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NAVIGATING DISRUPTIONS IN ELECTRICITY RETAIL: THE ROLE OF IS FOR DYNAMIC TARIFF ADOPTION

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NAVIGATING DISRUPTIONS IN ELECTRICITY RETAIL: THE ROLE OF IS FOR DYNAMIC TARIFF ADOPTION

Completed Research Paper

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Abstract

European governments are driving the energy transition by, amongst others, mandating the promotion of dynamic electricity tariffs for demand-side flexibility. However, this regulation turns the existing sociotechnical system of electricity retail upside down, introducing new tensions between social and technical components. Through three expert discussions with stakeholders from energy retail, policy, and research, we identify imbalances resulting from the externally enforced introduction of dynamic tariffs and explore how information systems can help realign system components to enhance systemic resilience. Our findings highlight three tension fields, focusing on consumer protection, home automation, and residential technology adoption. Ways to mitigate these tensions with information systems range from nudging to IT-integrated product development - all aimed at fostering sustainable consumption during the energy transition. This paper not only supports European energy goals by identifying key tensions and opportunities for practitioners but also encourages further information systems research on dynamic tariffs and energy services.

Keywords: Dynamic electricity tariffs, disruptions, sociotechnical system, resilience, energy transition.

1 Introduction

As the climate crisis intensifies, energy-related information systems (IS) research (Valogianni & Ketter, 2016) and European policy initiatives (Küpper et al., 2020) highlight the increasing importance of residential demand flexibility. Residential demand flexibility describes a household's capability to adjust to the volatile generation of green electricity, offering emission reductions, grid relief, and cost advantages (Parrish et al., 2020). In recent years, dynamic electricity tariff (DT) schemes are increasingly promoted as a means to incentivize residential demand response and to enhance such flexibility (Küpper et al., 2020). DTs provide price signals reflecting the time-variable cost of electricity supply within a day, enabling consumers to adjust their usage accordingly (Schlereth et al., 2018). Although regulations like the EU Electricity Directive (2019/944) require energy retailers to offer dynamic tariff (DT) options, many retailers incorporate DTs in their portfolios without actively promoting them (Numminen et al., 2022). Further studies also show that residential adoption is lagging and households prefer traditional, more static pricing schemes (Schlereth et al., 2018). The market's reluctance towards regulatory directives such as DTs reveals underlying systemic barriers and misalignments between social and technical systems (Darby, 2020). Indeed, the adoption of energy services is shaped by the complex interplay of technical and social components within energy markets, which can experience significant disruptions due to regulatory interventions (Geels et al., 2018; Darby, 2020; Sovacool et al., 2020), such as the introduction of dynamic tariffs. We can therefore conclude that the electricity retail system, as a socio-technical system (STS), is under significant stress that affects businesses and consumers alike.

To evaluate the systemic tensions and imbalances resulting from the introduction of DTs, it is pivotal to understand the nature of the disruptions for the STS and how the STS and its components (Bostrom & Heinen, 1977a, 1977b; Sarker et al., 2019) can be realigned to accommodate the externally induced changes (Vogus & Sutcliffe, 2007). For this paper, we define the system's capability of accommodating external changes and re-aligning system components accordingly as system resilience. To date, we are not aware that any study considers the missing residential adoption of DTs as an issue that emerged from a sociotechnical misalignment in energy retail, investigating the interplay between social and technical components. Therefore, we formulate two research questions:

- **RQ1**: *What tensions and imbalances arise within the sociotechnical system of energy retail due to the externally enforced introduction of dynamic electricity tariffs?*
- **RQ2**: *How can information systems support realignment and resilience in energy retail?*

To answer these RQs, this study follows a qualitative approach using expert group discussions (Gawlik, 2018) with energy researchers, policymakers, and retail practitioners. This approach enables a comprehensive, in-depth exploration of how and why the introduction of DTs may create tensions within the energy retail system, a topic that is challenging to quantify due to the variability of stakeholder perspectives and subjective opinions. We identify a set of tension fields that describe imbalances within the STS that cause threats to humanistic objectives such as financial and mental consumer well-being. Our results advance energy research by pointing to opportunities for IS to manage the identified complexities of DTs and to build system resilience. These insights contribute to Europe's green energy objectives by identifying where technological, business, and consumer dimensions are not aligned. In addition, this research extends existing knowledge on STS and resilience into a new context, shaping a new paradigm of understanding electricity retail as a system of mutual interdependencies between technology, social structures, and human agents.

The remainder of the paper is organized as follows: Section 2.1 outlines the European energy retail system and policy motivations for DTs. Section 2.2 presents the sociotechnical system (STS) framework and the concept of system resilience. Section 2.3 reviews related research, highlighting the importance of a sociotechnical approach in understanding regulatory impacts in energy markets. Section 3 summarizes the research design and describes how we followed commonly used qualitative coding procedures to extract and map multi-stakeholder insights from the discussions. In Section 4, we present the identified tension fields and key concerns that shape the understanding of systemic imbalances. Section 5 provides a discussion on the role of IS in mitigating tensions and building resilience. Finally, Section 6 summarizes the main findings, highlighting limitations and opportunities for future research.

2 Background

2.1 The European Electricity Retail System: A Brief Overview

Energy retailers in Europe traditionally buy electricity from various energy production sources – including renewable, nuclear, or fossil fuel – and then sell it to consumers. The highly regulated interplay of volatile supply and demand determines the wholesale market price of electricity. Market communication tools, energy purchasing systems, and analytics are part of the broader IT infrastructure that enables businesses to participate in the wholesale markets (Golmohamadi & Keypour, 2017).

