UHASSELT

KNOWLEDGE IN ACTION

Faculty of Business Economics

Master of Management

Master's thesis

Risk preferences in the Adoption of Smart Energy System

Hasnae Laanaya

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Strategy and Innovation Management

SUPERVISOR :

Prof. dr. Stephan BRUNS

MENTOR :

De heer Brian FOWLER

2024
2025

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Preface

This thesis is the result of my graduation research and is the final part of my Master of Management specializing in Strategic and Innovation Management at Hasselt University. This thesis focuses on consumer risk perception in the adoption of smart energy systems, with a particular look to smart meters in Europe.

This work started as a program requirement, however it turned into a captivating topic. The question of "why" consumers are still hesitant about smart meter adoption piqued my interest. It shifted this research from surface level to a much deeper and more complex level that uncovered social and behavioral factors that significantly influence smart meter adoption.

Throughout the journey of writing this thesis, I have faced many challenges however I was able to not only learn about the topic itself but also how to navigate such complex research with reflection and perseverance.

I would like to thank my supervisor Prof. Dr. Stephan BRUNS and my Mentor Mr. Brian FOWLER for their support, encouragement and thoughtful feedback throughout this process. Their guidance was of immense help to complete this work.

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Abstract

This study investigates the relationship between consumer risk perception and smart energy systems adoption, more precisely, smart meter adoption in the European context. The purpose of this study is to understand and delve into the behavioral and social aspects of this relationship. A systematic literature review was conducted, combining peer-reviewed articles covering the different aspects of smart meter adoption and grey literature retrieved from official institutions to reinforce the conclusions. This review revealed that consumer risk perception is a complex construct that is formed by trust, culture, history and social norms and influences consumer's decision to either accept or reject smart meters. The conclusions are in line with the literature reviewed and underline the need for further research that focuses on consumers' perspectives.

Keywords: Smart meter, Risk perception, Consumer acceptance, Europe

Executive Summary

This paper focuses on the influence of consumers' risk perceptions on the adoption of smart energy systems, with a closer look at smart meters in the European context. Smart meters are units that record the energy consumption, track performance, and send back the data recorded to the central server meaning to the energy providers through communication networks. These devices also allow users to reduce their energy use by using the multiple services that come with it. Smart meters are an important part of smart grids as they add new features to the power grids, which in turn improve the whole energy system. Smart meters are becoming the next generation technology that will advance Europe to reach its sustainable goals.

Research around smart energy systems has attracted a lot of attention in recent years, especially that in many countries these technologies are becoming part of every household and are yet to expand. However, the human side of this expansion is usually dismissed or neglected leaving gaps that should yet be explored. Smart meters, more precisely, have faced challenges of low adoption rates and in some cases, complete rejection from the public despite the fact that they are always promoted for their benefits for users. Consumers' rejection is not always directed to the technology, the reason behind this rejection is much more complex and they combine many factors that are social, behavioral in addition to concerns, like privacy, financial risks, health effects and trust, that many people express. These factors are not just present in the public's mind, but they translate into actions that affect their decision-making therefore affecting adopting or rejecting smart meters.

The literature conducted about smart meters and consumers' risk perceptions is relatively limited. Most studies focus on the functional and technical side of smart meters and give little attention to the consumers' perspectives, even less to the factors that shape these perspectives. Improving and researching the technical side of smart meters alone, will not solve adoption challenges. The behavioral and social dimensions must be investigated and understood to reduce those perceived risks. To understand these dimensions further, this paper adopts a systematic literature review combining multiple fields, energy, behavioral economics, psychology and data analysis to give conclusions that are based on evidence.

The public has expressed multiple concerns that are related to smart meters, these concerns are about data privacy, financial implications and health risks. One of the main conclusions of this review is that these concerns seem to come from the same sources. Trust in the institutions behind smart meters is the first reason. Trust plays a significant role in consumers' assessment of risk. When the public questions the credibility and reliability of the official institutions, rejection seems to be higher. Another reason is consumer involvement. When the public feels excluded from the process and is only at the receiving end, without their input being considered, the public tends to reject the adoption. The third reason is the way the institutions communicate and deliver messages to the public. Most of the communication is not clear, does not answer the public's questions and comes in general statements. This type of messaging causes confusion and exclusion which in turn causes resistance.

This paper also addresses the need to include consumers' viewpoints and perspectives when designing the technologies, the policies and the strategies that would help in encouraging adoption. Seeing how smart meters' role in smart energy systems is significant, it is critical to consider the civil liberties and moral issues before implementing them. This paper emphasizes that smart meters should be ethically and socially responsible while also being effective and functional.

