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Sustainability Impulses from Wuppertal

Heating Energy Feedback in Apartment Buildings: Interface Design as the Key to a Participatory Energy Transition

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Abstract

Progress in cutting greenhouse gas emissions in the heating sector has so far been modest. Apartment buildings present particular challenges due to the wide variety of technical conditions – such as their year of construction, the building envelope, their size and the diverse needs of their tenants. Digitally processed energy consumption data offers a valuable opportunity to improve transparency, foster participation and encourage energy saving.

Researchers at the Wuppertal Institute conducted two online surveys to investigate whether tenants are receptive or opposed to receiving heating energy feedback, or remain undecided. Their findings show that attitudes are shaped by several factors, including sensitivity to energy prices, the types of sensors used and trust in data privacy. A key insight is that tenants' perceived self-efficacy – the belief that their actions make a difference – emerged as a key factor in their motivation and willingness to adopt energy-saving measures. However, effective feedback needs to be presented in a way that is easy to understand, practical and relevant to everyday life. It is essential that the impacts of energy-saving measures, including implications for energy costs and CO_2 emissions, are communicated clearly. To build meaningful digital interfaces, users need support in developing their energy literacy and digital literacy. For social trust into digital systems, data collection should be limited to the essentials and comply with data protection standards.

1. User interfaces as enablers of energy efficiency

The energy transition is a far-reaching transformation. The most significant achievements to date primarily relate to the decarbonisation of electricity supplies. In contrast, the heating sector remains largely dependent on fossil energy sources. Gas-fired boilers remain the dominant heating systems in residential buildings (dena, 2023). The current phase of the energy transition extends beyond technical processes: transitions increasingly aim to change behavioural patterns, including through electrified mobility, and thus impact consumers' everyday lives. **Public acceptance, transparency and participation** are therefore essential to the successful realisation of the energy transition.

Recent legislation at both European and national levels emphasises the growing importance of consumers in the energy transition. In Germany, the EU Energy Efficiency Directive (EED) has been implemented through instruments such as the Heating Costs Ordinance (Heizkostenverordnung – HKVO) and the Buildings Energy Act (Gebäudeenergiegesetz – GEG). These legal frameworks are intended to increase consumer transparency and incentivise energy efficiency.

New requirements from the EU Energy Performance of Buildings Directive (EPBD) must be transposed into national law by 2026. Moreover, the upcoming introduction of the European Union's new emissions trading system (ETS2) will lead to higher costs of fossil-based heating from 2027. These regulations pose significant challenges for the building sector, energy service providers and technology companies – while simultaneously increasing the urgency to develop innovative solutions to improve energy efficiency, information and monitoring. These developments promote the implementation of new energy products and business models in which user-friendly and effective digital interfaces serve as a key enabler to monitor energy consumption. **User interfaces (UIs)** are points of interaction between people and digital systems and appliances and can take the form of screens, buttons and voice control functions. They enable people to access information, input data and operate system functionalities. User interface design should focus on making the interaction with software and devices as intuitive and efficient as possible.

In the future, user interfaces may help consumers engage with emerging business models in digital energy. Smart energy technologies could enable flexible energy consumption or function as energy management software by intelligently linking distributed energy generation, storage and consumption. **High-quality data processing and presentation is essential for easy-to-understand energy feedback.** Many users struggle to make sense of energy consumption data. It is therefore essential to design user interfaces that are both intuitive and informative – in particular to help tenants in apartment buildings to better understand their energy use and identify meaningful actions they can take.

2. Online surveys and living lab in the rental housing

Tenants in apartment buildings are directly affected by price fluctuations, including for natural gas, oil and district heating. Unlike property owners, they have limited decision-making authority and cannot influence the building's technical infrastructure; instead, they can only affect their personal energy behaviour. For this reason, the VISE-Interface (VISE-I) project primarily investigates attitudes, preferences, and behavioural intentions regarding heating energy interfaces of tenants. VISE-I was developed as part of the Virtual Institute Smart Energy (VISE) and funded by the Ministry of Economic Affairs, Industry, Climate Action and Energy of the State of North Rhine-Westphalia from July 2022 to June 2025. Project partners included the Wuppertal Institute, TH Köln – University of Applied Sciences and the Europäische Bildungszentrum der Wohnungs- und Immobilienwirtschaft (EBZ).

In VISE-I, the Wuppertal Institute combined qualitative and quantitative research approaches to develop a comprehensive understanding of tenant attitudes toward heating energy interfaces. The Institute conducted an online survey in February 2024 to analyse tenants' preferences regarding interface communication media and forms of user interaction. The survey was completed by 540 tenants in apartment buildings, representative in terms of their age, gender and education level. Preference groups were derived from the survey data using a latent class analysis. These groups are not directly observable but were identified through similar response patterns. A logistic regression analysis was then conducted to identify the key differences among these groups.

