expectations simultaneously, the study identifies both areas of alignment and important differences that may influence the implementation of behavioural engagement mechanisms in DH.

4 Results

This section presents the empirical findings from the surveys of DH providers and end-users. Following the analytical framework introduced in Section 2, the results are structured around four analytical areas rather than the individual survey questions. The section first examines the current implementation of motivational tariffs in DH before presenting the perspectives of DH providers and end-users separately. Finally, both stakeholder perspectives are compared to identify areas of alignment and divergence regarding motivational tariffs and gamification.

Table 2 Structure of the Results section and analytical focus.

Section	Analytical focus
4.1 Current implementation of motivational tariffs	What is the current implementation status of motivational tariffs in DH?
4.2 Provider perspectives	How do DH providers perceive behavioural engagement mechanisms?
4.3 End-user perspectives	How do end-users perceive behavioural engagement mechanisms?
4.4 Alignment between provider capabilities and user expectations	Where do provider capabilities and user expectations align and where do they differ?

4.1 Current implementation of motivational tariffs

Before comparing the perspectives of DH providers and end-users, it is useful to establish the current implementation status of motivational tariffs. The survey results show

that such tariff models are still at an early stage of development and cannot yet be regarded as common practice within DH.

Among the 15 participating DH providers, five organisations (33.3%) reported that motivational tariffs had already been introduced or were currently under development, whereas ten providers (66.7%) indicated that no comparable model was implemented. The participating organisations represent municipal, private, and mixed utilities serving communities of different sizes. Most responses originated from Germany, complemented by providers from Denmark. Existing examples of motivational tariffs therefore reflect individual initiatives rather than an established approach within the DH sector.

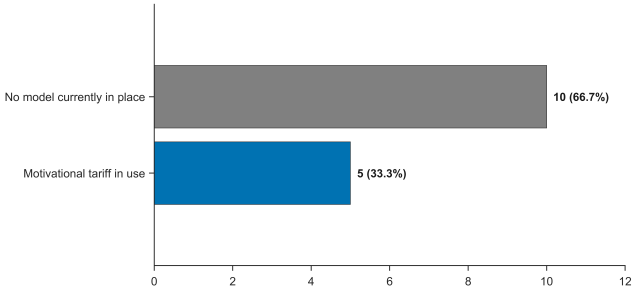


Fig. 2 Current implementation of motivational tariffs among participating DH providers (n = 15). Five providers reported using a motivational tariff model, whereas ten reported that no such model was currently in place.

Although implementation remains limited, this should not be interpreted as a lack of interest in behavioural engagement. Instead, the findings suggest that motivational tariffs are still evolving from isolated pilot concepts towards practical implementation. The following sections therefore examine how these approaches are perceived by both stakeholder groups and which factors may facilitate or hinder their wider adoption.

4.2 Provider perspectives on behavioural engagement

As the organisations responsible for designing tariff structures, communicating with customers, and implementing engagement measures, DH providers play a key role in enabling behavioural engagement. This section therefore examines the organisational context of the participating providers, the perceived benefits of motivational tariffs and gamification, and the factors currently limiting their wider implementation.

4.2.1 Current practices and organisational context

The participating providers represent a range of organisational settings and operational contexts. Twelve of the 15 organisations were located in Germany and three in Denmark. The sample included municipal, private, and mixed organisational structures as well as utilities serving communities of different sizes.

Despite growing interest in behavioural engagement, the practical implementation of motivational tariffs remains limited (Figure 2). Five of the 15 participating providers (33.3%) reported using such a tariff model, whereas ten providers (66.7%) reported that no motivational tariff was currently implemented.

In contrast, communication with end-users was already an established practice among the participating providers. Across both questionnaire branches, analogue and digital communication channels were frequently selected, alongside websites, social media, and visual communication formats. However, systematic customer research appeared less established. Among the five providers already using motivational tariffs, only one reported having conducted a dedicated customer survey. Among the ten providers without such a tariff, six stated that they relied primarily on internal assessments rather than customer surveys.

