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SPECIAL FEATURE: CASE REPORT

Individuals within the Larger System to Support the Energy Transition

Social acceptance of district heating: evidence from the Netherlands

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Abstract

The Netherlands Climate Change Agreement aims to reduce CO_2 emissions and seismic events by halting natural gas usage by 2050. This will require widespread societal acceptance by 90% of households. The study investigates the social acceptance of a district heating network (DHN) among social housing tenants in Haarlem, Netherlands. The findings of a survey administered to ninety-five tenants revealed a substantial level of support for the DHN project. A significant portion of respondents, 75%, expressed their approval for the DHN, surpassing the legally required threshold of 70% for implementing building retrofits. Findings imply that although the participants possess an adequate comprehension of the rationale for energy transition, their familiarity with the precise particulars and practical information pertaining to the proposed transition to DHN is inadequate. The level of trust in housing corporations, energy providers, and the municipality is uniformly low, indicating a lack of institutional trust. Generally, the interpersonal trust among tenants tends to be lower than their trust in the broader public, which in turn restricts their capacity for self-organization and exercising influence over energy institutions. Although DHNs are typically regarded as environmentally friendly and secure, there are several challenges that need to be addressed, including the uncertainty about who will cover the costs of transitioning and the doubts surrounding DHN feasibility (warmth and reliability). We suggest implementing interventions to improve tenants' comprehension of the DHN project's particulars (capability), provide practical information regarding costs and feasibility (motivation), and foster trust at both interpersonal and institutional levels (opportunity).

Keywords Social acceptance · Energy transition · Institutional change · Systemic change · Sustainable behaviour · COM-B model

Introduction

In alignment with the Paris Climate Agreement, governments worldwide, including the Netherlands, have set ambitious targets to replace fossil-based energy systems with renewable alternatives. In response to the varied landscape of energy infrastructures, each country has devised distinct targets and strategies to align with their unique needs and challenges. Notably, the Dutch government has prioritized a departure from natural gas, aiming to mitigate both CO_2 emissions and seismic activities in the northeastern province of Groningen, attributed to prolonged natural gas extraction. The 2019 National Climate Agreement outlines the overarching ambition for the Netherlands to achieve a natural gas-free status by 2050 (EZK 2019). However, this transition is riddled with substantial challenges, primarily stemming from the nation's heavy reliance on natural gas, predominantly sourced from domestic reserves.

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As of now, natural gas usage for heating in the Netherlands is the highest in the European Union, with Dutch homes contributing to approximately 9% of the nation's total CO_2 emissions (Cole 2021; Eurostat 2022; EZK 2019; Jansma et al. 2020). Heating alone accounts for two-thirds of the overall energy consumption, making it a crucial aspect of the transition (Jansma et al. 2020). The Netherlands is ranked the highest among European countries in the use of natural gas for space heating (84.7%), followed by Italy (60.6%) and Hungary (60.4%) (Eurostat 2022). By 2019, only 5.7% of Dutch households were natural gas free (CBS 2021). The challenge intensifies as nearly 90% of households are deeply intertwined with the natural gas system (Eurostat 2022; Jansma et al. 2020), creating a pressing need for over 7.5 million Dutch households to transition within a short period (Ebrahimigharehbaghi et al. 2019).

Recognizing the multifaceted nature of the transition, the 2019 National Climate Agreement identifies three critical factors: 'feasibility', 'affordability,' and 'participation' (EZK 2019). By and large, the approach to address the energy transition has focused on feasibility and affordability, with a strong emphasis on exploring gas alternatives and their infrastructures. However, participation is key because a transition of this scale at the micro, meso, and macro levels cannot simply be achieved with technological solutions alone (Kieft et al. 2017; Van Rijnsoever et al. 2015). The often-underestimated challenge lies in the social dynamics of accepting proposed energy transition projects and embracing existing technologies (Poortinga et al. 2003; Van Rijnsoever et al. 2015). Participation and the social aspect of acceptance becomes paramount to energy transition, contributing to ownership and commitment (EZK 2019, p. 216).

In the recent past, District Heat Networks (DHNs) or *Warmtenet* in Dutch emerged as a major strategy to replace natural gas use in the Netherlands. These networks, which utilize heat from alternative sources like geothermal or residual heat, offer promising solutions for densely populated areas with high-rise buildings, particularly those constructed before 1995 (EZK 2019). Despite their potential benefits, including enhanced energy efficiency, reduced greenhouse gas emissions, and potential cost savings, the social acceptance of DHNs is not guaranteed, even when economically and technically feasible. To comprehend the intricacies of social acceptance of DHNs, this study adopts the capability, opportunity, motivation, and behavioural (COM-B) model (Michie et al. 2011). By operationalizing its three essential factors—capability, opportunity, and motivation—our aim is to gain a comprehensive understanding of the social acceptance dynamics influencing the energy transition.

This article specifically explores the social acceptance of DHNs among social housing tenants in Haarlem, the Netherlands. With 75% of the three million rental homes in the Netherlands falling under social housing, constituting 28.7% of the entire housing market (Government of the Netherlands 2022; Kromhouter and Wittkämper 2019), this demographic becomes a crucial focal point for our research. Moreover, the social housing sector presents a unique complexity, requiring a minimum of 70% tenant approval for building retrofit, making tenant participation crucial (Government of the Netherlands 2022). Despite being a demographic most affected by the transition, social housing tenants exhibit lower social acceptance levels compared to the general public, as indicated by previous studies (Bal et al. 2021; Glad 2012; Santangelo and Tondelli 2017). By narrowing our focus, we offer insights that go beyond the general discourse, providing nuanced perspectives that contribute to addressing the multifaceted challenges associated with the energy transition and the implementation of DHNs. In doing so, this research aims to make a significant contribution to the existing body of knowledge, shedding light and offering insights into the factors influencing social acceptance within the specific context of social housing tenants.

Literature review and theoretical underpinning

Social acceptance of energy alternatives

A collection of studies reveals the complex nature of social acceptance—people often do not see how moving away from gas could be an improvement for them (Beernink 2022; Ebrahimigharehbaghi 2022; Have 2022; Onencan and de Koning 2022; Steenbekkers and Scholte 2019). Concerns predominantly revolve around the perceived financial implications and inconvenience stemming from potential construction work in residential areas (Hajer and Versteeg 2019; Spandagos et al. 2022). Qazi et al. (2019) emphasize the role of education and risk attitude in shaping individuals' openness to embracing new technologies. Paradoxically, while acknowledging the severity of climate change, individuals may not feel personally responsible for its mitigation (Spandagos et al. 2022).

Despite the growing interest in DHNs, research on their acceptance remains limited (Kort et al. 2020). Kort et al. (2020) identify a scarcity of studies capturing the intricacies of DHN social acceptance. Noteworthy insights stem from other studies, where Groenewegen and Wendelyn (2021) emphasize the potential impact of DHNs on indoor comfort, financial well-being, and trust levels. Van Lidth de Jeude and Midden (2014) find a somewhat positive attitude towards DHNs, but highlight minimal perceived individual benefits and a negative perception of limited personal control. Autonomy, financial aspects, and knowledge gaps emerge as decisive factors (Kort et al. 2020).