The overall conclusion of this paper states that the technology alone is not enough to integrate smart meters effectively into smart energy systems. There are two aspects of this adoption and one seems to get less attention. Understanding the reasons and motivations behind consumers' decision-making is the first step for a successful integration. The conclusions of this review provide a solid foundation for policymakers and smart meters designers to work towards solutions that include all stakeholders

1 Introduction

1.1 Background and context

1.1.1 Smart energy systems and smart meters

Smart energy systems (SEM) are infrastructures that can combine all the actions of the sources connected to them like electricity, gas and thermal grids, to upgrade the efficiency of the whole system. This is what is called "sector coupling", an approach that links smart energy systems together in order to achieve stronger support (Ilo et al., 2021). For example, households with surplus in energy can keep that excess energy by storing it and later using it to generate gas or heat. Smart energy systems can stabilize the supply and demand by using communication networks and smart controls making renewable energy affordable and easier to use (REN21, 2024). Smart energy systems connect multiple technologies together, however at the core of smart energy systems are smart grids, which are power grids that have integrated new smart features (European Commission, 2019).

A smart grid is an updated electricity distribution network that allows the consumers to manage and track their energy in real time, using sensors, automation and digital technology to send that information to the energy providers (Ohanu et al., 2024). The European Commission describes smart grids as systems that "enable consumers to control and manage their own energy use and therefore contribute towards establishing a power system that generates less carbon." (European Commission, 2011). CEN-CENELEC also adds that "A smart grid is an electricity network that can integrate in a cost-efficient manner the behavior and actions of all users connected to it (generators and/or consumers) in order to ensure economically efficient, sustainable power system with high levels of quality and security of supply and safety." (CEN-CENELEC, n.d.). Smart grids are equipped by what is known as smart meters which allow real time management of energy consumption. Smart meters are considered to be a critical step towards the next generation systems and an important part of power grids that already exist (European Commission, 2019).

A smart meter is a metering device that measures digitally the energy usage of households or buildings and communicates that data back to the energy provider (Chen et al., 2023). What differentiate traditional meters and smart meters is that smart meters allow energy providers to have access to real time information which helps them understand consumption patterns which is important to detect any problems that might occur or plan for future demand (Bimenyimana & Asemota, 2018). Smart meters give households the possibility to use the infrastructure designed by their energy providers to track their energy data which helps in their decision-making and lower both their energy consumption and their bills (Rausser et al., 2017). Thus, smart meters are considered important components of smart energy systems, as they provide a two-way communication and connect both sides (Shuhaiber, 2020).

1.1.2 Energy transition in Europe

Governments all around the world are under immense pressure to lower their carbon footprint and attain sustainability objectives as nations are facing increasing environmental issues such as climate change, rising greenhouse gas emissions and resource depletion (Hoppe et al., 2023). In response, the global energy sector is facing new challenges that require major changes and Europe is no

exception. As these environmental concerns grow for Europe, the European Union has declared that it is committed to leading this global energy transformation (Hafner & Raimondi, 2020). This is where the shift towards smart energy systems emerged combining Information and Communication Technologies (ICT), communication networks and automation that will help improve energy efficiency, allow real time management all while supporting renewable energy within existing power grids (Ohanu et al., 2024).

1.2 Motivation

Smart meters are not only devices that will improve the power grids, but they are also part of the EU's plan to transition to smarter and effective energy systems (Kádár & Varga, 2012). Countries all over the continent are pushing to meet their energy and climate goals, many derived from the European Green Deal (EGD) and the "Fit for 55" package (FF55 Package) (Oberthür & Kulovesi, 2025). Smart meters are now using many integral aspects of the energy system infrastructure and are becoming an important role in this transition. These units are not only a digital update replacing the old meters, but they are also making the transformation of the energy system be consumer centric (Harris & Walker, 2024). Smart meters give both the user and the energy providers the possibility to track and manage energy consumption by having access to information, data, and energy use in real-time (Chen et al., 2023). This access and control allow for more metrics to be accounted for in terms of how the energy is produced, its delivery and its use (Chen et al., 2023).

Smart meters support and provide dynamic pricing and it is considered to be one of the most notable contributions. These models give users the option to pay for the energy fluctuations based on the time of day or level of demand. Thus, this model pushes users to shift their activities that use a lot of energy and avoid high-demand hours, this means a balanced supply and demand which reduces the pressure on the grid (Koukouvinos et al., 2025). In addition, this setting can maximize renewable energy efforts, like for wind and solar energies (Ma et al., 2017). Europe's goal of decarbonization requires matching energy use and renewable availability (Hafner & Raimondi, 2020) and smart meters create this possibility by helping users understand and respond to those fluctuations.