In parallel, researchers implemented a living lab by equipping an apartment building with smart thermostats. During the 2023/2024 and 2024/2025 heating seasons, thermostat and energy consumption data was analysed to identify key areas of heating energy feedback. Tenants were able to access heating energy feedback through an online dashboard. The design was further explored in a second online survey of 1,275 respondents, conducted in April 2025. This survey investigated user perceptions and understanding of the feedback designs, and their motivational effects on energy-saving behaviour.

3. User preferences for the design of heating energy feedback

The analysis of user preferences reveals three main groups for heating energy feedback:

- Receptive – those who approve of the idea of regular heating energy feedback (28.7%)
- Undecided – those who do not state a clear preference for, or aversion to, regular heating energy feedback (41.7%)
- Opposed – those who clearly disapprove of the idea of regular heating energy feedback (29.6%)

The receptive group is characterised by a preference for digital interfaces (e.g. apps) and subtle incentives (e.g. energy-saving tips). The analysis revealed age as an important predictor: the older the respondent, the more likely they are to oppose the concept of heating energy feedback. Moreover, the **impact of energy price fluctuations** is an important factor: people who feel more vulnerable to rising costs are more receptive to heating energy feedback. The groups also vary in their willingness to accept in-home sensors (e.g. for temperature or humidity): those more open to installed measurement technology are also more receptive to feedback. Another **key aspect of receptiveness to heating energy feedback is the respondents' confidence in the secure storage of personal data**. The relationship between receptiveness to heating energy feedback, sensor acceptance and data protection concerns is illustrated in Figure 1.

Effective heating energy feedback is built on clear messages and concrete options for action

We identified key areas for actionable heating energy feedback by combining energy consumption data with behavioural patterns. Feedback on **temperature ranges** in living spaces allows room-specific recommendations, i.e. 19°C for the kitchen and 22°C for the living room. Feedback efficiency improves significantly when combined with recommendations on **temperature adjustments**. This kind of feedback can motivate tenants to adjust room temperatures to the times when rooms are actually in use. While generalised recommendations are often difficult due to varying living situations, smart thermostats can considerably ease demand-based control through automation. Another important indicator of a healthy indoor climate is **room humidity**, as the risk of hazardous mould increases in sparingly heated rooms. Lastly, **heating and ventilation efficiency** makes it possible to determine energy consumption relative to the average temperature. For example, very low efficiency might point to instances of prolonged tilt-window ventilation. This, in turn, makes it possible to produce specific guidance, such as on more efficient ventilation.