These findings show that communication structures were already present among many participating providers, whereas systematic customer research was less common. Within the surveyed organisations, these activities had only rarely been connected to motivational tariffs or other engagement mechanisms.

4.2.2 Expected benefits and application areas

Although motivational tariffs are still uncommon in practice, the participating providers generally viewed them as promising instruments for strengthening behavioural engagement. Rather than functioning solely as pricing mechanisms, they were considered a means of improving communication with end-users, increasing customer engagement, and supporting more efficient system operation.

Among the ten providers that did not currently operate a motivational tariff, all respondents selected financial bonuses or tariff discounts as an incentive they would consider when introducing such a model. Regarding the intended objectives of such incentives, six providers identified load management, four customer satisfaction and loyalty, four behavioural change, and three climate or policy objectives. These findings indicate that financial incentives are regarded as a particularly relevant mechanism, while the anticipated benefits extend to both operational and customer-related objectives.

The qualitative responses reinforce these observations. One provider emphasised that behavioural engagement would only succeed if users experienced a clear personal benefit, stating that *"at the end, there has to be a monetary benefit for the customer."* This response illustrates the perceived importance of a clear financial benefit for encouraging user participation.

Besides monetary incentives, providers repeatedly highlighted transparent communication and continuous feedback as essential elements of successful behavioural engagement. Several respondents suggested that providing users with information about their own energy consumption and overall system performance could increase awareness and strengthen participation. Taken together, these responses indicate that providers perceive motivational tariffs primarily as communication and engagement instruments rather than purely economic pricing mechanisms.

Despite these perceived benefits, providers also identified several factors that currently limit practical implementation (Figure 3).

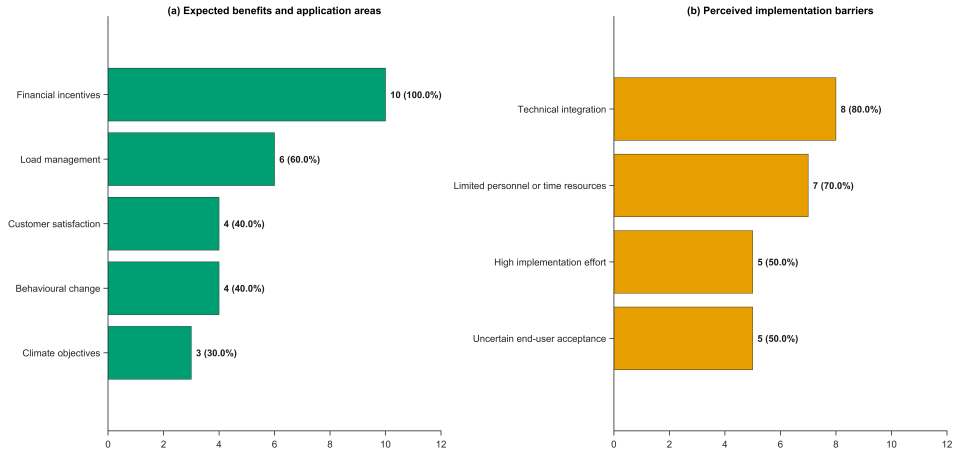


Fig. 3 Expected benefits and perceived implementation barriers among DH providers without an existing motivational tariff model (n = 10). Multiple responses were possible.

4.2.3 Implementation barriers

Although providers recognised considerable potential in motivational tariffs, the responses also revealed practical barriers to wider implementation. Among the ten providers without an existing motivational tariff, technical integration represented the most frequently reported concern: eight respondents (80.0%) identified issues related to system integration or software. Seven respondents (70.0%) cited limited internal resources, particularly personnel and time, while five respondents (50.0%) identified high implementation effort or technical complexity and five (50.0%) expressed uncertainty regarding user acceptance.