From a policy standpoint, smarts meters are not devices that only improve efficiency. They are part of more complex and interconnected goals that are set to reduce greenhouse gas emissions, increase the role of renewable energy in the energy system, enhance energy security and encourage users by offering them more control on how and when they use energy (Koukouvinos et al., 2025). Countries such as Sweden, Italy and the Netherlands, that had a fast deployment of smart meters, are already witnessing great progress and are benefiting from these advantages. For example, in Sweden smart meters offered users the ability to manage their energy consumption more efficiently which helped in significantly reducing peak demand (Huang et al., 2018). In Italy, outrages and theft issues are quickly identified, and the clear and direct billing system was much more improved after successful deployment of smart meters which resulted in higher public trust in the system (Pitì et al., 2017).

These examples show that smart meters have a lot of potential. The pricing models used by these devices have shown that consumer behavior does change when the right tools are present, and information is accessible and easy to understand (European Commission, 2012). The European Commission estimated in a study done in 2019 that smart meters can save an average of 2% to 10% of energy. These percentages might seem small in numbers however when they translate to national or continental levels, the emission reduction is substantial.

Even though smart meters are promoted for their great potential, they are not just devices to be plugged and used. Installing them is not the only step for them to be effective, it is actually the users' participation and engagement with the device that let it reach its full capabilities (Schweiger et al., 2020). For smart meters to reach their full potential, users must engage and interact with them (Schweiger et al., 2020). This includes that users understand how smart meters work, use the features and services they offer to make better decisions about energy use and most importantly be able to trust the institutions that are deploying them (Gangale et al., 2013). This engagement helps users actually benefit from smart meters, by reducing their energy bills and having adaptable and flexible demand (Rajaguru et al., 2023). On the other hand, when there is a lack of engagement, of understanding or distrust, users cannot fully benefit from the device and therefore the technology will not reach its potential (Rajaguru et al., 2024).

This only shows that the most underestimated and overlooked part is the most important in energy transition and that technical or regulatory challenges are not the only aspect of this transition but are present alongside social and behavioral ones (Sareen, 2020; Rajaguru et al., 2023). The concerns that the public expresses about smart meters are not because of lack of information or that they are ungrounded and irrational. Rather, they represent a more complex construct that is formed by emotions, reason and context (Sun et al., 2023). The public is not responding to the technology itself, but to what it means. Users feel that smart meters take control from them, force them to change their routines and also could potentially leak their sensitive information and data to unwanted external parties (Asghar et al., 2017).

The public expressed multiple concerns related to smart meters, however, in the public eye, some concerns were more urgent than others, this includes data privacy and cybersecurity, financial impacts and potential health risks (Hafner & Raimondi, 2020; Gerpott & Paukert, 2013; Draetta, 2018). On one hand, some users are afraid of external parties having access to the detailed records of their electricity usage without their permission and use it for surveillance or sell it to third parties (Rajaguru et al., 2023) even with strict data protection laws in place like the General Data Protection Regulation (GDPR) and technical protection like encryption and anonymization (European Union, n.d). On the other hand, other users are afraid of the financial burdens that might come with the installation of the devices (Gerpott & Paukert, 2013).

Public concerns are also heightened by misinformation on social media, dramatic headlines or personal stories that gain media attention (Hmielowski et al., 2020). The public is even more doubtful and resistant when the official communications delivered to them feel vague or disconnected from their actual experiences, which makes these fears more challenging to address. The public does not

always react to the technical data the way policymakers intend, they respond to stories, feelings and personal connections.

Understanding risk perception is the first step to explaining consumer behavior. Recognizing that these risks exist is not sufficient, it is understanding how people feel and react to them and how much they trust the institutions providing them with the information that is critical to addressing these risks. The literature has shown that even when the technology itself is effective and safe, when the public feels their concerns dismissed, excluded from the process, receives confusing communication, and has low trust in their institutions, the rejection rates grow. Policymakers should consider these emotional sides to reduce public resistance.

Smart meters should be approached as devices that build connections and relationships with the public and not just a technology that will advance and improve the energy systems. For smart meter deployment to succeed, policymakers should address the public concerns and communicate with them using direct and inclusive messaging and develop systems and strategies with people in mind. As Europe is advancing to reach its energy and climate goals, the human aspect of this adoption must also be part of the plan and should be treated with the same level of importance as the functional side. Only at that time could smart meters achieve their full potential.

1.3 Research question and objective

1.3.1 Research question

This paper investigates the various behavioral and psychological challenges facing the adoption of smart meters in Europe and more particularly how consumers' risk perceptions affect their decision-making regarding smart meters and how these risks can be addressed.