Crucially, the timing and manner of public involvement are identified as pivotal factors in increasing social acceptance (Van Lidth de Jeude and Midden 2014). Their research underscores the significance of strategic interventions, advocating for an array of recommendations aimed at fostering a positive reception of DHNs. Recommendations include enhancing the business case for DHNs, stimulating DHN innovation, improving perceived control of price and quality, and actively involving citizens in development and implementation processes (Van Lidth de Jeude and Midden 2014). Moreover, the costs of transition and whether they will eventually be incorporated in the tenant's energy bill is a crucial element that emerged in various studies (Bouw 2017; Van Aalderen et al. 2021).

An overarching theme in the literature is the pivotal role of trust, both institutional and interpersonal, in shaping public attitudes towards energy transitions, including DHNs. While some studies highlight a lack of trust in institutions and suppliers (Van Lidth de Jeude and Midden 2014), others underline the importance of connectedness and solidarity in fostering acceptance (Kort et al. 2020). Trust in local authorities is deemed crucial (Van Lidth de Jeude and Midden 2014), and a lack of trust can hinder cooperation and acceptance (Caferra et al. 2021; Greenberg 2014; Huijts et al. 2012; Onencan et al. 2018). Recognizing the critical role of trust, Greenberg (2014) argues for its underappreciation in energy research and policy. Caferra et al. (2021) stress the significance of both political and social trust, as they foster pro-social behaviour and strongly influence energy-saving behaviours. Proof of trust, as demonstrated by Bahri and Girdzijauskas (2018), encourages collaboration among consumers in energy transition actions.

Previous studies recommend a holistic consideration of factors, such as financial implications, individual autonomy, and, critically, the role of trust, both institutional and interpersonal (Beernink 2022; Bouw 2017; Ebrahimigharehbaghi 2022; Hajer and Versteeg 2019; Have 2022; Kort et al. 2020; Onencan and de Koning 2022; Spandagos et al. 2022; Steenbekkers and Scholte 2019; Van Aalderen et al. 2021; Van Lidth de Jeude and Midden 2014). These insights underscore the complex dynamics influencing social acceptance of energy alternatives, particularly in the context of emerging technologies like DHNs.

Capability, opportunity, motivation and behavioural (COM-B) model

We used the COM-B model as the conceptual framework for this research. The model operationalises social acceptance, and is based on the following factors: capability, opportunity, motivation, and behavioural intent. The COM-B model is the innermost wheel of a larger framework known as the behavioural change wheel (BCW), (Michie et al. 2015). The second wheel comprises nine intervention functions (coercion, education, enablement, environmental restructuring, incentivization, modelling, persuasion, restrictions, and training). The outer wheel consists of seven policy categories (legislation, service provision, regulation, fiscal measures, guidelines, environmental/social planning, and communication/marketing). In this study, we focused on the inner wheel of the BCW (see Fig. 1). The nine interventions were not selected as the next level of analysis because the primary focus of the research was on the key factors that motivate social housing tenants to accept ongoing energy transition government-led plans.

The COM-B model (see Fig. 1) recognizes the influencing power of three behavioural factors (capabilities, opportunities, and motivation) (Michie et al. 2015). Capability focuses on whether the person has the physical (physical strength, physical skills, stamina, and knowledge) and psychological (understanding, memory, and social skills) ability to accomplish the target behaviour. Opportunity assesses whether the external environment provides sufficient social (interpersonal influences, social norms, and culture) and physical (finances, material resources, location, and constraints) opportunities for the target behaviour to occur. Motivation is the "aggregate of mental processes that energize and direct behaviour" (West and Michie 2020, p. 2). Motivation can be either reflective (e.g. evaluations or plans) or automatic (e.g. habits or desires). Michie et al. (2011) developed the COM-B model with the theoretical underpinning of PRIME (planning, response, impulse/inhibition, motive and evaluation processes) theory. PRIME is a coherent framework that integrates numerous psychological theories and models to bridge the intention-action gap created by a lack of capability, opportunity, or motivation (West and Michie 2020).

Materials and methods

Research context

The global trend towards greater tenant participation in building retrofit decisions reflects a broader movement for inclusive and democratic urban governance. While some institutional settings treat tenants as mere consumers, there is a growing acknowledgement of the rightful involvement of tenants in the renovation process. This recognition is crucial due to the profound impact of changes on their daily lives, affecting comfort, health, and well-being. Countries such as Sweden (Palm et al. 2020), Germany (Grossmann 2019), and Canada (Short 2021) have demonstrated the importance of tenant participation in housing decisions, including energy transition, emphasizing the need for inclusive policies.

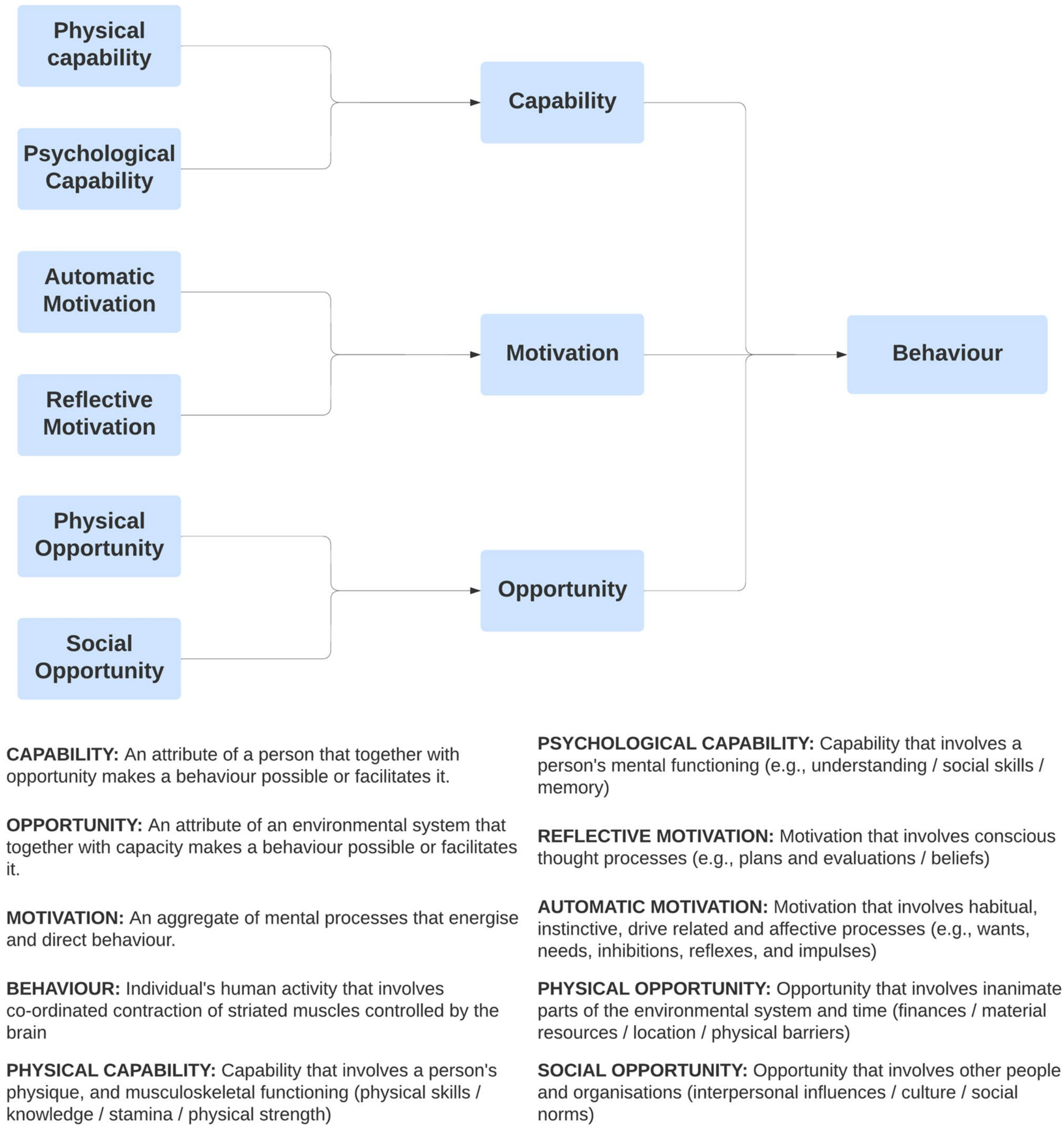

Fig. 1 The capability, opportunity, motivation and behavioural (COM-B) change model designed by Michie et al. (2011). The definitions of the key concepts were modified by Onencan and de Koning (2022) to align the COM-B model within the energy transition context