The open responses provide concrete examples of what these barriers may involve. Respondents referred to challenges associated with meter rollout, system and software integration, billing processes, internal coordination, and the availability of personnel and time. These examples illustrate that implementation barriers extend beyond tariff design itself and also concern the metering, digital, billing, and organisational infrastructure required to operate motivational tariff models.

The qualitative responses illustrate these concerns. Several providers referred to the additional workload associated with adapting billing systems, developing new tariff structures, and communicating more complex pricing models. One respondent summarised this challenge by noting that *"complex pricing structures are difficult to communicate in district heating."*

Notably, fundamental opposition to motivational tariffs was mentioned only rarely. Instead, providers questioned whether the expected benefits would justify the organisational effort required for implementation. The limited uptake of motivational tariffs therefore appears to result less from scepticism towards behavioural engagement itself than from the practical challenges associated with introducing and operating such schemes.

Overall, the provider perspective reveals a clear pattern. DH providers recognise the potential of motivational tariffs and related behavioural engagement mechanisms, yet their implementation is constrained primarily by organisational capacity, technical integration, and operational complexity. These findings provide the organisational perspective against which the views of end-users are examined in the following section.

4.3 End-user perspectives on behavioural engagement

While the previous subsection examined behavioural engagement from the perspective of DH providers, this section focuses on the views of end-users. The survey explored their awareness of motivational tariffs, their willingness to participate in such schemes, and their preferences regarding incentives, gamification, and communication.

4.3.1 Awareness and acceptance

Awareness of motivational tariffs among end-users was generally limited. Prior to participating in the survey, only a minority of respondents indicated that they were familiar with this type of tariff model, suggesting that motivational tariffs have so far received little public attention within DH.

Despite this limited awareness, respondents expressed considerable interest in behavioural engagement and energy-related topics. Most participants regarded energy-efficient behaviour as important and showed a positive attitude towards measures that could improve the performance of DHSs. Throughout the survey, transparency emerged as a recurring theme. Many respondents stated that they would like to receive more detailed information about their own heat consumption, associated costs, and the influence of their behaviour on overall system performance.

After motivational tariffs had been introduced and explained within the questionnaire, acceptance increased noticeably. A large proportion of respondents indicated that they would be willing to participate in such schemes, provided that they were transparent, easy to understand, and associated with tangible benefits. Within the surveyed sample, these findings suggest that limited awareness may represent a more immediate barrier than fundamental resistance towards behavioural engagement.

4.3.2 Preferences for motivational tariffs

Respondents were asked how motivational tariffs should be designed and which incentives would most strongly encourage their participation. The responses reveal a clear preference for simple, transparent, and financially rewarding approaches.

Direct financial incentives clearly dominated all proposed reward mechanisms. Of the 93 respondents, 89 (95.7%) selected monetary rewards or tariff discounts as a preferred incentive (Figure 4). Donations to environmental or social projects and vouchers from local businesses were each selected by 26 respondents (28.0%), whereas symbolic recognition attracted only limited interest (3 respondents; 3.2%). Within the surveyed sample, financial incentives were clearly the most frequently preferred form of reward.

The willingness to participate was similarly high. Seventy-four respondents (79.6%) indicated that they would participate in a motivational tariff based on a point system

rewarding energy-efficient behaviour. When asked which measures they would personally be willing to implement, correct ventilation and reducing room temperatures during periods of absence were each selected by 55 respondents (59.1%). Hydraulic balancing was selected by 43 respondents (46.2%).

The most frequently reported concern was uncertainty regarding the actual benefit of the proposed measures (46 respondents; 49.5%), followed by excessive complexity (40; 43.0%), potential additional costs (36; 38.7%), and data protection concerns (29; 31.2%). Eleven respondents (11.8%) reported having no concerns.