The main research question guiding this paper is:

How is the adoption of smart meters in Europe influenced by consumer risk perceptions and what strategies must be implemented to reduce perceived risk and spread acceptance?

To answer this question, four sub-questions are posed:

1. What are the main concerns related to risks frequently raised by the public regarding smart meters in Europe?
2. What role do social, cultural and personal factors play in forming these concerns?
3. How do these risk perceptions affect consumer's decision-making?
4. What strategies are in place to address these concerns and minimize adoption rejection?

1.3.2 Research objective

The main objective of this paper is to uncover how consumers' perceived risk influences the adoption of smart meters in Europe. In a more focused scope, it will identify the main and most common concerns among the public and how these concerns shape the image of smart meters and affect their acceptance or rejection. By understanding how external influences such as social and behavioral

factors can affect perceived risk, this paper aims to go beyond the surface and explore the deeper motivations behind public resistance.

The goal of this paper is to suggest recommendations for policymakers, regulators and institutions to implement in order to encourage smart meter acceptance and adoption as well as push the public to engage with the technology. Unlike other studies, this paper's objective is to suggest improved strategies that consider differences in cultures, regions and individuals and not just a standardized solution. At the end of this paper, the goal is to build on evidence and present a thorough understanding of the reasons affecting the acceptance of smart meters in Europe and what can be done to address these challenges in ways that are effective and publicly accepted.

This paper will first explain the selection strategy for the literature review in the Methodology section, followed by visual presentation of the data from the literature review in the Results section, the results will be then analyzed in the Discussion section, the Recommendations section will then cover strategies addressed to both policymakers and future researchers and lastly, the main conclusions from this review will be then presented in the Conclusion.

2 Methodology

This section details the methodological approach used to conduct this paper. It first explains the rationale for choosing a systematic literature review method, then goes in detail defining the research scope specifying the thematic focus and geographical limits, then the research strategy including databases, keywords used and inclusion criteria followed by a visual presentation of the screening and assessing phase of the literature in the selection method. And lastly, it will explain the data classification and thematic coding used to identify the main themes related to the paper’s research question.

2.1 Methodological approach

This paper used a systematic literature review as the method for this study on consumers’ risk perceptions related to smart meters in Europe because it allows to combine multiple fields that are different in focus but related to this review’s main research question. These fields include engineering, behavioral science and policy and will be used as a foundation to base the final conclusions. Rather than repeating what is already present and examined in previous studies, this review will collect and evaluate existing literature and present conclusions that are built on a comprehensive understanding of what is already known and proved. This method will be able to identify the most expressed concerns among the public as well as show how these concerns might appear differently from one European country to the other. A systematic literature review also reduces any bias as it is a structured and detailed process. The search strategy and inclusion criteria assure that the literature chosen will provide consistency and reliability of the review’s conclusions.

Using a different method for this review or doing new research in different countries across the continent will take a lot of time, resources, and coordination, which might hinder the results of the review and might not provide conclusions in line with policy deadlines especially related to the European Green Deal and the FF55 package.

One of the primary contributions of a literature review is that it shows which parts of the studies lack more research. By identifying the parts that get the most attention, the literature review maps the next steps towards collecting new data that focuses on the most significant and unresolved questions.

2.2 Research scope

The main objective of this systematic literature review is to answer the research question:

How is the adoption of smart meters in Europe influenced by consumer risk perceptions and what strategies must be implemented to reduce perceived risk and spread acceptance?

This paper will focus mainly on the following areas:

Consumer risk perceptions related to data privacy & cybersecurity, financial and cost risks and health risks.

How risk perception affects and influences customer decision-making related to smart meter adoption.

The strategies that are put in place, such as policies and regulations, to address consumers' concerns.

2.3 Search strategy

2.3.1 Search limits

To assure the relevance of the sources used in this paper, the following search limits were applied:

Only peer-reviewed articles and grey literature published in English or French are included. Peer-reviewed articles were prioritized as they contain detailed and validated information and address topics that have gained most attention. The sources included are either in English or French, as it is assumed that the research about smart energy systems has either been translated or published in either or the languages. For the grey literature, only publications and documents issued by official institutions were included as their content is impactful and contain actual data and statistics from authoritative sources.

This paper will only review publications from 2010 onward. This time frame was chosen because in 2010, the smart meters deployment started after the launch of the 2009 EU Electricity Directive and the formation of the EU Smart Grids Task Force. These two initiatives moved the theoretical implementation to be applied in the real world. Therefore, including publications from 2010 will base this review's conclusions on current policies and actual statistics instead of reviewing research that focuses on theory and pilot implementation that might not be relevant in the current context.