Selling electricity to consumers is managed through retail electricity tariffs. In the traditional setting, in countries like in the pricing zone of Germany and Luxembourg, flat-priced electricity tariffs are set to define contractually the amount of electricity provided through retailers to a household at an average energy price of €/kWh. Consumers can pay their electricity bill annually, or in monthly instalments that mirror the expected monthly consumption. Electricity meters are installed in households to allow consumers and energy businesses to track and evaluate actual consumption. Under the traditional flat-rate pricing scheme households are free to consume electricity for the same price at any time of the day

(Schlereth et al., 2018). The central objectives within electricity retail are secure and affordable electricity for households (EU Directive 2023/2413) and profitability in commodity retail (Golmohamadi & Keypour, 2017).

As the transition toward a carbon-neutral energy system progresses, the electrification of various sectors is driving up electricity demand. This surge in demand highlights the need for greater efficiency and flexibility within the system to successfully integrate renewables. In response, policymakers are considering DTs as one option to adapt the system to these new flexibility requirements (Küpper et al., 2020). DTs reflect through their pricing structure demand and supply fluctuations, allowing households to engage with wholesale market dynamics directly. Though DT designs can vary—e.g., real-time pricing (RTP) with hourly changing prices and time-of-use tariffs (TOU) with rates on set time blocks—all aim to encourage households to actively shift consumption according to price fluctuations. This approach can help households to save on their electricity bills while also providing flexibility to the energy system (Schlereth et al., 2018; Parrish et al., 2020). By introducing DT regulations, policymakers aim to create price-driven incentives for households to consume energy during periods of low demand and low supply costs (Schlereth et al., 2018). This strategy tackles grid congestion at traditional peak-consumption times and minimizes the need for costly infrastructure investments to accommodate the increasing demand requirements. Additionally, it enables further integration of volatile renewables, which often drives low-price periods due to its low generation costs (Golmohamadi & Keypour, 2017).

2.2 Sociotechnical System (STS) Framework and Resilience

The sociotechnical system (STS) framework comprises interrelated and interdependent systems – that is the technical and social (Bostrom & Heinen, 1977a, 1977b). The technical dimension encompasses the entirety of the technical infrastructure within the system, including hardware, software, data sources, processing techniques, and tasks (Bostrom & Heinen, 1977a; Sarker et al., 2019). The social components include human actors and resources, their knowledge, skills, culture, behaviour, economic systems, organizations, and relationships (Bostrom & Heinen, 1977a; Sarker et al., 2019).

In the residential energy retail system, the social dimension includes human agents, such as residential consumers and employees of energy retail organizations. Retail businesses interact with consumers primarily through electricity tariff products, establishing a supplier-consumer relationship. Public and policy bodies, like the *Bundesnetzagentur* in Germany, oversee market regulation, protect consumer rights, and ensure fair access to essential energy resources. On the technical and operational side, retailers are responsible for purchasing and supplying affordable electricity to end consumers (EU Directive 2023/2413). In the traditional retail model with time-invariant pricing, households have a passive role: they simply consume the electricity and pay for their consumption as agreed on in their energy contracts (Schlereth et al., 2018). Physical systems are manifold and ensure the operability of the system. For example, energy retailers leverage installed electricity meters to track electricity consumption in homes (Corbett, 2013). It also includes analytics and Energy Trading and Risk Management (ETRM) software to handle energy purchasing (Golmohamadi & Keypour, 2017).

In general, systems like electricity retail must strive for a balance and harmonious fit between social and technical components. Otherwise, the instrumental or humanistic goals of a system, such as economic profitability or stakeholder satisfaction, will not be realized (Sarker et al., 2019). This means that misalignment between the components creates disturbances and can prevent the system from achieving its intended goals. A typical cause of misalignment is the disruption of routine operations (Vogus & Sutcliffe, 2007). Routines include all repetitive patterns and actions of actors, which are crucial for system stability (Becker et al., 2005). In the energy retail system, such routines can include the way an energy retailer maintains the electricity tariff portfolio or the way households consume electricity. Potential disruptions can arise from different dimensions, including regulatory interventions and business model innovations (Johnstone et al., 2020). Such disruptions might threaten electricity system goals like secure, and affordable electricity for households (EU Directive 2023/2413), and ultimately put the system's functionality at risk. Figure 1 displays a conceptual STS.

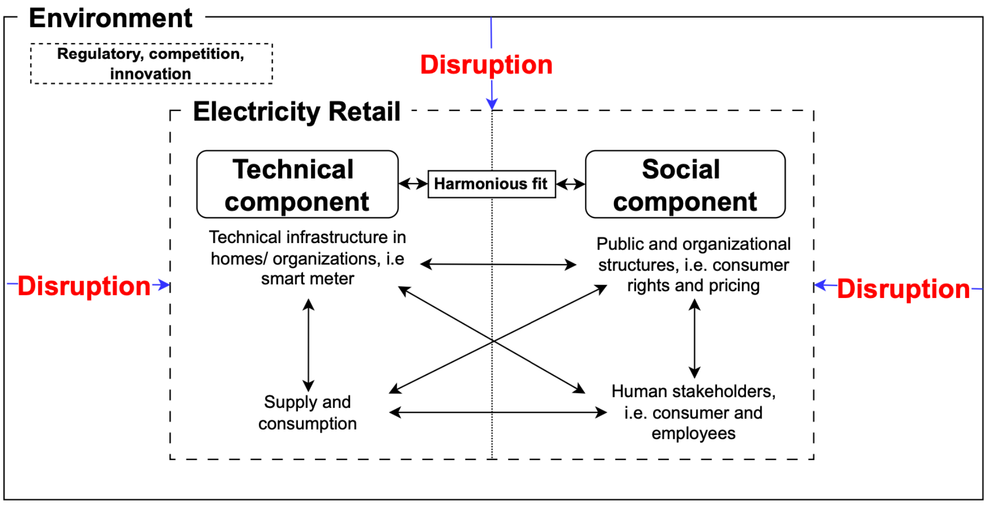

Figure 1. Own figure of conceptual STS based on Bostrom & Heinen (1977a) and Johnstone et al. (2020).