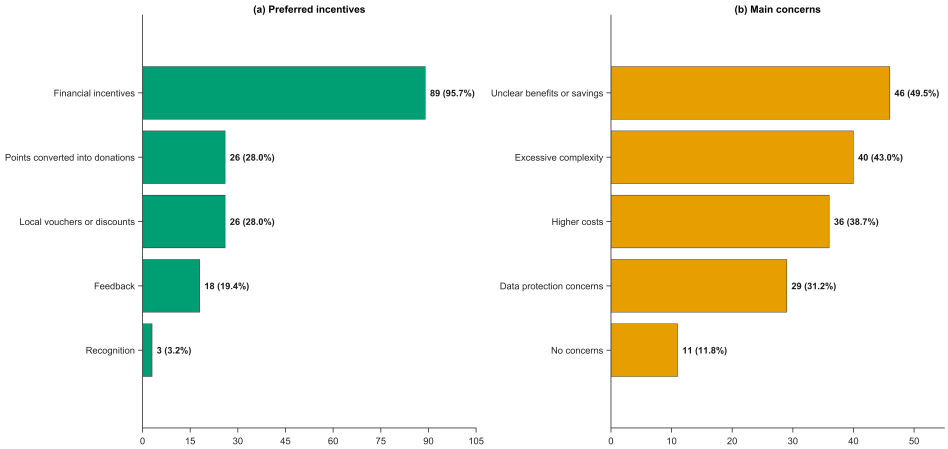


Fig. 4 Preferred incentives and perceived concerns regarding motivational tariffs among DH end-users (n = 93). Multiple responses were possible.

Taken together, the responses indicate substantial stated willingness to participate in motivational tariff schemes within the surveyed sample. Transparency, understandable rules, and clearly visible financial benefits were recurring conditions associated with this willingness.

4.3.3 Preferences for gamification and digital engagement

Beyond motivational tariffs, the survey investigated how gamification and digital tools could support behavioural engagement in DH. Overall, respondents preferred practical features that increase transparency, provide meaningful feedback, and support everyday decision-making over primarily competitive game elements.

General attitudes towards gamification were more mixed than the willingness to use individual gamified features. Of the 93 respondents, 22 (23.7%) expressed a positive attitude towards the use of game elements in heat supply, 43 (46.2%) were neutral, and 28 (30.1%) expressed a negative attitude. This contrasts with the comparatively high acceptance of individual mechanisms such as point systems and digital consumption feedback.

Among the proposed gamification elements, reward points, progress indicators, and personalised feedback received the highest levels of acceptance. Competitive mechanisms such as rankings or comparisons with other users were considerably less attractive. Rather than seeking competition, respondents appeared to value gamification primarily as a means of improving their understanding of heat consumption and supporting energy-efficient behaviour.

This preference is also reflected in respondents' attitudes towards a dedicated digital application. As shown in Figure 5, 79 respondents (84.9%) indicated that they would be willing to use such an application, whereas 14 respondents (15.1%) stated that they would not.

Regarding preferred application functions, real-time visualisation of heat consumption received the strongest support, selected by 89 respondents (95.7%). Comparison with a reference value was favoured by 69 respondents (74.2%), while 52 respondents (55.9%) selected progress tracking. Energy-saving recommendations were considered useful by 43 respondents (46.2%).