2.3.2 Data Selection

The search strategy will have two steps:

All peer-reviewed publications related to this paper's topic will be retrieved from the following academic databases: IEEE Xplore, Google Scholar, ScienceDirect, MDPI, ResearchGate, Russian Journal of Economics, Taylor & Francis and Springer Link.

The grey literature will be retrieved from online repositories known to publish official documents and reports of official institutions. These repositories were systematically reviewed and the following sources were chosen for the retrieval: The European Union, the European Commission, the International Energy Agency (IEA), European Committee for Standardization (CEN), European Committee for Electrotechnical Standardization (CENELEC), Agency for the Cooperation of Energy Regulators (ACER), Environmental Health Trust (EHT) , International Agency for Research on Cancer (IARC), Federal Ministry for Economic Affairs and Energy of Germany (BMWK), Research Institute for Energy (FfF), Centre on Regulation in Europe (CEER) and national energy regulators. To efficiently find relevant documentation, specific searches were done within each website, for example "DPIA smart grids site:ec.europa.eu" or "smart meter deployment report site:ffe.de".

2.3.3 Keywords

Specific keywords were carefully chosen after the assessment of the literature review and the following combination of keywords were used without the quotation marks:

"Smart meter adoption in Europe", "smart meter rejection in Europe", "customer risk perception", "data privacy concerns", "cybersecurity concerns", "financial risk", "health concerns", "smart meter radiation", "Europe energy transition", "smart energy systems", "electromagnetic hypersensitivity", "smart grid", "smart meters", "smart meter deployment", "consumer behavior", "energy policy", "GDPR", "radiation", "smart energy systems", "institution trust", "financial incentives", " customer engagement", "energy regulations".

2.3.4 Inclusion/Exclusion Criteria

In order to select relevant literature, inclusion and exclusion criteria were set. Both peer-reviewed articles and the grey literature included must address smart energy systems, and in particular, smart meters in the European context. Each study must cover one or more of the following topics: data privacy, cybersecurity, financial and cost concerns, health risks, smart energy systems policies and regulations, smart meters deployment or consumer behavior. Furthermore, each study has to provide actual examples and initiatives and present conclusions that are based on evidence. Studies that did not focus on at least one of the specified topics or were not relevant to the European context are excluded. In addition, to make this review more accurate and to avoid confusion, this review will only include studies either published or translated to English or French to avoid any misinterpretations and translation mistakes. Using publications in other languages risks misunderstanding the information. The following table presents the inclusion and exclusion criteria that were set to filter the sources.

Table 1: Inclusion/Exclusion criteria for peer-reviewed publications

Criteria	Inclusion	Exclusion
Geographic scope	European countries, cross border studies in Europe or comparative global research that include Europe	Research done in a non-European context or does not focus on European states
Thematic focus	Consumer risk perceptions, consumer behavior, energy policy/regulation, technical smart meters integration, adoption challenges/barriers	Studies with no relevance to smart energy systems or smart meters or extensive focus on marketing strategies and unrelated technologies
Publication type	Peer-reviewed articles	Non-peer-reviewed articles, news articles or conference summaries
Language	English or French	Any other language not officially translated
Time frame	2010 – present	Pre 2010 studies