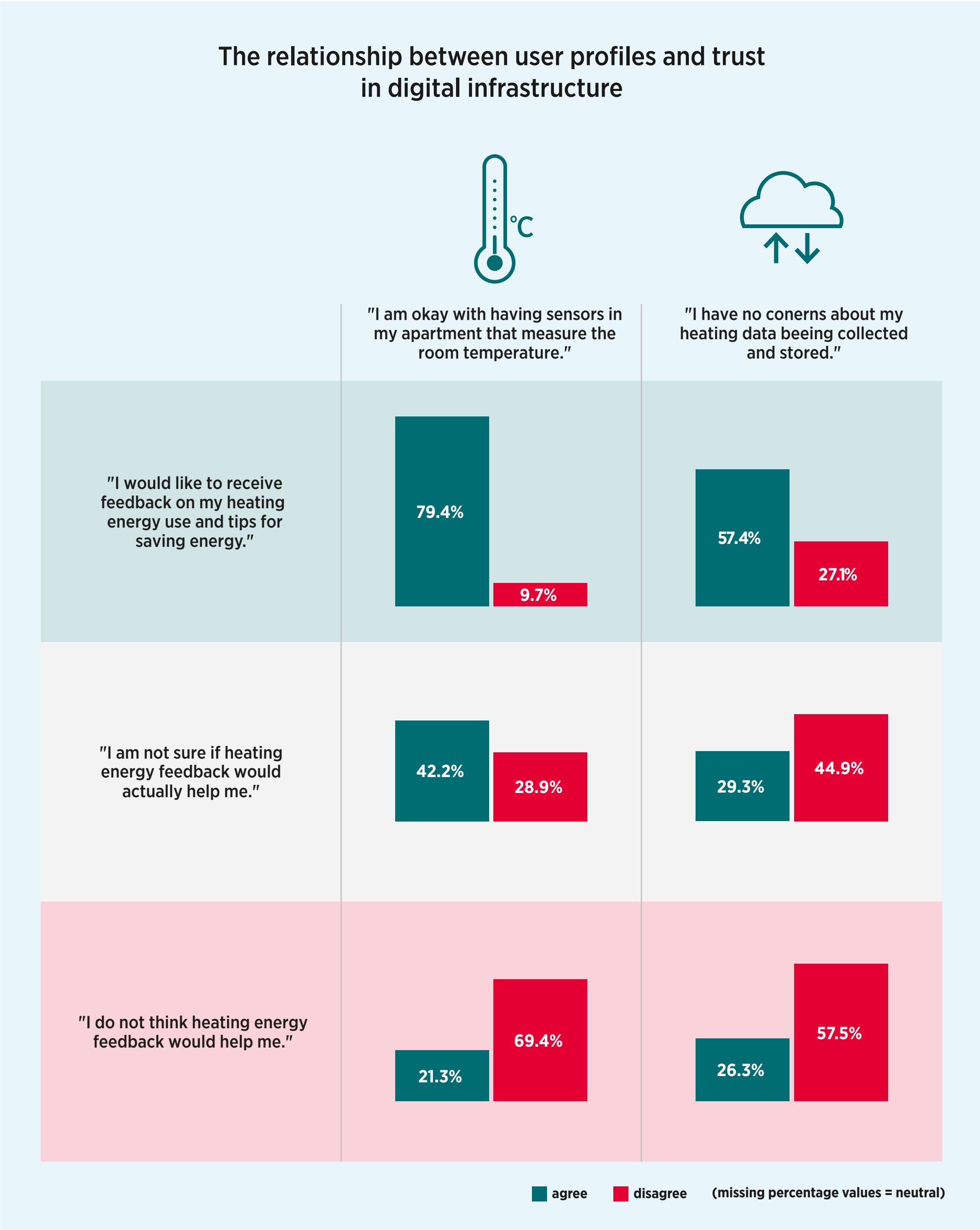

Figure 1: *Different perceptions of sensor acceptance (e.g. for temperature or humidity measurement) and concerns about data protection. Sorted into three groups – receptive, undecided and opposed – based on their views of heating energy feedback.*
Source: *Wuppertal Institute*

High self-efficacy motivates users to take action

The challenge in energy feedback design lies in simplifying information while retaining all crucial details. The second online survey reveals that over 60% of those who already receive intra-yearly information about their heating energy consumption find this information useful. The results show that most respondents understand simple forms of presentation, like bar charts. By contrast, more complex visualisations – such as calendar-based timetables – are often misunderstood. This emphasises the importance of researching feedback designs to create target group-specific energy feedback.

When designing energy interfaces and feedback, perceived **self-efficacy can be a crucial factor**. If people believe they can actively influence their energy consumption, they are more likely to rate information on energy consumption as helpful and are also more likely to implement measures based on the information presented (see Figure 2). Perceived self-efficacy could be an important lever for motivating energy-efficient behaviour. Feedback should therefore outline the realistic scope for action and demonstrate the impact of measures. Impacts could be presented on a personal level (e.g. as cost savings) and on a societal level (e.g. as CO_2 savings).