Recognizing the sensitivity of such complex systems, resilience emerged as a pivotal system attribute (Kohn et al., 2023). Resilience can be broadly defined as a system's capability to adapt to internal or external changes and maintain functionality by successfully establishing a re-alignment of the system's structural components (Kohn et al., 2023). This understanding of resilience is broadened by the work of Taysom & Crilly (2017), who introduce a "*fluid*" description of resilience. The authors note that different actors within an STS describe resilience according to their subjective understanding of the system's boundaries, purpose, and timescale. System boundaries are defined as the perceived limits within which a system operates, and its components interact, while the system's purpose outlines its objectives. The timescale, on the other hand, refers to the period over which stakeholders engage with the system, influenced by their roles, values, and broader concerns (Taysom & Crilly, 2017). Therefore, for this paper focusing on DTs, we need to consider resilience within the electricity retail system as a multi-faceted construct shaped by various stakeholders who have historically been conditioned to fixed price tariffs and now need to adapt to new regulations.

As the importance of system resilience grows in a progressively fast-changing world, information systems have demonstrated their value as a key tool for building and strengthening resilience against major shocks (Boh et al., 2023). Acknowledging, that building resilience can include context-specific requirements and specifications, the design of features of information systems within STSs should consider the circumstantial purposes (Bostrom et al., 2009).

2.3 The sociotechnical perspective in energy research

While the interplay of social and technical components has long been a cornerstone in traditional IS research (Sarker et al., 2019), its relevance is gradually recognized within energy and climate research (Eyre et al., 2018). The IS research community has contributed significantly over the last decades to the discourse of a green energy transition to mitigate climate change and build resilience in the energy sector. Examples include investigations about the potential of smart meter-enabled demand-side management initiatives (Corbett, 2013) and the role of information systems for consumption flexibility (Fridgen et al., 2016). Building on this growing recognition of IS-driven research, Geels et al. (2018) and Sovacool et al. (2020) emphasize that energy services and systems are shaped by the co-evolution of infrastructure, skills, knowledge, institutions, and technologies. Their findings align with the broader consensus that a sociotechnical energy transition perspective is more suited to address emerging challenges and barriers concerning systematic change, public engagement, and embedded agency of individuals and organizations than traditional approaches (Cotterman et al., 2021; Darby, 2020). Expanding on this research stream, further studies delve deeper into the importance of social and economic constraints alongside technology adoption for a clean energy system. Examples include

Cotterman et al. (2021) who argue that chosen pathways of the energy transition often neglect social, political, or economic factors. The study considers social constructs like technology acceptance, and risk concerns, and underscores how such social dynamics play a leading role in shaping consumer engagement and influencing broader changes in the energy landscape.

Additional research in the energy domain investigates the role of disruptions and emerging tension fields for the smart energy system. In a recent study by Sovacool et al. (2023), the authors conclude on four frontiers that shape the tension fields for carbon removal: policy and governance, modelling and assessment, innovation and scaling, and user behaviour and acceptance. Gordon et al. (2023) also deploy such perspective to investigate the barriers and hurdles of the hydrogen market development by drawing through a literature review on sociotechnical interdependencies and disturbances for energy businesses and consumers. By proposing a transition framework, they create a baseline for identifying imbalances within the system that slow down the adoption of climate-friendly energy services and consumption. Researchers like Johnstone et al. (2020) take on a more abstract perspective and derive from a review of sociotechnical management research four interrelated dimensions of energy system disruptions: technology, markets and business models, ownership and actors, and regulation. They suggest expanding the techno-economic view toward systemic awareness to handle diverse disruptions.

Building on this broader systemic perspective, attention has been directed toward the sociotechnical evaluation of regulatory interventions in the energy system. Darby (2020), for instance, analyses regulatory-driven demand response programs like dynamic pricing in a large-scale European case study of distributed thermal storage. In line with previous findings, the study advocates for breaking silos of traditional technical and economic perspectives and broadening the scope towards human-centred energy service designs. Darby's (2020) conclusion states that a crucial design requirement of a smart and green energy system is evenly distributed capabilities between people and technology, or in other words – between technical and social components of a system. Building on Darby's (2020) insights and the growing body of sociotechnical energy research, we recognize the importance of understanding and describing the emerging tension fields within the sociotechnical energy retail system caused by DTs. This approach allows us to identify opportunities to realign components of the electricity retail system that are out of balance.

3 Research Design

3.1 Preparation and execution of the expert discussions

To address the research questions, we conducted three semi-structured expert group discussions, involving a total of eleven voluntary participants. Group discussions are recognized as valuable tools for gathering stakeholder insights such as opinions and perceptions about the design, implementation, and impact of products, processes, services, or software (Gawlik, 2018). The discussion guide consisted of ten main questions and additional follow-up questions designed to steer the conversation while allowing participants the flexibility to shape the direction of the conversation (Gawlik, 2018). Examples include high-level questions such as "*In general, what do you think of this policy initiative and the underlying motivation of the policymakers?"* and specific follow-up questions such as "*Do you think consumers are sufficiently or excessively aware of risks and downsides?".* We designed the questions to discern the expert opinions on the impact of DTs on the social and technical components, as well as their interdependencies within the sociotechnical electricity retail system. The full questionnaire and information about its rationale are available in the online appendix (Burcheri et al., 2025).