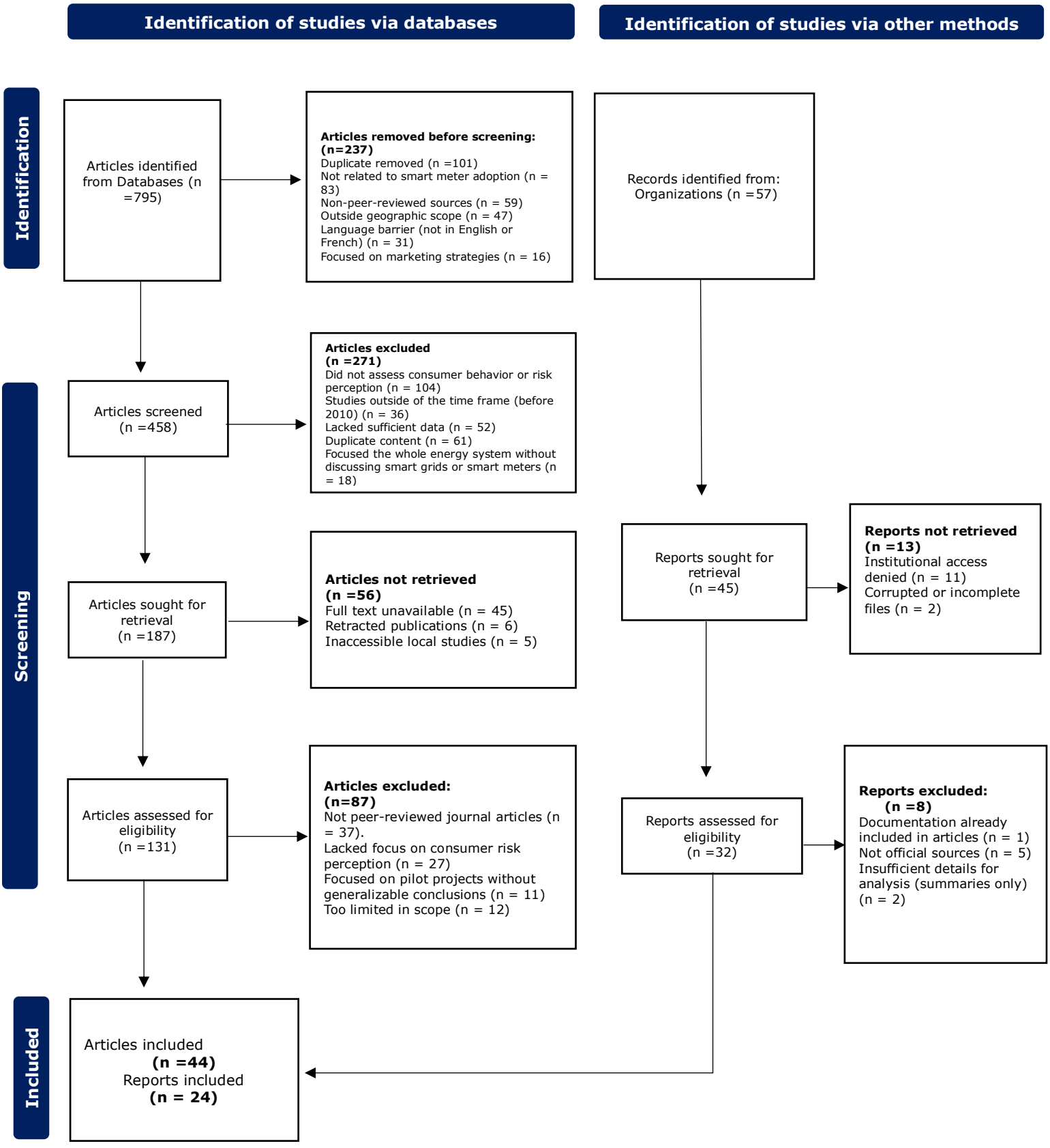
Table 2: Inclusion/Exclusion criteria for grey literature

Criteria	Inclusion	Exclusion
Category	Official regulation reports, policy documents, white papers, technical guidelines, deployment monitoring reports	Advertising materials, press releases, event summaries or newsletters
Thematic focus	Documents addressing engagement strategies, regulatory frameworks, deployment progress, governance	Documents discussing mainly technical specifications without any relevance to policy, behavior or adoption
Authority	Publications by European institutions, national energy regulators, international organizations	Publications or document from non-institutional sources such as personal blogs or editorial comments

2.3.5 Selection method

Figure 1 shows the selection method used in this review, following PRISMA flowchart guidelines. All initial studies were first screened based on their title and then were chosen based on their relevance to smart meter adoption in Europe. The abstracts were then screened in the second step of the process by checking if they cover the topic related to this review. Each source's full text was then checked to verify that the inclusion criteria are met. In addition, manual searches were done to select the main websites and links publishing official documents, this allowed to identify grey literature that might not be present in other databases. The relevant peer-reviewed articles and grey literature were grouped in the final step of this process to proceed with the review. This group of studies form the basis of the thematic analysis in the results section of this paper.

Figure 1: PRISMA flowchart detailing the Selection Process



2.4 Data Classification

2.4.1 Thematic Coding

In order to analyze and evaluate the included studies, this review used an inductive thematic coding, meaning that themes will arise automatically from the content of each study. The first step of the process was to read all the peer-reviewed articles and grey literature included in this review, identifying patterns related to consumers risk perception regarding smart meter adoption. In a spreadsheet, each source was manually coded indicating geographic context, research method, focus theme and final conclusions or recommendations suggested in the source. This process was especially helpful because it showed the issues expressed in the literature related to consumer risk perception, any behavioral and social studies, trust in institutions and how the public reacts to risks.

Themes were then separated and grouped into categories based on their similarities, this process resulted in identifying six main thematic concepts: adoption & engagement, data privacy & cybersecurity, policy & regulation, technology & grid integration, health concerns and lastly financial and cost concerns. This categorization was the foundation to combine conclusions from both peer-reviewed articles and data from grey literature.