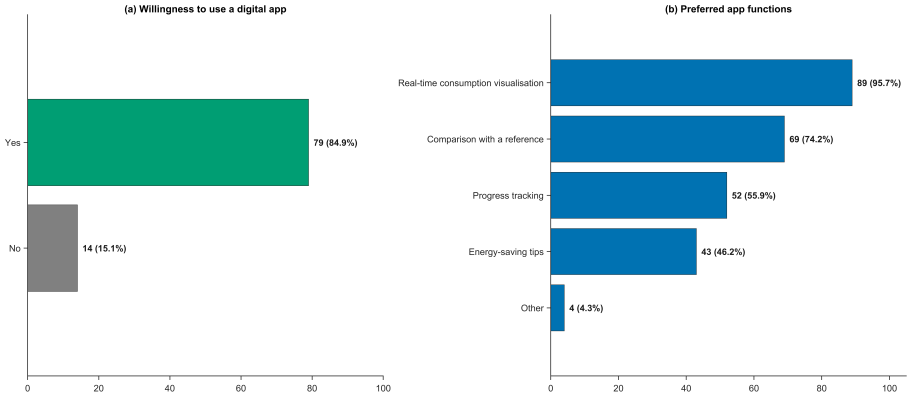


Fig. 5 End-user willingness to use a digital application and preferred application functions for supporting behavioural engagement in DH ($n = 93$). Panel (a) shows respondents' willingness to use an application, while panel (b) presents the functions considered most useful. Multiple responses were possible for the preferred application functions.

Overall, the findings indicate that digital engagement received the strongest support when it provided immediate and understandable information on heat consumption, enabled users to assess their performance, and offered practical guidance. Gamification is therefore primarily valued as a supporting feedback and communication mechanism rather than as a game itself. These preferences provide an important basis for comparing provider capabilities with user expectations in the following subsection.

4.4 Alignment between provider capabilities and user expectations

Comparing the perspectives of DH providers and end-users reveals a consistent pattern. Both stakeholder groups recognise the potential of behavioural engagement mechanisms, yet they emphasise different conditions for their successful implementation. Rather than indicating a fundamental conflict between providers and end-users, the results suggest that behavioural engagement in DHSs depends primarily on aligning organisational capabilities with user expectations.

A first area of strong alignment concerns the overall acceptance of behavioural engagement. Providers generally perceived motivational tariffs as an opportunity to strengthen customer engagement, improve communication, and encourage more energy-efficient behaviour. Similarly, end-users expressed a clear willingness to participate in such schemes. Seventy-four of the 93 respondents (79.6%) indicated that they would participate in a point-based motivational tariff, while financial incentives were selected by 89 respondents (95.7%). Within the surveyed sample, acceptance did not emerge as the primary perceived obstacle to behavioural engagement.

Transparency represents a second area of clear agreement. Throughout the provider survey, communication and user feedback were repeatedly identified as important prerequisites for successful implementation. End-users expressed similar expectations by emphasising their desire for more detailed information about heat consumption, costs, potential savings, and the effects of their own behaviour on overall system performance. For both stakeholder groups, transparency was therefore viewed not simply as a supporting measure but as an essential component of behavioural engagement.

Despite these common objectives, the surveys also reveal important differences in perspective. DH providers primarily evaluated motivational tariffs from an organisational viewpoint, focusing on technical integration, personnel resources, administrative effort, and operational feasibility. End-users, in contrast, approached the same concepts from the perspective of everyday usability. Their concerns centred on whether participation would be straightforward, whether the expected benefits would be sufficiently transparent, and whether financial savings would justify the required behavioural changes. While providers therefore questioned whether motivational tariffs could be implemented efficiently, end-users primarily considered whether they would be easy to understand and worthwhile to use.

A more nuanced pattern emerged regarding gamification. Although 79.6% of respondents were willing to participate in a point-based tariff and 84.9% would use a corresponding digital application, only 23.7% expressed a generally positive attitude towards gamification as such. Functional elements such as point systems, real-time consumption visualisation, reference comparisons, and progress tracking received considerably stronger support than explicitly game-like or competitive elements such as rankings and avatars. This indicates that users may value selected gamified features primarily when they provide practical feedback and tangible benefits rather than when they create a strongly game-like experience.

Taken together, the comparison reveals that providers and end-users largely share the same overarching objectives, including improved communication, greater transparency, and more energy-efficient heat use. The principal differences arise in

the conditions required for implementation. Providers are primarily constrained by organisational resources, technical integration, and operational complexity, whereas end-users emphasise simplicity, transparency, and tangible personal benefits. Within the surveyed samples, the main differences concerned the conditions for implementation rather than fundamental opposition to behavioural engagement. This points to the importance of aligning provider capabilities with user expectations. The main areas of alignment and divergence are summarised in Figure 6.