To account for the fact that STS disruptions in the energy context affect multiple stakeholders (Johnstone et al., 2020), our sample includes two policymakers (PE1&PE2), three energy retail practitioners (BE1-3), and six energy researchers (RE1-6). The senior-level policy experts (PE1-2) focus on energy market regulations. The director-level business experts (BE1-3) have backgrounds in innovation, digitalization, strategy, and product management. The research experts (RE1-6) have backgrounds in energy markets, behavioural economics, energy informatics and technology, and consumer research. We selected the researchers based on their strong involvement and experience in industry partnerships. We conducted all discussions between July and October 2024. To control for group biases and to allow participants to express their opinions as freely as possible, we avoided mixing different stakeholders and conducted the discussion formats exclusively per stakeholder group (Gawlik, 2018). The recorded expert discussions lasted on average 65 minutes in total. The transcripts for each discussion were on average 41 pages long.

3.2 Analysis

To analyze the transcribed discussions with regard to the outlined research motivation, we applied an inductive three-step coding process using Microsoft Excel (Saldaña, 2013) (see Figure 2).

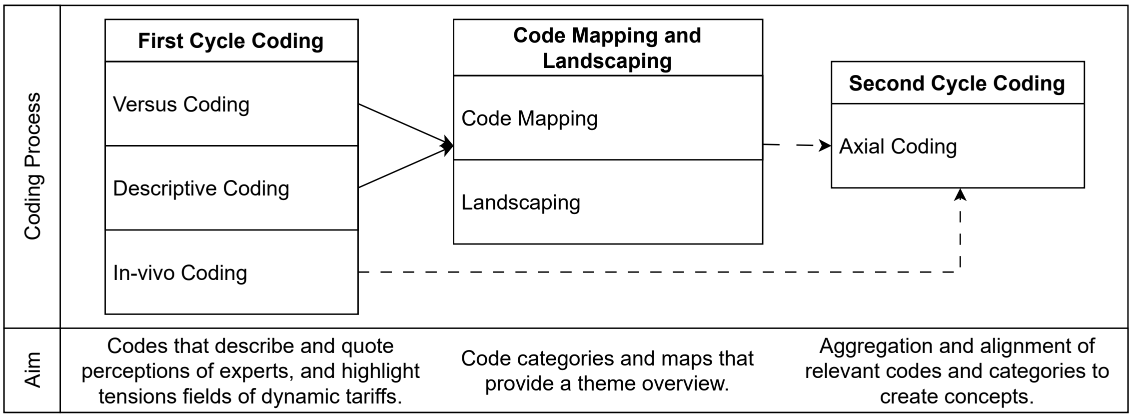

Figure 2. Three-Step Coding Process according to Saldaña (2013).

In the first step, descriptive, in-vivo, and versus codes were defined. By combining different coding types, we aimed for a holistic analysis approach that allows us to distill insights from various dimensions, ranging from aggregated subject areas to detailed descriptions and subjective perceptions. Thus, descriptive codes are identified to capture the essence of transcript segments by assigning topics that summarize the key themes of each part of the conversation. In-vivo codes are codes that use direct quotations from the discussants. This coding type is applied in this study to preserve the natural opinions and framing of terms. Versus codes capture contrasting viewpoints and terms that conflict with each other—meaning tension fields that shape the thematic understanding. We chose versus coding as the leading coding strategy for this study to identify inherent contradictions and competing dynamics imposed by dynamic tariffs on the STS (Saldaña, 2013). Two researchers participated in the first cycle of coding to reduce individual bias and strengthen the interpretation of the data. One researcher conducted the initial coding. Subsequently, a second researcher reviewed the codes, indicating agreement or disagreement with each code. Both researchers then discussed any discrepancies and worked collaboratively to reach a consensus.

The second step comprises a transition step toward the second cycle coding. It includes code mapping and landscaping – two methods to organize and overview the generated codes from the first coding cycle (Saldaña, 2013). This intermediary step serves as a second iteration to the initial first cycle coding, in which we mapped the generated versus codes into respective categories and the descriptive codes into sub-codes (code mapping). Sub-codes were identified as valuable enablers for further analysis as they allow us to decompose complex descriptive terms into their components. Then, we visualized these categories and sub-codes for an overview before advancing to the next coding phase (landscaping).

In the third step, axial coding was applied. For this paper, we used the generated categories from the second step to reorganize and group the versus, descriptive, and in-vivo codes accordingly. We applied a hierarchical perspective by assigning first descriptive codes to the versus code categories and then the corresponding in-vivo codes to the descriptive sub-codes. This approach helps to identify the imbalances within the STS by conceptualizing the insights from the discussions as part of a broader field of tension before highlighting details and specific sub-themes. Where applicable and helpful for analysis, additional descriptive code categories were created to summarize related terms with strong similarities.

4 Tensions fields

Based on the coding results, we identified three tension fields (RQ) (see Figure 3). The regulatory push towards DTs induces tensions between structures and people, people and tasks, and tasks and physical systems. The analysis indicates that the introduction of DTs is shaking up the financial and mental well-being of residential consumers and demands a re-evaluation of the traditional retailer business model. At the same time, information technologies can provide opportunities to address these tensions and rebalance the social and technical system. We present the tension fields following sub-sections.

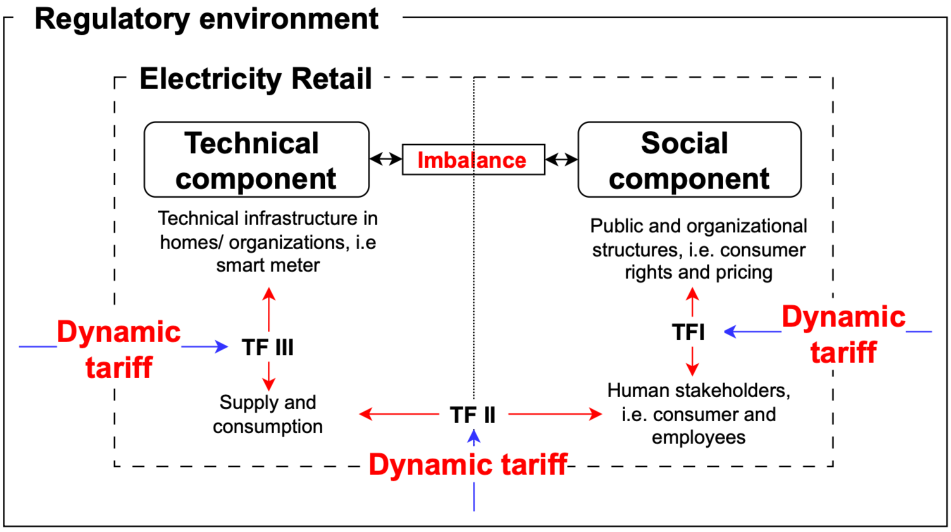

Figure 3. Tension fields (TF) in electricity retail.