The second part of the thematic coding is the analysis of the data and the existing research on smart meter adoption. This review combined two theoretical frameworks: Risk Perception Theory and Institutional Trust Theory. These two frameworks were chosen because they have direct relevance to the research question: how do consumer concerns and trust in institutions influence their risk perceptions, affecting the adoption of smart meters?

Risk Perception Theory is directly connected to this paper's topic as it explains how individuals psychologically evaluate the potential risks related to new technologies. Smart meters are no exception and the public seems to have many concerns and possible risks linked to them. This theory focuses on explaining the difference between the actual level of risk and how individuals see those risks. It also explains the importance of beliefs and feelings in forming that behavior. From a psychological viewpoint, this theory will add to the review a new perspective to understand how individual's view risk and how these risks increase or decrease depending on their context and conditions, which will help in understanding why consumers either accept or reject a technology that is supported by strong regulations and has demonstrated great benefits.

On the other hand, Institutional Trust Theory covers a different yet complementary aspect which is the social and institutional setting that also influences how people react to technologies, including smart meters. It is critical to trust the institutions behind the technology to accept it. In the case of smart meters, since they collect and record data, trusting the energy companies and regulators is one of the main determinants to accept adoption because consumers consider the institutions' competence and capability before accepting or rejecting smart meters.

The literature shows that adoption rates are different from one European nation to the other and that is mainly due to the different levels of institutional trust. Institutional Trust Theory will allow to view

smart meter acceptance from a political and institutional context, it will also show how culture, political experiences and history affects trust which in return affects consumers' decision-making.

Combined, these two theories will provide a strong foundation to uncover the relation between individuals' risk perceptions and social and behavioral aspects and their influence on smart meters adoption across the continent.

2.4.1.1 Peer-reviewed journal articles

In order to have a detailed understanding of the distribution and scope of the literature regarding smart meter adoption, the 44 peer-reviewed articles included in this review were thematically categorized based on their research focus. This classification resulted in six main themes: adoption & engagement, data privacy & cybersecurity, policy & regulation, technology & grid integration, health concerns and lastly financial and cost concerns. This classification by research focus is an important step and helps organize the literature studies that cover different scopes and themes in addition to supporting comparisons between different studies. It also allows to identify gaps and oversights in the literature and see which areas are receiving less attention. Grouping the literature by themes keeps the analysis and interpretation focused on this review's topic and research question, especially that smart meter adoption combines various areas such as technical, regulatory, behavioral and ethical fields. Additionally, including a thematic classification in a systematic literature review reinforces its conclusions.

2.4.1.2 Grey Literature

An additional 24 documents of grey literature were included in this review to create a foundation for more relevant conclusions. These documents include reports, regulation briefs and guidance models published by official institutions. The institutions have full access to data and regulations that are relevant to smart meters deployment that might be too recent to be present in studies and research or are not available to researchers. Including these grey literatures also means access to deployment statistics, laws, policy requirements and technical details to reinforce the analysis of the literature. Furthermore, after every new development, these documents are updated, therefore giving faster access to any policy changes to reflect accurate status of smart meter deployment in Europe as of 2025. By including grey literature, this review can check the results from the studies against real world data from the reports. And lastly, since the grey literature is published by official institutions, they add credibility to this review's conclusions and recommendations. Supporting the academic research with actual data from the grey literature will help close the gap between expectation and reality.