In the Netherlands, possessing one of Europe's largest inventories of social rented housing, the 1901 Housing Act played a pivotal role in its current state of affairs. Housing corporations, operating as self-sustaining entities, are key players in managing the energy transition process. Indeed, these corporations hold a crucial position in overseeing tenant involvement in the energy transition, given their responsibility for the upkeep and modernization of residential properties, as well as their influence on tenant interaction and deliberation.

The research context of Schalkwijk in Haarlem is characterized by a high concentration of social housing units in need of energy retrofits, mirrors global patterns of socio-economic diversity, and the challenges associated with retrofitting older buildings. Schalkwijk is a postwar expansion district in Haarlem. Comprising four sub-districts, Schalkwijk was constructed in phases after 1965 on sand sprayed over a peat layer. Meerwijk, located in the southeastern corner of Schalkwijk, is home to over 8,000 Haarlem residents and features a substantial number of flats and social housing units built in the 1960s and the 1970s. Moreover, the housing supply in Meerwijk is dominated by social rented housing owned by corporations, with a limited availability of owner-occupied dwellings and private rental properties. The existing housing inventory, particularly older homes owned by housing associations, exhibit inadequate insulation and low energy efficiency ratings. The primary heating source for these residences is natural gas. The vast majority of houses in Haarlem have been awarded an energy label of F or G. Conversely, only a small fraction of homes, roughly 8%, have received an energy label of A or B. Furthermore, the number of residences equipped with solar panels is notably lower in this area compared to other neighbourhoods in Haarlem (Gemeente Haarlem and van Dijk 2020).

The socioeconomic structure of Meerwijk reveals a diverse group of residents with low average income levels, emphasizing the need for socially conscious retrofitting strategies. In 2021, the average gross annual income per inhabitant was €20,437, placing it as 42nd lowest among 3,184 neighbourhoods in the Netherlands. Meerwijk represents a highly diverse group of residents, with 15.8% coming from one of the countries in Europe (excluding Turkey), North America, Oceania, Indonesia, or Japan; 25% from Morocco; 23.1% from Turkey; 4.9% from Suriname; and 28.8% from other countries. In addition, a substantial proportion of households consist of single-parent families, and many residents are searching for work or live on low income (AlleCijfers.nl 2023).

Many flats in Schalkwijk belong to three housing corporations, Elan Wonen, Pré Wonen, and Ymere. A total of 5,200 housing corporation houses will be connected to the proposed heat network. The units in these flats are similar, posing the advantages of scale. The DHN project will first be tested in Meerwijk, where its implementation is phased, and the pilot area is divided into six clusters (Fig. 2). The DHN connection will start in cluster one and progress with the other clusters, culminating in cluster six houses before the end of 2040 (Gemeente Haarlem 2022a, 2022b; Gemeente Haarlem and van Dijk 2020).

The current plan is to replace natural gas with DHN. Different options have been explored to replace natural gas in Schalkwijk with a (local) district heating network which relies on energy from residual heat, geothermal energy, or a combination of the two. There is a lot of residual heat available from the Datacentre Polanenpark, but because of the long distance, energy distribution will be very expensive

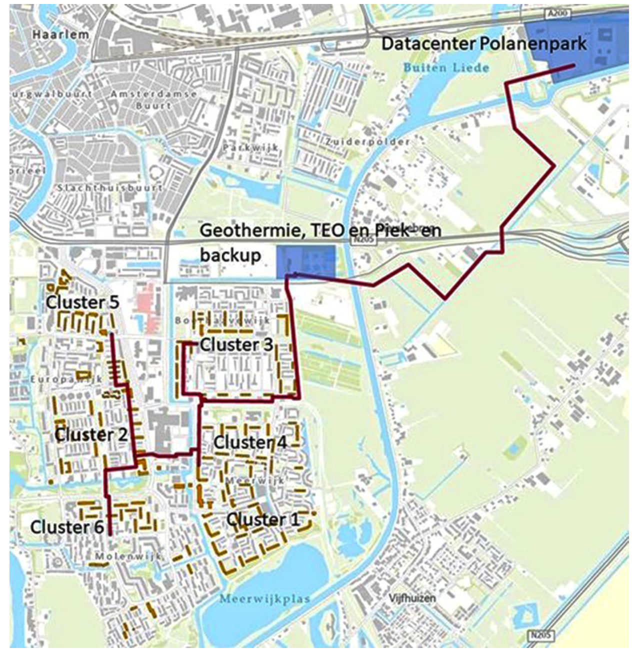

Fig. 2 Map of Schalkwijk (Source: Gemeente Haarlem and van Dijk (2020). There are six clusters divided according to when the heat grid will be made available. The map also shows the location of the geothermal site and the data centre in Polanenpark

(see Fig. 2). Moreover, there is ongoing seismic surveys and exploratory test drilling for geothermal sources. The municipality Warmtenet Schalkwijk project team, together with Firan (energy transport and distribution company), EQUANS (energy supplier) and three housing corporations (Elan Wonen, Pré Wonen, and Ymere), are looking into whether developing a heat network is feasible (Gemeente Haarlem 2022b).

However, the transition faces legal requirements, as housing corporations need 70% approval from residents to initiate collective renovations. This includes changing energy systems and insulating entire buildings, in accordance with Article 7:220 of the Dutch Civil Code (Government of the Netherlands 2022). For tenants, the operation involves weeks of construction, changes in appliance use, and possibly increased rent, posing short-term costs, inconvenience, and uncertainty regarding long-term gains. Balancing these challenges is crucial for successful social acceptance of the proposed DHN and sustainable energy transition in Schalkwijk.

Selection of the case study

The district of Schalkwijk is a promising area for a heat grid mainly because of the relatively large proportion of social rented housing and stacked housing. Haarlem was selected because it is one of the few municipalities that had made significant progress in designing a DHN project with energy companies and was at the phase where they needed to assess social acceptance before making any significant investments. The case study was selected because it met our initial criteria for conducting the research.

Meerwijk was selected over other neighbourhoods in Haarlem because a collective number of apartment complexes of housing associations need to be replaced in a relatively short term, and it was prioritized in Haarlem as the first zone for implementing the project. In the coming years, The Warmtenet Schalkwijk project will be implemented along with other ongoing projects to reduce nuisance and costs. One such project is the Meerwijk integrate vernieuwing openbare ruimte (IVORIM) (Gemeente Haarlem 2022a). This project seeks to renew the Meerwijk sewerage system and improve public green spaces, including children's playgrounds. The simultaneous implementation of various projects offers a unique opportunity to build heat tubes for the heat grid while renovating the sewage system. If the tenants and institutional actors approve of the DHN project, the construction of the heat network can begin. Meerwijk's sewerage system will be replaced in the coming years. When the street opens, DHN heat pipes can directly enter the ground. The urgency of replacing the infrastructure in Meerwijk presents a unique opportunity for researchers to conduct research with immediate implications for community and institutional actors.