4.1 Tension Field I: Structures vs. People

The first tension field concerns the misalignment between people and existing social structures due to the externally enforced introduction of DTs. Current regulatory, public, and organizational structures do not adequately support the new role that residential consumers need to play once DTs are in place. Initially, the regulatory and organizational structures, like pricing, customer support, and consumer policies, were designed for passive, predictable consumers. Yet, with the introduction of dynamic tariffs (DTs), the role of consumers within the STS is evolving, requiring them to become active participants in energy markets (Darby, 2020; Golmohamadi & Keypour, 2017). However, consumers often lack the resources or information to adapt to this fundamentally new role, placing excessive responsibility on them (Schlereth et al., 2018). Accordingly, "consumer protection and empowerment" emerged as the key concern in this tension field, with several underlying descriptive themes (see Table 1).

Tension field	Explanation according to STS	Key concern	Themes
Structures vs. People	Tensions that arise due to the introduction of dynamic electricity tariffs between current social structures within the system, e.g. organisational or policy structures, and people, e.g. consumers.	Consumer protection and empowerment	Consumer stress (T1.1)
			Information transparency (T1.2)
			Heterogeneous consumer types (T1.3)
			Cross-industry practices for product design and services (T1.4)

Table 1. Concern and Themes of Tension Field I.

Both practitioners and researchers underscore how regulatory changes have disrupted the traditional role and risk profile of residential consumers, often without adequate possibilities to adapt accordingly. As DTs require consumers to decide hourly, based on price signals whether to consume or not, its introduction increases consumer stress in *"(...) times of perpetual poly-crisis*" (BE1). One suggestion is that established system structures could shift to a consumer-centric design approach. Rather than of overregulating the market, preventive structures that prioritize consumer protection are needed (*"(...) try not to regulate but protect the consumer"* – BE2). Policy experts point to the economic motivation that DTs are optional tools to benefit from residential flexibility and not an obligation for households with limited flexibility potential – "*This is aimed at customers who (...) have flexibility*" (PE2).

All experts agree that dynamic tariffs are highly relevant for activating demand-side flexibility in adequate cases, even though adoption remains limited ("*Strong brick towards energy transition, but not widely adopted brick*" – BE2). However, the practitioners also emphasize the shared responsibility of businesses and policymakers to empower overburdened consumers with flexibility potential to successfully engage with DTs ("*(...) part of a wider explanatory campaign (...)*" – BE1 and "*Both sides are responsible in this sense.*" – PE2). This includes reducing the risks associated with DTs by empowering consumers through information transparency (*"It's important to bring in a certain degree of transparency and to give customers a certain amount of guidance."* - PE2). To maintain stability in the STS, this shared responsibility between business and politics requires structures that support consumers (Geels et al., 2018; Sovacool et al., 2020). Information transparency is seen as a main driver for consumer protection and enablement ("*(...) informing him and making sure he is aware*" – BE2).

However, the heterogeneity of electricity consumers makes it difficult to provide guidance and empowerment. Consumers can be distinguished based on their nationality, education, income, and further sociodemographic attributes that shape their acceptance of products like DTs (Parrish et al., 2020). Consumer heterogeneity was a recurring theme in discussions, shaping how energy retailers and policymakers approach the design of DTs and related services to ensure inclusion and fairness. As one expert noted, "*the ones who are more empowered are the ones who have the highest income*" (RE5). Therefore, supplementary measures such as price insurance and cost caps should be incorporated into the future design of DTs to address these challenges ("*And what I am wondering about is [] that I have not seen any tariff models that limit the risk*" - PE1).

Given this consumer variability, both practitioners and researchers assert that one-size-fits-all solutions are insufficient, and that DTs may not be equally beneficial for all consumers reflecting a tension between standardized structures and a diverse consumer base. One business expert noted, "*Is the dynamic tariff good for all customers? It is clearly a no*" (BE3). Experts emphasize that DTs are for now mostly of interest to early adopters, wealthy households, and technocrats but must develop into a product feasible for a mass market (*"(...) convince the mass of the consumers"* – BE1). From the STS perspective, this is a structural issue that inhibits the full adoption of DTs because it overlooks the diversity in the population and associated requirements that make DTs accessible and relevant for different types of consumers who may have flexibility potential.

In addition, energy retail experts draw a parallel to the developments of residential retail banking, emphasizing cross-industry learnings for consumer protection in unforeseen "*Black Swan Events*" (BE1). However, in contrast to banking products, electricity is a fundamental necessity, and consumers cannot opt-out whenever they want (RE1). From an STS viewpoint, this observation highlights the unique challenge between structures and people: electricity is essential for daily life, and its pricing structure affects fundamental human needs and flexible preferences, such as heating and cooling depending on comfort ideals ("*They are willing to pay, just not to have heat an hour*" – RE6 and "*(...) there are different preferences*" – PE1). This elevates the perceived risk profile far beyond that of financial products, making it imperative to provide additional support. Failing to do so could lead to system instability, as consumers are forced to manage high-risk decisions without adequate safety nets and insurance options. Ultimately, it affects the overall objective to provide secure and affordable electricity ("*Risky product for the customers*" – BE2). Tension field I suggests that limited promotion and adoption of dynamic tariffs (DTs) is linked to concerns over consumer protection and empowerment on both sides - retailers and households.