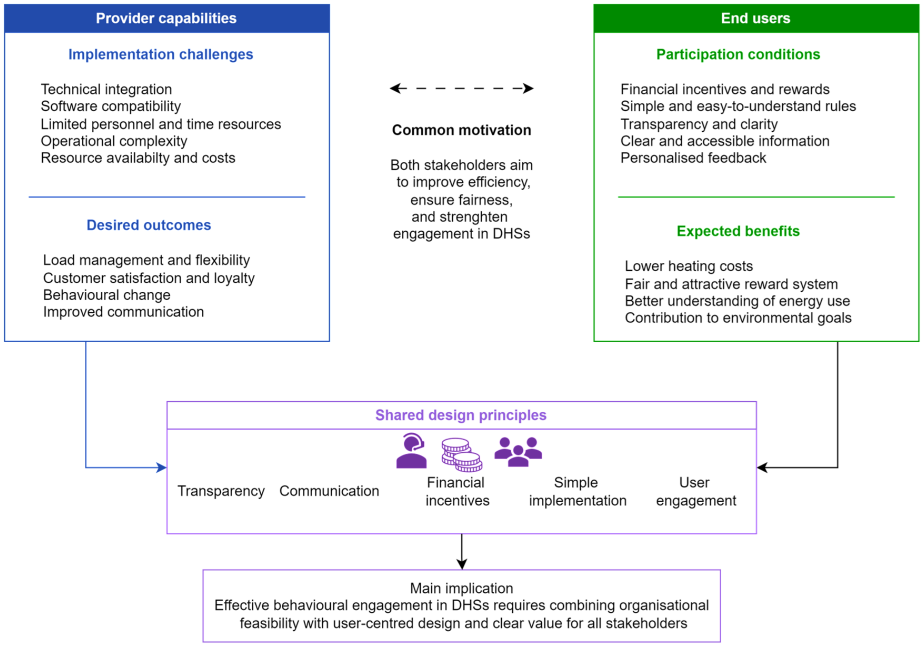


Fig. 6 Synthesis of the alignment between provider capabilities and user expectations. Both stakeholder groups value transparency, communication, and financial incentives, while the principal differences concern the conditions required for implementation.

These findings provide the foundation for the following discussion, which interprets the results within the broader literature on socio-technical transitions and behavioural engagement in DH.

5 Discussion

This study explored behavioural engagement in DH by comparing provider perspectives with end-user expectations. The comparison shows a relatively consistent pattern. Both groups saw value in greater transparency, communication, and financial incentives, but they approached implementation from different sides. Providers focused mainly on technical integration, personnel resources, billing and operational effort. End-users focused on whether participation would be simple, understandable, and

associated with a visible benefit. The main issue emerging from the comparison is therefore not whether behavioural engagement is viewed positively in principle, but how it can be translated into a workable DH service.

The provider results show that motivational tariffs are still at an early stage among the participating organisations. Five of the 15 providers reported an existing or developing model, while the remaining ten did not. This should be interpreted cautiously given the small sample, but the reported barriers are relevant for implementation. Technical integration was the most frequently selected concern, followed by limited personnel and time resources. Open responses further referred to metering, software, billing, internal coordination, and the difficulty of communicating more complex pricing structures. These findings indicate that a motivational tariff is not only a tariff-design question. It also requires a technical and organisational infrastructure that can measure relevant variables, process them reliably, communicate the result to customers, and integrate the mechanism into existing billing and customer processes.

This is consistent with previous DH research showing that motivational tariffs are closely linked to the technical performance of the secondary system. Lygnerud et al. [10], for example, discuss tariff components that encourage customers to improve return temperatures or flow conditions. The present results add a stakeholder perspective to this discussion. Even where a technically meaningful indicator can be defined, implementation still depends on whether providers can integrate the model into existing processes and explain it in a way that customers understand. The technical and behavioural dimensions are therefore difficult to separate in practice.