Participants and procedures

Procedure

The preparation of the survey instrument was participatory and lasted several months. First, researchers from two key Universities, Delft University of Technology and Utrecht University, developed a draft and shared it on Google Forms with all members of the Warmtenet Schalkwijk project working group. Subsequently, we held bilateral meetings with all three housing corporations to review the content. The final approved content was reviewed by the Haarlem municipality and project working group members before adoption. The next phase involved approval of the survey by the Utrecht University ethics committee, subject to adjustments to safeguard the privacy of the tenants.

Thereafter, we held several online meetings with three housing corporations to select the buildings. Later, we held offline meetings with five district managers (wijkbeheerders in Dutch) representing three housing corporations. Offline meetings were held on 11th, 16th and 19th March 2021, at various locations in Meerwijk. During the meetings, we used various interactive techniques to elicit information on tenants living in various housing corporation buildings. We finally selected five buildings: four that used the collective heating system, and one that used the individual heating system. The selection criteria were based on several factors including the demographics of the tenants, number of houses in a building, and type of grid connection (collective or individual). We limited the survey to houses within cluster one, where the DHN will be implemented first. At the end of the preparatory phase, we selected 18 houses from Elan Wonen, 144 from Pré Wonen, and 108 from Ymere.

A total of 270 households received questionnaires by post in June 2021. The respondents had one month to complete the survey and send it back by post. Participation was voluntary and took approximately 20-min. Personal information was changed into codes, and the filled questionnaires were destroyed. The participants received a twenty euros VVV gift voucher upon completion. The VVV gift card is commonly utilized in The Netherlands for both in-store and online purchases. In our case study, we obtained vouchers that tenants could use to purchase items at the neighbourhood supermarkets. Only female researchers were dispatched to knock on doors in an effort to encourage tenants to participate in the survey, as a prior study conducted in the same region had observed that Muslim women were reluctant to open their doors to unfamiliar men (Ligterink 2018).

Participants

Ninety-five participants completed the Haarlem household survey. The initial plan was to receive at least a 50 percent response rate (135 respondents) within one month (June 2021). However, most of the respondents informed us that they were extremely busy and did not have the time to complete the survey, while others did not trust that they would receive VVV vouchers. We ensured the representativeness of our data by reaching out to different groups of tenants and urging them to complete the household survey. Within one month of data collection, we reached out to the unrepresented tenants in person, though door-to-door personal appeals to tenants, with VVV vouchers and other incentives. We also held meetings outside the buildings and in the shared kitchen area as the tenants came for tea or lunch. Our final sample was more diverse (see Table 1 and 2), and we achieved a response rate of 35%.

The majority of the participants were female, had resided in the building for over ten years, and their native language was Dutch (see Table 1). Most of the participants were aged between 30 and 49 years, followed by the 50–69 years age bracket (see Table 2). Most participants had basic education, with only a few 5% who had attained a bachelor's, master's, or doctorate degree. Eleven participants were not formally educated. Many (61%) of the respondents did not work; they were pensioners (25%), unemployed (22%), searching for a job (8%), or students (6%).

Survey

The structured household survey consists of four sections with 24 questions (Onencan et al. 2023). The first section assessed the nature and extent of social influence, which was not the focus of this study. "Literature review and Theoretical Underpinning" probed participants' trust in neighbours and energy transition institutions (opportunity). "Materials and methods" asks questions on tenants' knowledge (physical capability), understanding (psychological capability) of energy transition, and perceptions (motivation) of different energy sources. The final questions in "Results." gathers individual and household demographic data (Table 1 and 2). The COM-B variables are presented in Table 3 and discussed below.

We used a 5-point Likert scale for agreement for all COM-B components, with options ranging from strongly disagree to strongly agree. We incorporated the neutral option because housing corporations felt that it was important to provide a neutral option for participants who did not have clear-cut responses or perceptions. The questions asked during the structured household survey are available as supplementary material together with responses from the participants (Onencan et al. 2023).

Table 1 Demographics: gender, number of years as tenant, and first language, $n = 95$ [%]

Gender		Residence (yrs.)	Mother tongue[1]					
Female	62	[65%]	<1	8	[8%]	Arabic	11	[12%]
Male	29	[31%]	>10	55	[58%]	Dutch	61	[64%]
Other	4	[4%]	1 to 5	17	[18%]	English	2	[2%]
			6 to10	15	[16%]	Turkish 3	[3%]	
						Others	18	[19%]

[1]A few participants have two mother tongues, the first Dutch and the other either Arabic or Turkish

Table 2 Demographics: age, highest education attained, and current work situation, $n = 95$, [%]

Age			Highest education [a]			Work situation		
18–29	3	(3%0)	None	11	(12%)	Fulltime	17	(18%)
30–49	41	(43%)	Primary education	5	(5%)	Parttime	19	(20%)
50–69	34	(36%)	LBO / VBO	16	(17%)	Pensioner	24	(25%)
≥70	17	(18%)	MAVO, MBO	26	(27%)	Searching	8	(8%)
			HAVO	5	(5%)	Student	6	(6%)
			VWO	4	(4%)	Unemployed	21	(22%)
			HBO, HBS	22	(23%)			
			Bachelor's	4	(4%)			
			Master's	1	(1%)			
			PhD	1	(1%)			

[a]junior secondary vocational education (LBO), pre-vocational education (VBO), junior general secondary education (MAVO), pre-vocational secondary education (VMBO), senior general secondary education (HAVO), and pre-university education (VWO)

Table 3 COM-B variables used to measure the intention–action gap

Construct	Variable	Type	Measurement
Capability	Physical capability	Interval: continuous	5-point Likert scale
	Psychological capability	Interval: continuous	5-point Likert scale
Opportunity	Physical opportunity	Interval: continuous	5-point Likert scale
	Social opportunity	Interval: continuous	5-point Likert scale
Motivation	Reflective motivation	Interval: continuous	5-point Likert scale
	Automatic motivation	Interval: continuous	5-point Likert scale
Behaviour	Tenant behaviour	Nominal: dichotomous Cardinal	0 = No; 1 = Yes Count visit/greet

Results

This section provides the survey results on participants' current behaviour with regard to transitioning to DHN (4.1), capability (4.2), opportunity (4.3), and motivation (4.4).

Behaviour

The target behaviour was willingness to transition from natural gas to district heating. Behavioural intention was based on participants' responses to question 12 ("If your energy bill and rent remain the same, will you agree to switch from natural gas to other cleaner energy sources?") and question 8 ("Would you like to have more information about the 'DHN'?"). Results to question 12 show that of the ninety-five participants, seventy-one would like to transition to district heating, indicating a 75% approval rate. This is slightly above the legal requirement of 70% tenant approval before initiating any collective building retrofits.

Based on the results to question 8, most respondents (52 out of 95) prefer not to receive further communication from the municipality on DHN. For the 41 respondents who prefer to receive more information, most chose non-personal communication channels where the messenger makes no personal contact with the tenants or seeks feedback. The most chosen option was a letter or brochure (34 out of the 41 responses).