4.2 Tension Field II: People vs. Tasks

The second tension field addresses the imbalances in the relationship between people and the tasks they would need to perform within the STS when adopting DTs. As DTs require consumers to actively shift their electricity consumption based on price signals, previously passive consumers are now expected to take on a more dynamic role (Schlereth et al., 2018). Policy experts emphasize that understanding how individuals react to price incentives and process information is essential to anticipate how they will respond to the new demands. However, all experts believe that even when households receive relevant information, they may still struggle to translate it into actionable decisions as they face daily consumption challenges. From an STS perspective, this reflects a systemic imbalance in which people's capabilities and tasks are not synchronized. To address this complexity, all expert groups acknowledge the importance of home automation as a key enabler. We summarize in Table 2 the tension field.

Tension field	**Description**	**Key concern**	**Themes**
People vs. Tasks	Tensions that arise due to the introduction of dynamic electricity tariffs between the tasks/activities that need to be performed and people, e.g. consumers.	Home automation as key enabler	Complexity of tasks (T2.1)
			Information as precursor (T2.2)
			Trust and control (T2.3)
			Energy Literacy (T2.4)

Table 2. Concern and Themes of Tension Field II.

Business experts emphasize that just "*giving them* (consumers) *information alone does not solve the problem*" (BE1) and empowering consumers "*is not putting into action*" (BE1). While transparent information may help reduce misalignments between structures and consumers, they do not ensure that consumers will make economically favorable choices for themselves and the system. Discussants explain that previous scientific observations about correlations between information provision and behaviour are done by "*(...) looking at the consumers in the vacuum*" (BE 1) and, therefore, face limitations for real-world validity. Research experts partly agree and underscore the mental effort for households in real-life situations to change consumption routines such as making the laundry or cooking ("*That is something you cannot change*" – RE4). Even technology-affine individuals like electric vehicle (EV) users might experience such real-life limitations even though they are often classified as early adopters ("*Even with an electric vehicle, I am not sure whether I would think about it every day*" - PE2). Recognizing this challenge, "*(...) the real potential will only be realized when it works automatically*" (PE1). Expecting households to react to price signals manually might work at the beginning, "*but later these things get a bit boring as well*" (BE1), and households won't engage in the long term.

All expert groups concluded that home automation is the key component of enabling households in the long run. While "*information is a precursor to automation*" (BE1), home automation takes over the role of the "*glue that holds everything together*" (BE3), enabling households to play an active role while taking into account electricity supply dynamics. Although households still lack extensive home automation systems, research underscores the critical role of automation in advancing the energy transition, particularly by exploring the residential potential of smart home systems and Direct Load Control (DLC) (Stenner et al., 2017). However, business experts highlight an inherent barrier: automating a home and transferring control to applications managed by a business requires a significant leap of trust from households. Based on first-hand experiences and anecdotes from practitioners, such interventions in homes are taken seriously by individuals, as trust in energy retailers and non-human decision-makers is limited ("*But it requires a kind of trust in the system*"- BE3).

Missing consumer trust in dynamic tariffs and associated services can refer back to deficiencies in consumers' understanding of how to navigate DTs - known as energy literacy (Reis et al., 2021). This theme represents a critical tension between consumers and the tasks they are expected to perform. Researchers (RE1, RE6) highlight that many consumers lack adequate literacy, which weakens the overall resilience of the system. They emphasize that poorly informed consumers are less likely to engage with DTs and automated services and may even misuse them, resulting in inefficiencies (Reis et al., 2021). In a nutshell, Tension Field II attributes the low residential adoption of DTs to the increased complexity of daily tasks and the current lack of home automation systems to circumvent complexity.

4.3 Tension Field III: Tasks vs. Physical Systems

Tension Field III arises alongside Tension Field II and captures the gap between new task demands and existing physical systems in the European electricity retail system. Throughout the group discussions, experts repeatedly highlighted the need for home automation, but noted a significant lack of infrastructure – i.e., the necessary smart devices, and applications in homes. Therefore, in our coding process, we identified "technology adoption in households" as the key concern (see Table 3).

Tension field	**Description**	**Key concern**	**Themes**
Tasks vs. Physical Systems	Tensions that arise due to the introduction of dynamic electricity tariffs between the current technical infrastructure of the system and tasks that need to be performed in the system.	Technology adoption in households	Missing technical infrastructure and liquidity constraints (T3.1)
			Chicken-and-egg problem (T3.2)
			DTs as catalyst for innovation and technology adoption (T3.3)
			Business model change (T3.4)

Table 3. Concern and Themes of Tension Field III.

As part of the discussions about the importance of automation to meet new requirements, experts point to a lack and asymmetries of enabling technical infrastructure in households (“*Now it's getting more and more relevant on their agenda, but mostly on the agenda of customers who have this type of equipment already*” – BE3). While consumers with installed photo-voltaic appliances, EV charging stations, and batteries already hold an advantage to benefit from dynamic electricity pricing, many households lack such equipment. Such asymmetries in equipment ownership hold a challenge for the consumers and ultimately for the system, as the acquisition of appliances is determined through households’ monetary resources (“*But because you have liquidity constraints and uncertainty, all the kinds of things, some people will not be able to invest, even if it will make sense to do it*” – RE1). Liquidity constraints of households therefore limit significantly their freedom to purchase the necessary technical infrastructure and, ultimately, their ability to provide flexibility. All expert groups emphasize that the adoption of DTs goes together with the adoption of the necessary infrastructural components that enable households to participate in flexibility provision – dominantly in an automated manner. After critical reflection within the groups, the lack of relevant enabler technology and the policy-driven promotion of DTs symbolizes a form of a “chicken-and-egg-problem” that describes the current residential transition process (“*It's the chicken or the egg problem*” – BE2). This reflects the current dilemma: without the right infrastructure in place, households cannot fully benefit from automated flexibility provision in DT schemes. At the same time, there is little incentive to invest in additional smart devices and appliances without DTs and deployed automation software in place.