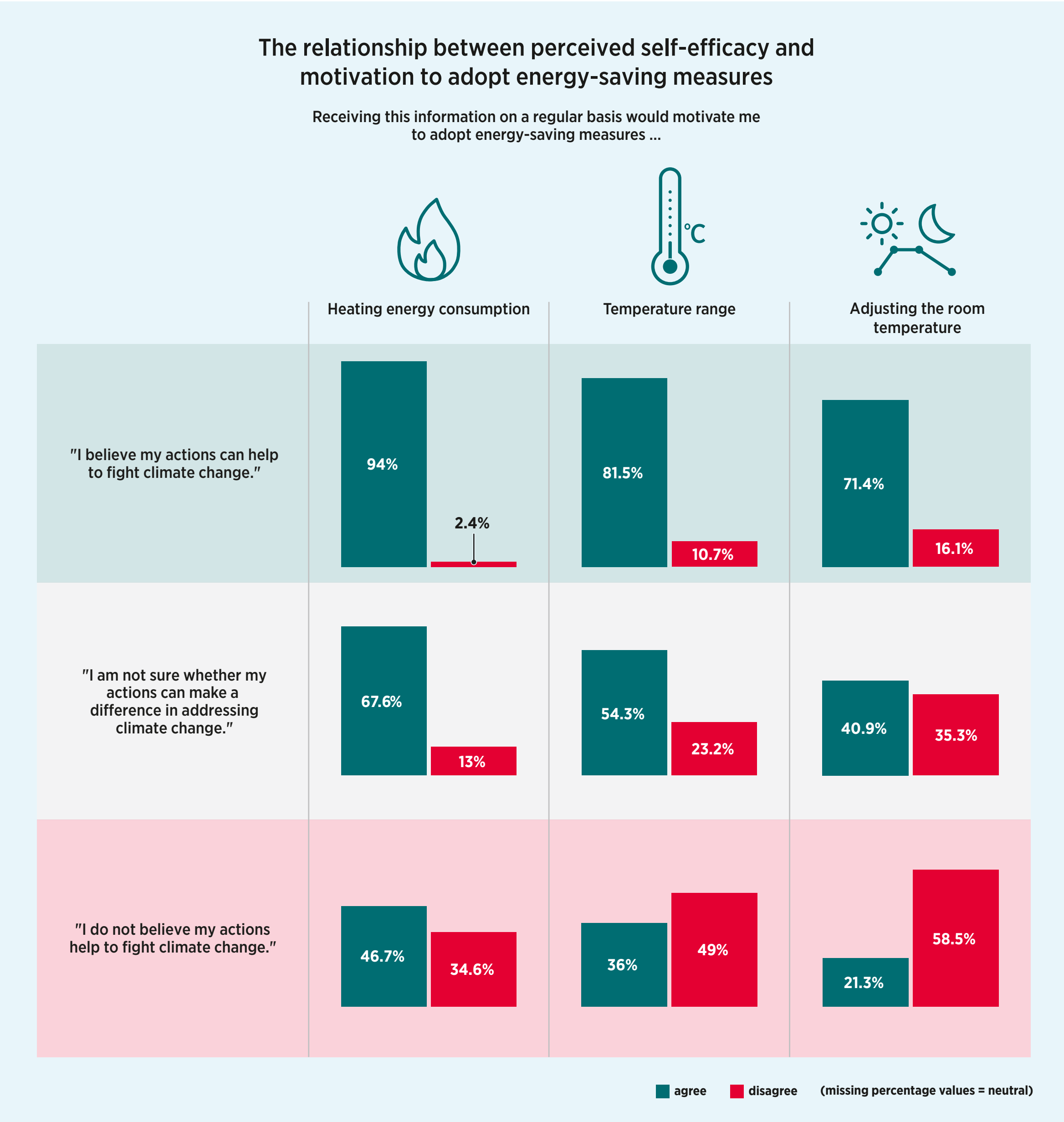

Figure 2: *Respondents' rejection and approval of whether the feedback on energy consumption, room temperature and temperature adjustments motivate them to implement energy-saving measures. Sorted by groups with low, medium and high self-efficacy.*
Source: *Wuppertal Institute*

4. Recommendations

Using interface design to build key competencies: Energy literacy and digital literacy

- When it comes to enabling participation and ensuring comprehensibility in the energy transition, energy literacy and digital literacy go hand in hand. To improve these competencies, **energy feedback** must be accessible, understandable and offer users **tangible added value.**
- Technology **supports competence development** and simplifies energy-efficient heating. Automation should be transparent and avoid creating a feeling of being observed or a loss of autonomy.
- Information should be presented in **easy-to-understand infographics** and supplemented with text. The combination of visual and textual presentation methods promotes inclusion. Once understood, graphic structures enable users to identify changes quickly and draw simple conclusions regarding energy-related behaviour.

Strengthen self-efficacy through communication and transparency: Link impact to social and personal goals

- Energy feedback should **highlight specific, comprehensible actions**, visualising the impact to the individual (e.g. lower costs) and as a contribution to society (e.g. in terms of climate protection)to strengthen users' self-efficacy.
- **Feedback formats should also be flexible** and reflect different life situations. Instead of rigid concepts such as 'day/night mode', adaptive approaches should allow for personal settings that take into account shift work and prolonged periods away from home, while still offering clear actions for energy-efficient behaviour.

Data protection and digital infrastructures: Designing suitable target visions and framework conditions

- Digitalisation must be implemented strategically – especially in building infrastructure – to ensure data achieves the **maximum impact**. In addition to room-specific information, peer-group comparisons and data from the central heating system represent important data sources. In the long term, energy information should be collated to optimise design and improve data quality.
- Feedback should support **behavioural changes in the long term** – minute-by-minute feedback is not necessary; daily to monthly information appears to be sufficient.
- **Digital infrastructure should be kept to a minimum** in the interests of data and resource efficiency.
- Feedback systems must **process data securely** and present it transparently to avoid users perceiving a loss of autonomy.

Further reading

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