The end-user results show a different set of priorities. Respondents expressed substantial stated willingness to participate in a point-based motivational tariff, and financial incentives were by far the most frequently selected reward. At the same time, the main concerns were unclear benefits, complexity, additional costs, and data protection. This combination is important. It suggests that willingness to participate should not be interpreted as unconditional acceptance. Rather, respondents expected a clear relationship between the requested action and the resulting benefit. In practical terms, a tariff that is technically sophisticated but difficult to understand may have limited value as an engagement mechanism.

Transparency was one of the clearest points of alignment between the two groups. Providers repeatedly referred to communication and feedback, while end-users wanted clearer information on consumption, costs, savings, and the effect of their behaviour. Previous research on energy feedback and demand-side management similarly identifies information and feedback as relevant conditions for user engagement [9]. For DH, this may be particularly important because heat consumption and network operation are less visible to users than many everyday electricity uses. A motivational tariff can therefore serve two functions at the same time: providing an incentive and making the relationship between user behaviour and DH operation more visible.

The results on gamification require a more differentiated interpretation. Only 23.7% of end-users expressed a generally positive attitude towards gamification, while 79.6% were willing to participate in a point-based tariff and 84.9% would use a corresponding digital application. Real-time consumption visualisation, reference comparisons, and progress tracking also received considerably stronger support than

explicitly competitive elements. The term gamification therefore appears to capture only part of what respondents found useful. Users did not show a strong preference for making heat use game-like. They responded more positively to individual features when these provided information, progress feedback, or a tangible reward.

For DH applications, gamification may therefore be more appropriately implemented as a design layer around useful feedback and incentive functions rather than as a strongly competitive or entertainment-oriented concept. Points can make progress visible, and progress indicators can support feedback, but these elements need a clear purpose. Rankings, avatars, or competition should not be assumed to increase acceptance simply because they are common gamification elements. This distinction is relevant for the design of digital DH applications because it shifts the focus from adding game mechanics to selecting features that help users understand and respond to the system.

The direct comparison of providers and end-users is the main contribution of the study. Both groups valued financial incentives, transparency, and communication, but the reasons behind these preferences differed. Providers considered whether an engagement mechanism could be technically and organisationally implemented. End-users considered whether it would be understandable and worthwhile to use. These are complementary rather than conflicting perspectives. A technically feasible tariff will not necessarily lead to participation if the benefit is unclear, while a user-friendly concept cannot be implemented if metering, billing, or organisational resources are insufficient.

This comparison also helps place behavioural engagement within the wider transition of DH systems. Research on low-carbon heat increasingly considers not only technology but also the capabilities and expectations of the actors responsible for implementation [14]. The present study extends this perspective to the provider–customer interface. As DH systems integrate more diverse heat sources, digital monitoring, and flexible operation, some system objectives may increasingly depend on customer-side operation or demand patterns. Behavioural engagement can support this interface, but it should be linked to a specific operational or customer-related objective rather than introduced as an isolated measure.

The findings do not demonstrate that motivational tariffs or gamification reduce energy use, improve return temperatures, or increase system flexibility. The surveys capture perceptions and stated preferences, not observed behaviour. Within this scope, however, the results identify conditions that appear relevant before such mechanisms are tested in practice. For providers, these conditions concern technical integration, resources, and operational feasibility. For end-users, they concern simplicity, transparency, and visible benefits. Future pilot studies can build on these conditions and examine whether the stated preferences translate into actual participation and measurable system effects.

Overall, the study indicates that behavioural engagement can be considered an additional part of DH system development alongside technical optimisation. Its practical value is likely to depend on how well system-level objectives are translated into actions and benefits that are understandable to end-users and feasible for providers. The main findings are summarised in Table 3.

Table 3 Summary of the main findings across the analytical areas addressed in the study.