Further analysis using Pearson's Chi-squared test identified five factors (see Table 4) that contribute to the positive response of transitioning to district heating (Fig. 3). All five are motivational factors, one is automatic (comfort), and the other four reflective (Table 4). Most respondents prefer DHN and electrical or induction cooking over natural gas, largely because the preferred options are perceived to be environmentally friendly, sustainable, and comfortable.

Capability

The questions related to capability were divided into two parts: physical and psychological (Fig. 4a). Physical capability questions were based on practical information and skills that tenants needed to be able to make the transition. The psychological capability questions focused on understanding the goal and direction of the DHN project so that the

Table 4 Pearson's Chi-square test revealed five significant factors. All belong to motivation

Concept	Factor	X-squared	df	P value
Automatic motivation	"I think DHN is comfortable"	16.16943	8	0.040018
Reflective motivation	"I think DHN is sustainable"	18.68124	8	0.016661
Reflective motivation	"I think electricity is sustainable"	24.50158	8	0.001887
Reflective motivation	"I think DHN is environmentally friendly"	24.97526	8	0.00157
Reflective motivation	"I think electricity is environmentally friendly"	17.54095	8	0.024944

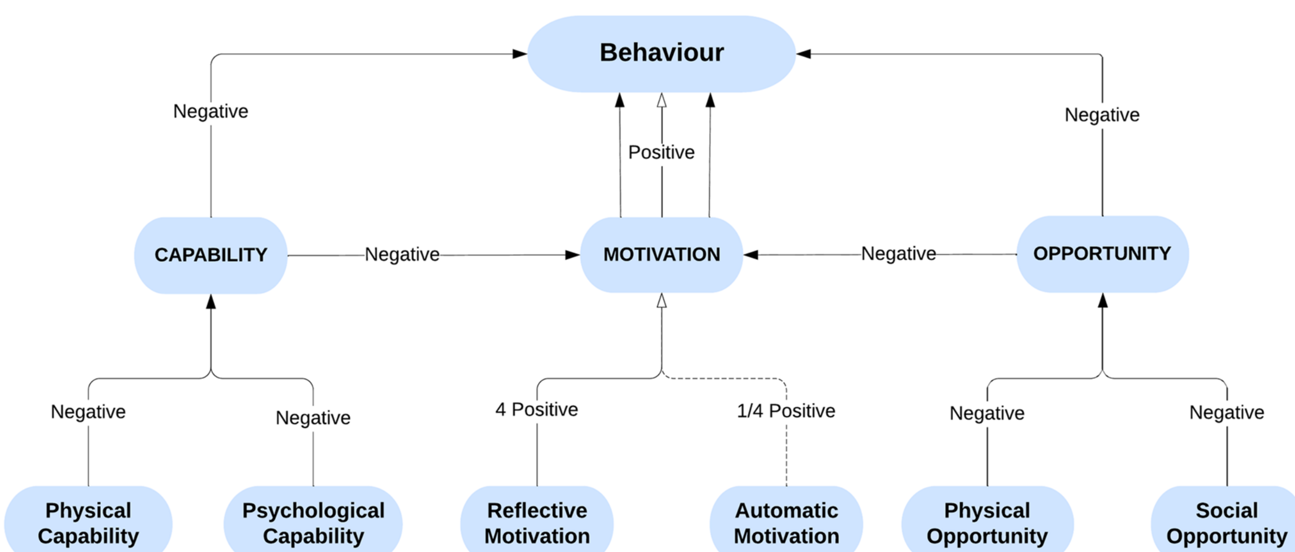

Fig. 3 Pearson's Chi-squared test results for the different concepts of the capability, opportunity, motivation, and behavioural (COM-B) change model

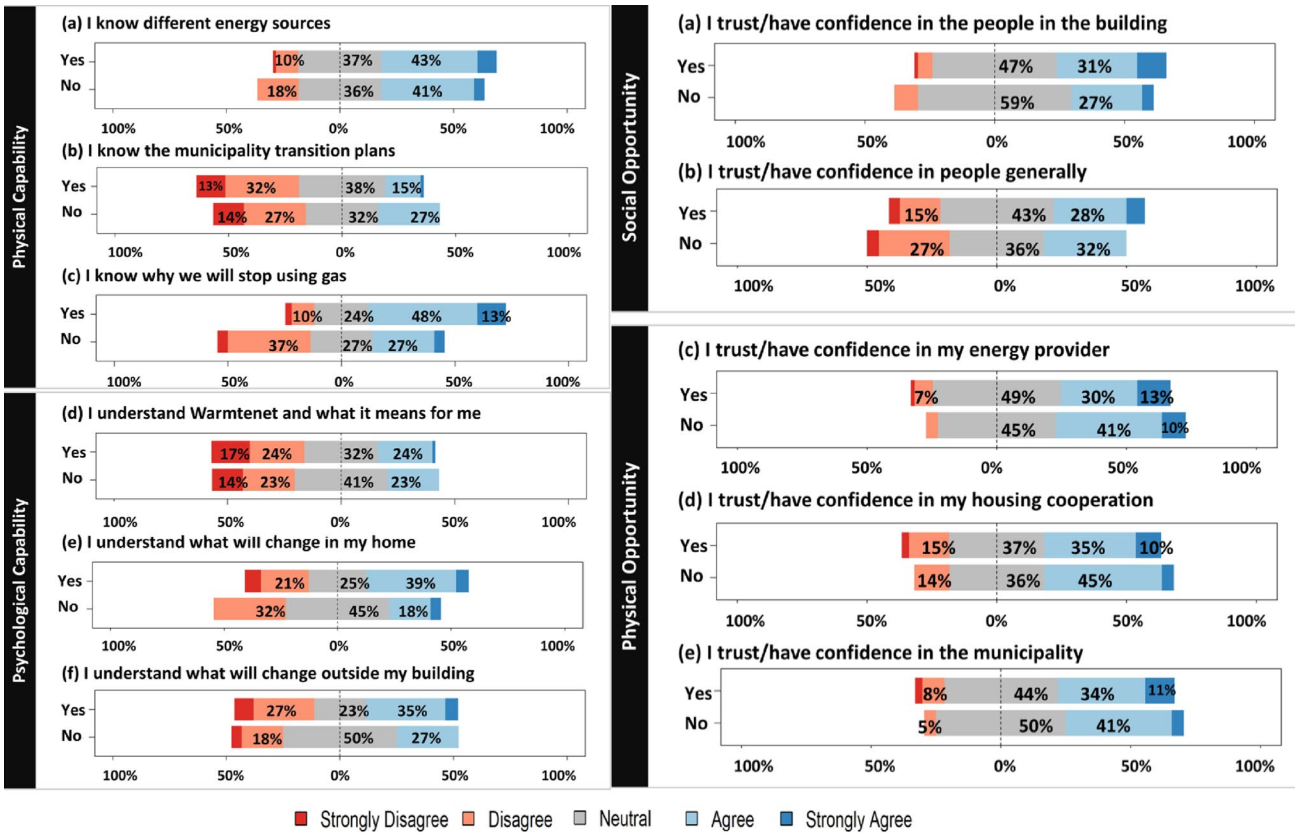

Fig. 4 **a** Tenants' physical and psychological capability (*n* = 95). **b** Tenants' physical and social opportunity (*n* = 95)

housing corporation tenants could actively participate in ongoing processes.