Retail experts emphasize this limitation, while policy experts highlight the role of dynamic tariffs (DTs) as a policy-driven catalyst. DTs not only drive further development and innovation in businesses to offer new and diverse products but also motivate households to consider and demand additional technical infrastructure to enable automation and fully benefit from DTs (“*[…][It] is a bit like setting the future rules early in the game, in order to set the right direction*” – PE1). Researchers agree with this perspective and ambiguously categorize DTs as the driver for tension and innovation (“*But the first thing is to have dynamic tariffs that manufacturers start to think about: OK, what should I invest or change in my equipment so the users would actually buy it?*” – RE3). Business experts conclude that the process of adoption of the necessary infrastructure is often the limiting factor in any form of transition process but positively mention that the residential adoption process of equipment has already started. Ultimately, from an STS perspective, physical systems are currently insufficiently prepared to accommodate the tasks of residential consumers when dealing with DTs. To address this technical issue and make DTs feasible for residential consumers, businesses must rethink their business models and make strategic investments in developing the required tools and infrastructure for their customers ("*It's an investment at the end of the day*" - BE1 and "*it doesn't just fall out of the sky and I have to develop tools, I have to develop interfaces, I have to deal with the end user. Call centers, etc.*" - PE1). The tension field requires suppliers to invest in and build the necessary structural (e.g., customer support and billing) and technical systems (e.g., IT infrastructure) to effectively synchronize consumers and DTs ("*The billing logic needs to be completely switched*" – BE3 and "*It's even pure IT infrastructure*" – BE1). Researchers argue similarly and stretch the importance of information as the precursor to the technical infrastructure. The availability of real-time consumption data, market data, and weather forecasts, influence the performance of systems that provide automated decision-making and energy optimizations ("*It is about information. This is what it's all about.*" – RE2). While DTs are "*one of those little things that suddenly spark a big change in the business model*" (RE2) and cause disruptions, policymakers, and researchers also mention new opportunities that arise in this tension field. New requirements for the technical infrastructure in households offer options to innovate the retailer's product portfolio and move from classical commodity retail to a portfolio with a diverse set of services and new profit opportunities ("*Almost all suppliers, include now modern technologies, and I think it will be the same with synchronic energy management systems for homes and automation*" – RE3).

In summary, Tension Field III highlights that the stability of the electricity retail system depends on the continued development of the technical infrastructure that supports home automation as a prerequisite for the long-term success of DTs. It also suggests that the limited promotion of DTs by energy retailers may stem from the substantial changes and investments required in their business models.

5 The role of IS in building resilience in the residential electricity retail system

The tension fields suggest that energy retail is insufficiently prepared to accommodate the changes that come with the introduction of DTs. This underscores the need for collaborative efforts among researchers, practitioners, and policymakers to explore and implement effective solutions for the resilience of the electricity retail system (RQ II). Advocating more than a decade ago for forming the energy informatics sub-discipline, Watson et al. (2010) described the transformative potential of information systems in addressing energy transition challenges. These systems present various opportunities, including informing consumers about their consumption, optimizing energy use to reduce peak costs, enabling automated or controlled energy conservation, and assisting suppliers and consumers in setting and achieving ambitious energy targets. While Watson et al. (2010) focus on the potential of energy informatics and present guiding but general research questions for the energy domain, our study explores the specific context of the resilience of electricity retail, which is put at risk through DTs.

All experts agree that information systems are not merely optional but are essential precursors for meeting emerging systemic needs to accommodate the introduction of DTs. Expert insights converge on the role of information systems as holistic, interconnected enablers of systemic resilience. Practitioners emphasize systems that connect homes, organizations, and markets, facilitating real-time data exchange and enabling automated or user-controlled activities tailored to individual preferences and systemic flexibility requirements. Adopting a sociotechnical perspective reveals that solutions should go beyond targeting isolated components of the system. Instead, they must account for the inherent interdependencies and dynamics of the electricity retail ecosystem highlighted in this paper. This means that solutions should consider the full range of tensions, connecting insights across domains, facilitating knowledge transfer, aligning conclusions, and evaluating outcomes through an STS lens. Further research is needed to navigate the ongoing digitalization of the demand and supply side, addressing social (i.e., consumer behaviour) and technical (i.e., use of AI for responsible consumption) components of the disrupted electricity retail system (Staudt et al., 2019; Schoormann et al., 2023). Recognizing the role of IS in addressing sociotechnical challenges and shocks (Boh et al., 2023), we used the identified themes to explore existing research and map actionable knowledge in Table 4. While not exhaustive, this list sets the stage for research through a holistic sociotechnical lens.