Analytical focus	Main finding
What is the current implementation status of motivational tariffs in DH?	Motivational tariffs remain uncommon. Most participating DH providers reported that no such model was currently implemented, indicating that practical application is still at an early stage.
How do DH providers perceive behavioural engagement mechanisms?	Providers generally recognise the potential of motivational tariffs and gamification, particularly for financial incentives, load management, communication, and customer engagement. Their implementation is constrained mainly by technical integration, limited organisational resources, and operational complexity.
How do end-users perceive behavioural engagement mechanisms?	End-users show high willingness to participate when tariff schemes are transparent, easy to understand, and linked to tangible financial benefits. However, attitudes towards gamification as a general concept are mixed; practical feedback and selected gamified features are preferred over competitive or strongly game-like elements.
Where do provider capabilities and user expectations align or diverge?	Both stakeholder groups value transparency, communication, and financial incentives. The main divergence concerns implementation conditions: providers emphasise organisational and technical feasibility, whereas end-users prioritise simplicity, visible benefits, and practical usability.

6 Conclusion

This study compared how DH providers and end-users perceive motivational tariffs and gamification as mechanisms for behavioural engagement. The results show that both stakeholder groups see potential in greater user engagement, but they emphasise different requirements. Providers are mainly concerned with technical integration, organisational resources, and implementation effort, whereas end-users place greater importance on simple participation, transparent information, and tangible benefits.

Financial incentives were the clearest common element. They were considered relevant by providers and were also the most frequently preferred reward among end-users. At the same time, the results show that financial incentives alone are unlikely to be sufficient. Communication and feedback were repeatedly identified by both groups, indicating that users need to understand what is expected, why it matters, and what benefit follows from participation.

The findings also qualify the role of gamification in DH. General attitudes towards gamification were mixed, while acceptance of individual features such as points, consumption visualisation, reference comparisons, and progress tracking was considerably higher. For DH, the more relevant application of gamification may therefore be to support transparent feedback and motivation rather than to create a strongly game-like or competitive experience.

The study is exploratory and its findings should be interpreted within the limits of the samples. The provider survey included 15 organisations, and the end-user sample of 93 respondents was non-representative and contained no demographic information. Participation was voluntary, which may have introduced self-selection bias. The study

also measures stated perceptions rather than observed behavioural change. Provider and end-user responses were collected from separate samples and cannot be linked at the level of individual DH systems. In addition, the end-user survey was conducted in Germany, while the provider sample was predominantly German with three organisations from Denmark. The results therefore cannot be generalised to the wider DH sector or directly transferred to other regulatory and cultural settings.

Future research should test motivational tariffs and selected engagement features in real DH settings. Longitudinal pilot studies are particularly needed to examine whether stated willingness translates into sustained participation and whether this produces measurable effects on heat consumption, return temperatures, load flexibility, customer satisfaction, or other relevant system indicators. Such studies should also examine how engagement mechanisms can be integrated with smart metering, digital customer platforms, and existing billing processes.

Within these limitations, the provider–end-user comparison provides a practical basis for further development. Behavioural engagement in DH appears most useful when it connects a clear system objective with a mechanism that providers can operate and users can understand. This makes behavioural engagement a complementary dimension of future DH development rather than a substitute for technical optimisation.

Declarations

Ethics approval and consent to participate

The surveys were conducted voluntarily and anonymously. No personal identifying or demographic information was collected. Data collection was conducted in accordance with the General Data Protection Regulation (GDPR), and the survey and data collection procedure were reviewed and approved by the responsible employee representation body (Works Council). Participation in the surveys was voluntary.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to data-sharing restrictions associated with the research projects under which the data were collected.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

NA: Conceptualization, Methodology, Data analysis, Visualization, Writing – original draft, Writing – review & editing. TA: Methodology, Data analysis, Writing – review & editing, Validation, Funding acquisition. AC: Supervision, Writing – review & editing, Validation, Funding acquisition. All authors read and approved the final manuscript.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used FhGenie, developed by Fraunhofer, and DeepL Translator by DeepL SE in order to improve language and readability. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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