More than half of the respondents agree that they know why the Netherlands should stop using natural gas (54%). Responses to the other questions are not as high (below 50%), indicating that the overall capability of the respondents (whether physical or psychological) is low. The results in Fig. 4a indicate that the general goal of the energy transition, why the Netherlands should stop using natural gas, and the different available energy sources are well understood. Most tenants were uninformed with the practical aspects pertaining to the energy transition plans of the municipality, including timelines and the modifications that would be made to their individual residences and the surrounding areas. A high number of respondents were neutral about their capability levels.

Opportunity

Opportunity questions (Fig. 4b) were divided into two parts: social (influenced by interpersonal trust) and physical (influenced by institutional trust). Trust plays a key role because most decision-making and energy transition processes are undertaken by various authorities on their behalf or collectively as a group of tenants. Overall, respondents who indicated that they wanted to transition to a DHN had higher levels of interpersonal trust and lower levels of institutional trust compared to those who did not support the change.

The social opportunity question (Fig. 4b) assessed the overall trust levels of tenants. Results show that the general trust levels of the respondents or social opportunity is below 50% in all instances. Respondents possess low trust for others whether living in the same building, the same floor, strangers, or people generally. According to the results, the positive social influence from neighbours, people sharing the same building, and people in general is not compelling. Thus, the level of social influence of neighbours and people from the same floor is relatively low.

The physical opportunity question (Fig. 4b) assessed the tenants' overall energy transition, institutional trust, or confidence levels. Results show that institutional trust levels of the tenants or physical opportunity is below 50% for all the energy transition organizations.

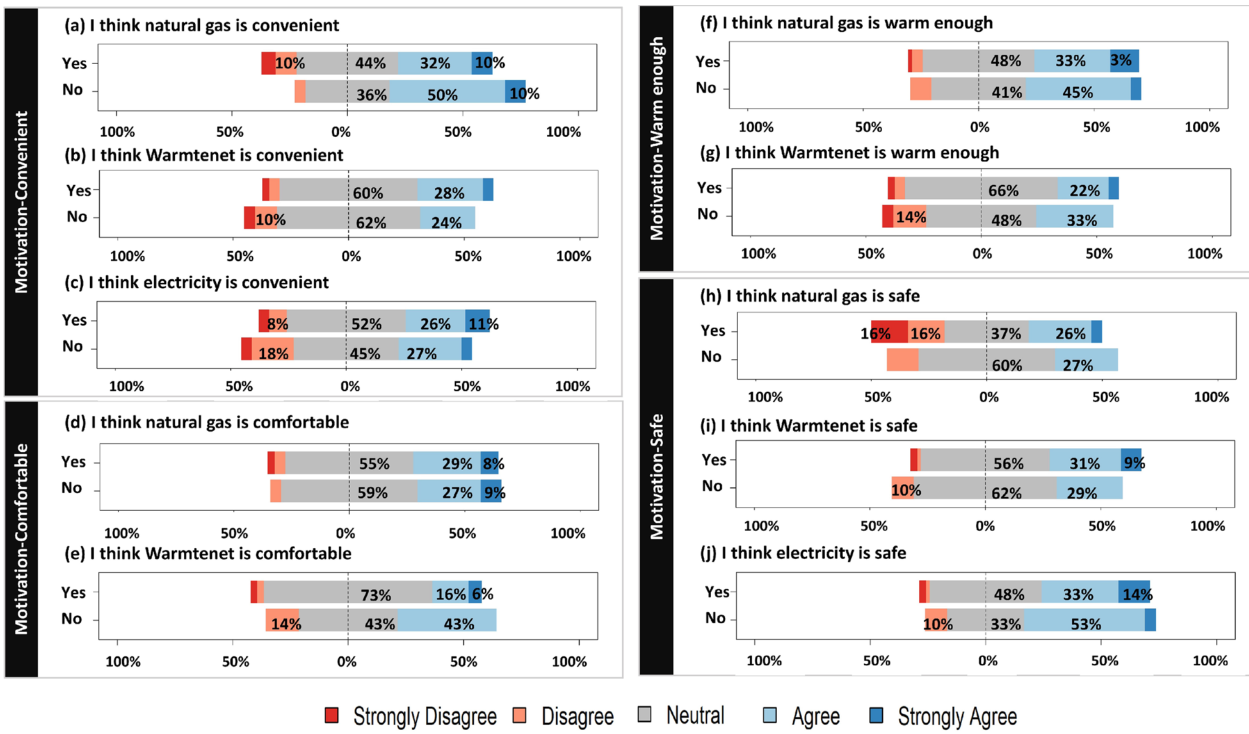

Fig. 5 Automatic motivation to transition to renewable energy sources ($n = 95$). Gas refers to natural gas. WT refers to DHN, and Elec refers to electricity

Motivation

Motivation questions were divided into automatic (Fig. 5) and reflective (Fig. 6) motivation. Overall, there is a consensus between the two groups that either approve or disapprove district heating regarding price (current or future), suggesting that a perceived increase in energy costs is a major demotivating factor. Natural gas is believed to be the most viable energy source based on automatic motivation results, compared to DHN and electricity. However, DHN seems to be considered more viable than natural gas when looking at reflective motivation factors. Electricity is the least preferred option when considering both automatic and reflective motivation factors. Reflective motivation (beliefs about consequences, beliefs about capabilities, and optimism) scores were higher for the sustainability and environmental friendliness of DHN compared to the issue of cost. Interestingly, most tenants chose to remain neutral on issues of cost, with the highest neutral score on "cheap now" for electricity (66 out of 95).

Discussion

This section discusses the results based on the COM-B change model. The final part of this section focuses on research limitations and recommendations for future research.

Behaviour

The results indicate that the key driver of the tenants' 75% approval rate to transition from natural gas to district heating is reflexive motivation. The results are 5% higher than the legal requirement for any major housing corporation renovation. The understanding of most tenants of why energy transition is needed is sufficient. They perceive climate change as a problem, which is a key motivation factor for high approval rates. The reason for discontinuing natural gas use is less clear among those who do not agree to a DHN. Other studies have shown a second external factor that could play a role: people want to stop further land subsidence in Groningen owing to many decades of natural gas extraction (Ridder et al. 2019; Steenbekkers and Scholte 2019; Van Dalen and Henkens 2019).