STS	Role of IS to build systemic resilience	Practical implications
Structures vs. People	Mitigating consumer stress (T1.1) and building resilience through consumer nudging and information strategies such as feedback, social comparison (Wendt et al., 2024), goal setting, and defaults (Loock et al., 2013).	Design of communication strategies that support and guide consumers in their decision-making, reducing mental effort and stress under DTs.
	Investigating and contributing to information transparency (T1.2) research to understand the effects of information provision on energy consumption decisions in household settings (Staudt & Werthschulte, 2024).	Build digital/physical tools that ensure transparent and accessible information for consumers with DTs to enable sustainable decisions.
	Consideration of heterogeneous consumer requirements (T1.3) through frameworks to choose consumer-tariff-fits (Behrens et al., 2018) and tailoring digital energy services to individual consumer contexts (Lumivalo et al., 2024).	Design and promote DT products that are adaptable to consumer needs (human stakeholders) and preferences, accommodating different contexts.
	Facilitating cross-industry learnings and product development (T1.4), i.e. by leveraging insights on support tools for daily decision-making in residential stock trading (AlSuwaidi & Mertzanis, 2024) or by considering risk decompositions in product design (Schilling et al., 2020).	Leverage best practices and learnings from other industries, i.e. draw from the design of digital products that are used in the banking industry to enable sustainable consumer decisions and risk reduction.
People vs. Tasks	Applying conclusions of exemplary research of IoT- and AI-based recommender systems to save energy and reduce carbon emissions (Himeur et al., 2021; Riabchuk et al., 2024) to residential task complexity under DTs (T2.1).	Consider AI-driven tools that mitigate the complexity of tasks by providing guidance or automate consumption based on individual needs.
	Supporting the design of information-enabled demand response products (T2.2) based on design components such as pricing, and enabler technology (Sangeeth et al., 2020).	Consider a set of products and services that work together with DTs - as a holistic solution.
	Leveraging technology acceptance research maturity (T2.3) within IS (Venkatesh et al., 2003) to push forward more research on automated service designs and user acceptance under DTs, i.e. with regard to DLC (Lackes et al., 2018).	Establish trust-building measures such as transparent risks/benefits promotion to encourage the adoption of home automation, i.e. load control.
	Supporting literacy (T2.4) by, i.e. evaluating digital interventions that help low-income households to adapt their behaviour financially advantageously (Bluhm et al., 2023).	Develop educational strategies to increase the literacy of vulnerable groups for new ways of consuming and managing electricity.
Tasks vs. Physical Systems	Building resilience through household adoption of smart appliances and digital services (T3.1) relies on understanding key psychological drivers: Wunderlich et al. (2019) and Sim et al. (2023) examine psychological antecedents and drivers of smart meter adoption, a pre-requisite for DT deployment.	Increasing acceptance of smart appliances like smart meters in homes by offering and promoting tools according to mental drivers, i.e. through collaborative campaigns of businesses and policymakers.
	Investigations on the dilemma between the diffusion of enabler technology and the adoption of DTs (T3.2) can be mirrored in similar studies, i.e. on EV adoption and charging infrastructure development (Brozynski & Leibowicz, 2022).	Stronger coordination and synchronization between DT roll-out and infrastructure development, i.e. through purpose-designed subsidies.
	Addressing uncertainties in the innovation process of IT-embedded products (T3.3) (Tarafdar & Tanriverdi, 2018) considering tariff-technology solutions and the role of IT-infrastructure in organizations and homes.	Foster innovation by expanding offerings to include diverse services and IT-enabled products, creating integrated solutions.
	Accommodating business model changes through IT-driven innovation and organizational transformation (T3.4) to meet sustainability goals and market requirements (Elliot, 2011).	Embrace and advance digital transformation of organizational structures and business models to ensure long-term business success.

Table 4. IS opportunities for enhancing resilience in the electricity retail system.

Table 4 illustrates the role of IS in building resilience based on the identified tension fields and how these can translate into practical implications. Each identified role of IS is supported by relevant research examples, highlighting how theoretical insights from various contexts can inform actionable steps across domains if the identified challenges are similar. By leveraging this overview, IS researchers can identify gaps in current DT-related knowledge and explore complementary avenues for investigation, and practitioners can implement and test existing recommendations to enhance system resilience in the field, improve decision-making processes, and foster sustainable consumer behaviour.

6 Conclusion and Outlook

In this paper, we explore the emerging tension fields and misalignment between system components in the sociotechnical electricity retail system due to the regulatory-enforced introduction of dynamic electricity tariffs (DTs). We also examine the role of IS in realigning system components to foster resilience against these tension fields. To identify the tensions, we conducted three semi-structured group discussions with experts from the energy research community, policymaking, and energy retail. We followed a three-step qualitative coding procedure to analyze the transcripts. We point to three tension fields according to the sociotechnical system (STS) framework. The tension fields (TF) describe misalignments between systemic structures and people (TF I), people and their new tasks (TF II), and new tasks and physical systems (TF III). Key concerns that shape the understanding of the tension fields are consumer protection and enablement (TF I), home automation as a key enabler (TF II), and technology adoption in homes (TF III). For each concept, we identified a set of descriptive themes that guide the exploration of IS opportunities to address and mitigate the challenges within the tension fields. While this paper contributes to a better understanding of why DTs face resistance from market participants and how IS can further contribute to the resilience of the electricity retail system, some limitations need to be considered. First and foremost, this study represents an initial qualitative exploration of a complex, multifaceted issue that is difficult to quantify. Second, the number of group discussions and participants was limited. Although we observed saturation effects in the evolving topics within the different expert discussions, further discussions with more stakeholders from different European countries should be conducted to deepen the analysis and build a pan-European understanding. Third, while this paper offers a first overview from a multi-stakeholder perspective on the implications of DTs for electricity retail, the identified tension fields and IS opportunities can benefit from refinement and further in-depth research.

By framing the electricity retail system as a sociotechnical system, this paper contributes to the growing body of energy-related IS research and strengthens the sociotechnical paradigm as a perspective for analysing and designing the smart energy system of the future. Our findings advance the understanding of dynamic tariffs from an interdisciplinary perspective, highlighting the unique sociotechnical challenges in achieving residential flexibility objectives through time-variant pricing schemes.

This paper highlights the essential role of information systems in advancing key success factors of the residential energy transition, emphasizing their function as holistic solutions for sustainable consumer choices and enablers of IT-driven innovation.

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