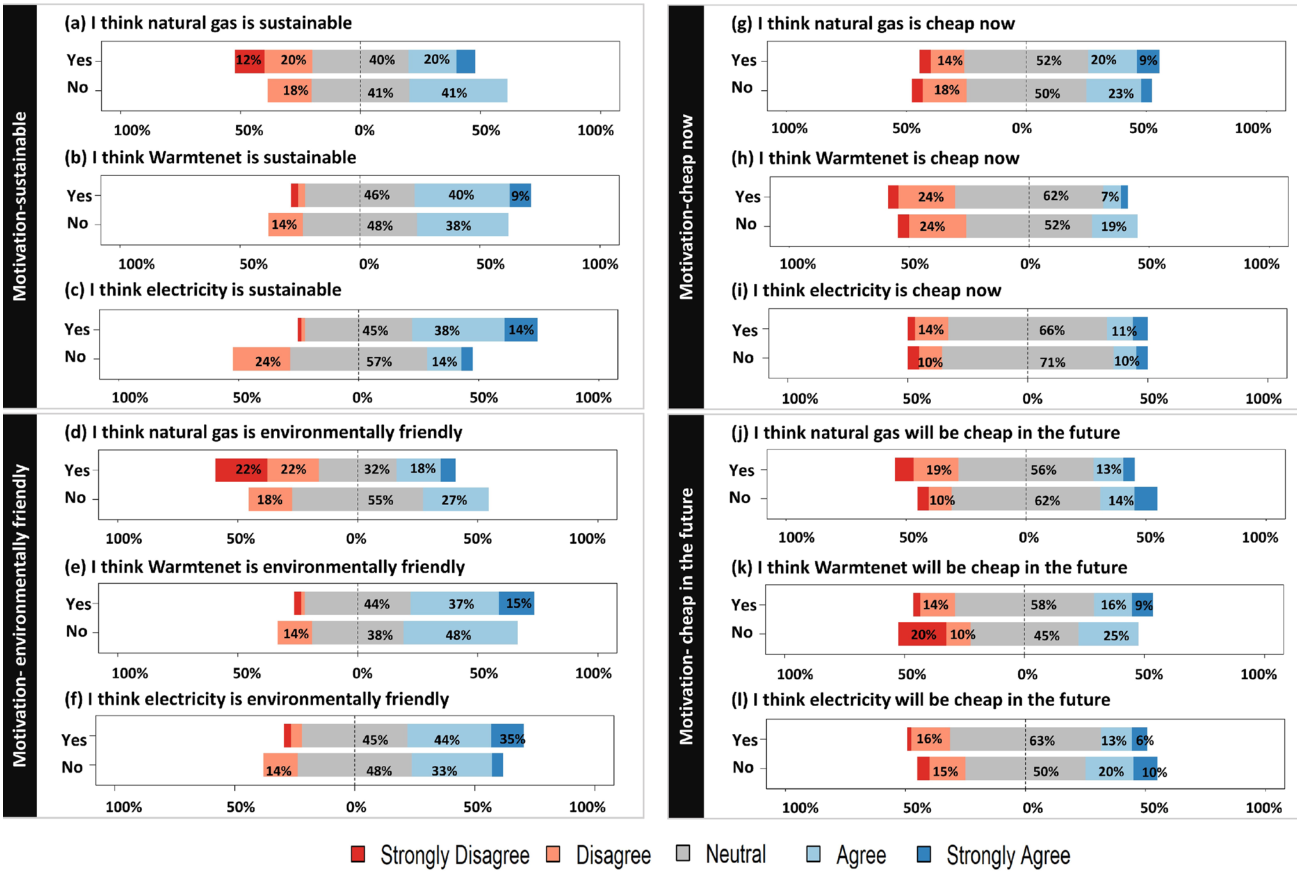

Fig. 6 Reflective motivation for transition to renewable energy sources ($n = 95$). Gas refers to natural gas. WT refers to DHN and Elec refers to electricity

The strong belief that energy transition is required seems to permeate the entire study. The "why" of energy transition in general should be reinstated repeatedly to be able to activate tenants to support ongoing energy transition processes in their neighbourhood.

Capabilities

These results indicate that the capability of social housing cooperation tenants is low for specific municipal plans. This potentially influences the future acceptance of specific plans because a lack of relevant information and understanding of DHN heightens risk perception (Ianole-Călin and Druică, 2022; Renn 1998; Slovic et al. 1991). Our findings align with previous studies in the Netherlands, which indicate that there is a lack of tenant knowledge on municipalities' plans for the DHN and the actual consequences (Bouw 2017; Kort et al. 2020; Van Aalderen et al. 2021; Van Lidth de Jeude and Midden 2014). However, less than half of the tenants (41%) indicated that they would want more information. Of these, 41% preferred institutional actors to provide practical information on the DHN in a passive form (brochure or flyer). Nevertheless, studies on behaviour change indicate that information is not always the strongest incentive for actual change (Cherney 2008). The choice of more passive information channels could indicate that the topic is not something people want to be bothered by or invest much time in. This makes it more difficult to engage people. This finding may require further studies on effective communication, because the passive mode of communication is contrary to what Kort et al. (2020) propose as the most effective means of communication (personal and accessible). Our results indicate that comfort and environmental friendliness are important factors. Tenants can be persuaded to actively engage in the process by convincing them that the transition will enhance comfort and environmental friendliness.

Motivation

Although 75% were in favour of district heating, we found six risk factors that influenced people's motivation. First, tenants fear that using DHN and electricity will not be as convenient as using natural gas. One reason that the tenants consider natural gas more convenient than DHN is because it does not require a separate energy source for cooking. Second, there is a fear that the DHN will not create a comfortable home temperature. DHN will either use geothermal or residual heat, and the initial temperatures will be lower than those of natural gas and will be further reduced in subsequent years (Gemeente Haarlem and van Dijk 2020). Third, tenants fear that DHN or electricity will not be warm enough to heat their poorly insulated houses compared to natural gas. More than one-third of the housing corporation buildings were constructed before 1980, with poor insulation (Lambrechts et al. 2021). Another aspect to consider is that tenants from warmer countries may prefer to keep their houses warmer in winter than others, which may not be possible with DHNs. Fourth, tenants fear that DHN, although safer than natural gas, is not as safe as using electricity. Fifth, some tenants feel that cooking on electricity will not suit their cooking habits or recipes and that induction cooking may pose limitations to some of the cooking methods they could use (e.g. charring vegetables). Survey results indicated that most respondents had positive perceptions of cooking on induction. Our study confirms what other studies found that there are concerns about whether the new energy source will be sufficient to meet current demand, hot enough to heat poorly insulated homes, and be functional to meet the unique cooking methods and needs of diverse communities (Bouw 2017; Steenbekkers and Scholte 2019; Van Aalderen et al. 2021; Van Lidth de Jeude and Midden 2014).

The final fear (risk factor) is the increase in monthly energy costs. Price is a critical issue that all tenants are concerned about, whether they voted for or against the DHN. This finding is consistent with those of previous DHN studies (Bouw 2017; Van Aalderen et al. 2021). Bouw (2017) identifies and explores six distinct pricing problems. First, consumer choice is severely constrained by obligatory connections to vertically integrated DHN energy supply and distribution companies, which curtails tenants' control over energy costs. The second concern is DHN monopoly pricing, Haarlem municipality has contracted one energy supplier and one energy distributor for the entire DHN project (Gemeente Haarlem and van Dijk 2020). Monopoly pricing denies tenants the ability to switch providers and benefit from competitive pricing. Third, DHN long-term energy contracts bind tenants to a single heating option for extended periods, restricting their ability to adapt, and potentially, they may miss out on more cost-effective alternatives. According to Bouw (2017), existing regulations, such as price cap regulations, fail to adequately safeguard consumer interests, resulting in discontentment and financial strain. Fourth, energy contracts lock-in tenants to the heat infrastructure. Currently, tenants are locked into the dominant gas infrastructure. Our research confirms that the current lock-in to natural gas (they find it more affordable, comfortable, and convenient) is deterring some tenants from embracing more sustainable options, such as DHN. A DHN, once implemented, may also create a lock-in situation. Lock-ins perpetuate higher prices for other energy options and hinder the proposed transition to more suitable or sustainable heating solutions. Fifth, some of the tenants expressed fear that they would eventually bear the high investment costs for extracting geothermal and residual heat, including costs for a new energy distribution infrastructure. Finally, the current pricing model that relies heavily on gas prices is distorted, and tenants fear that these distortions will affect energy pricing under the DHN. The fear of pricing is exacerbated by the ongoing discussions to revise the Heat Supply Act, and specifically the proposal to replace the NMDA (Niet-Meer-Dan-Anders) model, which protects tenants from heat tariffs and excessive connection costs, as a result of retrofits or energy transition (de Boer 2023). This uncertainty creates more fear and increases perceptions of risk (Bouw 2017; Van Aalderen et al. 2021). Housing corporation tenants need clear affirmations that the expense of replacing natural gas with DHN shall not be borne by the tenants and that the tenants' energy bill and rent will not increase now or in the future. Further, future behavioural change interventions should target the practical aspects of reflective motivation (costs of energy transition) more than the general aspects relating to sustainability and environmental friendliness of the various energy sources.

Opportunity

The results on social opportunity indicate a trust deficit that needs to be urgently addressed by increasing opportunities that target interpersonal and institutional trust. First, institutional trust is low, with less than 50% of tenants affirming trust in the housing corporation, municipality, and energy provider. Institutional trust is highly influenced by the prevailing institutions (energy laws, housing corporation regulations, energy transition plans, and contracts to extract geothermal energy) (Abson et al. 2017; Onencan 2019). Second, it is necessary to reconnect tenants to other tenants. The results of our survey showed that interpersonal trust between tenants in the same building is low; in fact, trust in neighbours is lower than trust in the general public. If the tenants want to pass a decision, a low level of interpersonal trust influences their ability to self-organize and influence the system. This is a major problem because decisions might be made to their detriment without their knowledge and input.

To encourage the emergence of a self-organized group of tenants who trust each other, the municipality and housing corporations should shift from hierarchical management structures toward emergent and self-managed cultures. To activate tenants' engagement in the energy transition, the municipality already organizes information evenings, talks, and activities. Since 2018, there has been a sounding board group consisting of residents and a neighbourhood council. The group produces ideas for the energy transition project and asks critical questions. Duurzaam Bouwloket (2019) was launched at the end of 2019 to help tenants renovate their homes sustainably. Despite these changes, the above examples have remained ineffective because, to a considerable extent, they are hierarchical and not self-emergent. At the time of data collection, the municipality and housing corporations were still unsure how to effectively engage tenants to accelerate the energy transition process (Gemeente Haarlem 2022a). Reconnecting the tenants to other tenants is a powerful behavioural change factor that could strengthen horizontal networks and organically lead to more trust and participation of the tenants in ongoing energy transition processes.

Limitations and recommendations for future research

This study focused on the role of tenants in the energy transition process. This study contributes significantly to the existing literature on the inclusion of tenants in building retrofits as active stakeholders. These findings are particularly relevant to governance structures and legal frameworks in regions with a substantial social housing sector. The case study we selected reflects a few common challenges faced by energy transition in the social housing sector, regardless of geography. First, the area is characterized by a high density of buildings with low energy efficiency, underscoring the pressing need for energy retrofitting. Second, the governance structure is complex, as it involves multiple players, including but not limited to tenants, housing cooperations, and local governments. The necessity of building trust, fostering effective communications, and crucially integrating tenants into the decision-making process is paramount. Third, the tenants in our study represent low-income and vulnerable households that face challenges in energy transition. A recent report (van Ooij et al. 2023) on energy poverty in the Netherlands indicates that 70% of the households struggling with energy poverty were living in social housing. Our study examined the acceptance and opinions of this vulnerable group. Fourth, the participants in this study come from a range of migration backgrounds, adding to the complexity of tenant dynamics. In summary, the findings from this study offer valuable insights for other social housing sectors grappling with similar dynamics of low-income, diverse tenants, housing cooperations, and local governments, in the context of urgent energy retrofit needs. The generalizability of these findings can guide policymaking and strategy planning in comparable settings, encouraging a more inclusive and effective approach to energy transition in social housing**.**

This study had certain limitations that should be considered when interpreting the results. First, there may have been response bias stemming from those who returned the survey. Despite achieving a relatively high response rate of 35%, the opinions and acceptance levels of non-respondents remain unknown. It is possible that those who did not participate may have had lower trust in housing cooperations and were less supportive of the energy transition. Consequently, the findings may not fully represent the entire spectrum of experiences and attitudes within the study area.

Second, the study's use of survey data introduces limitations commonly associated with self-reported information. Responses may be subject to personal bias and inaccuracies. Future research could benefit from incorporating additional methods such as observational studies to gain more objective and comprehensive insights.

Third, while the selected study area shares many characteristics common to the social housing sector, it does not fully encompass the diversity of socioeconomic and cultural contexts found in other regions. The cultural dynamics of the study area, predominantly influenced by migrants from various regions and religious backgrounds, may differ significantly from areas with more homogeneous populations. Future research should consider exploring social housing contexts with varying socioeconomic and cultural compositions to understand how these factors influence tenant dynamics and perspectives on energy transitions.

Concluding remarks

In this study, we assessed the social acceptance of a district heating network among the tenants of social housing corporations. Our study focused on a specific site in the Netherlands: five social housing buildings in Meerwijk, a neighbourhood in Haarlem. A survey completed by ninety-five tenants was the basis for the research findings. The main survey findings based on the capability, opportunity, motivation and behavioural (COM-B) model are summarized as follows:

1. **Behavioural intention:** The study revealed a 75% approval rate for DHN, surpassing the required legal threshold of 70% for retrofit implementation.
2. **Capability:** The respondents indicate that they know enough about the general energy transition and various sources of renewable energy. The extent of tenant knowledge regarding the plans for the DHN is not as well known, and it is unclear what changes will be made to

buildings or their surroundings. In contrast, most people do not want more information. Only 41% of the tenants want more information on the energy transition or the DHN from the municipality, mostly indicating a low-effort information channel, such as a general brochure.

3. **Opportunity:** In our study, we found that trust in the housing corporation, energy provider, and municipality is equally low (below 50%), not indicating a strong preferred source of trustworthy information. Moreover, the results of our survey showed that the interpersonal trust levels between tenants in the same building were low; in fact, they were lower than the trust in the general public.
4. **Motivation:** The results show that people feel that district heating is sustainable and safe, especially when compared to natural gas. Consensus in the subgroup analysis was the highest in relation to energy pricing. All tenants, whether they support or do not support DHNs, agree that energy pricing is a critical issue, and that the deep uncertainty surrounding it negatively impacts their motivation to support the transition. Also, respondents indicate that they are more uncertain about what it exactly means for them. Their fear is that district heating is not sufficiently warm or expensive.

Our results signify significant support for the DHN project in Meerwijk, suggesting social acceptance and a high likelihood of tenant adoption. The results also imply that for further support, institutional actors need to engage in interventions aimed at enhancing tenant knowledge and understanding (capability) of the specifics of the DHN in their neighbourhood. In addition, interventions should provide practical information on the consequences of DHN to enhance community acceptance (motivation). Finally, actors should design interventions to build trust at the interpersonal and institutional levels (opportunity).

The value of social acceptance research in the energy field cannot be overstated. A comprehensive understanding of individual and societal concerns, attitudes, and behaviours towards energy technologies is crucial for the success of energy initiatives. By integrating social acceptance research into energy transition planning, we lay the groundwork for a more sustainable and inclusive energy future, addressing the needs and aspirations of individuals and communities. This research provides valuable insights for policymakers, energy planners, and stakeholders to develop evidence-based interventions and policies that are both technically viable and socially acceptable.

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Declarations

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