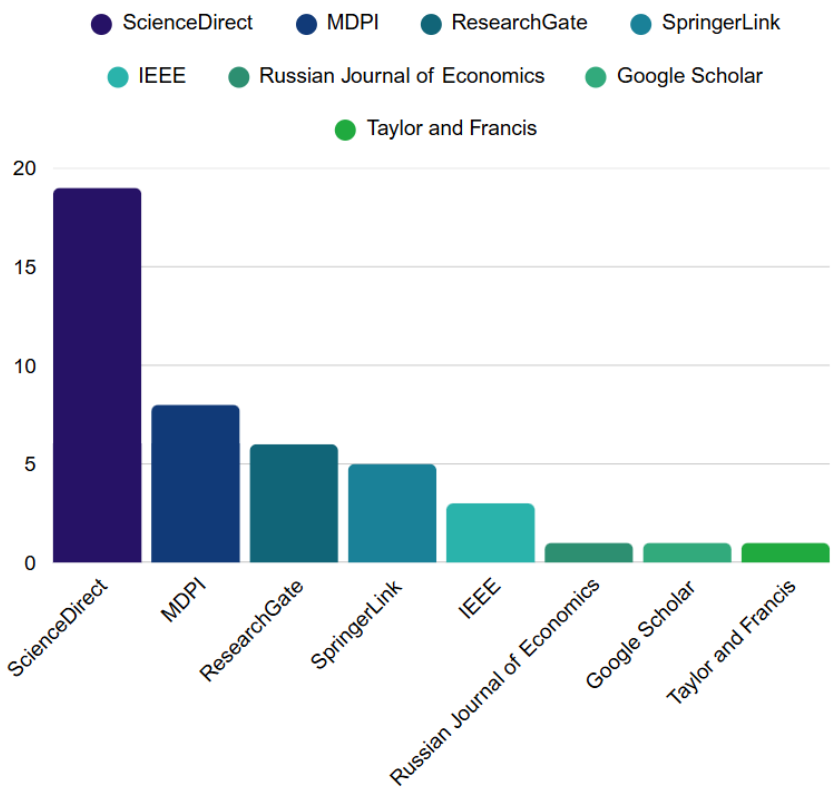
3 Results

This section presents conclusions from the systematic literature review. It first summarizes the database distribution of sources, the main research method used and the geographic distribution of the literature. It also identifies the areas that are constantly addressed in the sources in addition to identifying gaps noticed in the literature, the distribution and the thematic coverage.

3.1 Database Distribution

This review implemented a systematic search across multiple academic databases and repositories to collect the existing literature on consumer risk perceptions related to smart meter adoption in Europe, focusing only on retrieving literature from peer-reviewed sources. The graph below shows the distribution of the sources with ScienceDirect (19 publications) having the most relevant papers, followed by MDPI (8), ResearchGate (6), SpringerLink (5) and IEEE Xplore (3). In addition, one paper each was retrieved from the Russian Journal of Economics, Google Scholar and Taylor & Francis. This distribution shows the main academic platforms that publishes publications from the fields of energy and smart technology, in addition to the diversity of the existing literature.

Figure 2: Distribution of Databases



3.2 Literature overview

3.2.1 Methodological characteristics

The 68 sources included in this review used different methodologies for their research. This shows that research surrounding smart energy systems, including smart meters, combines different input from various fields such as, energy, law, behavioral economics, sociology, data analysis and public policy. The literature was categorized into 4 main research methods: empirical (both quantitative and qualitative), theoretical, technical, legal or regulatory analysis and literature reviews.

3.2.1.1 Peer-reviewed articles

Most of the peer-reviewed articles use empirical methods. Out of the 44 sources, 21 papers used quantitative methods such as consumer surveys and behavioral experiments. These sources focused mainly on understanding how much the people are willing to adopt smart meters, their level of trust towards the institutions behind them and their concerns related to smart meters. To investigate risk perception, most studies used surveys to examine the different countries and age groups, others used experiments that tested how effective feedback tools and nudges are. In addition to the quantitative studies, 13 papers used qualitative methods and used interviews, policy case studies or discourse analysis to investigate how differently each consumer interacts and how institutions work. Some studies look at the legal aspect of the energy sector like privacy laws, other studies examine the sociological side and look at the influence of society in shaping concerns such as data privacy and health risks. Five papers use theoretical or conceptual frameworks. These papers build on existing empirical research and question or challenge ideas that predict consumers' behavior and also suggest where the theory can improve and propose new strategies to build trust in institutions and encourage engagement. In addition, 5 papers used systematic literature review to show what the current literature is presenting on smart meters adoption. These papers combine different perspectives from different fields to suggest frameworks, evaluate current approaches as well as propose future improvements in multiple areas in the research.

3.2.1.2 Grey Literature

The grey literature included 24 pieces of documents retrieved from official national and international institutions. These documents were chosen based on their relevance to this review's topic and research question. The documents were then grouped based on their content into four categories: Policy evaluation, smart meter deployment status, technical analysis and regulatory reviews. Out of these documents, ten pieces covered policy evaluation published by multiple organizations including ACER and CEER, the European Commission and the International Energy Agency (IEA).

These documents used mixed methods like performing comparison and data analysis from different countries to examine the smart meter deployment progress and also evaluate and follow the process of legal standards and investigate consumers' legal protections put in place.

Six pieces retrieved focused on setting legal requirements, guidance or technical analysis covering new models on how smart energy systems should work together and how they can be protected against cyberattacks.

Five pieces are legal and administrative reviews that detail the data protection laws put in place, the legislation related to smart meters and explain the different options available to the public if they wish to withdraw from participation. These documents were retrieved from the European Data Protection Supervisor, the European Parliament and VREG. The remaining two documents use public hearings or expert consultations to provide individual case interpretations or suggest future policy recommendations.

For this review, the grey literature completes and deepens the peer-reviewed articles by supplying current policies, laws, regulations and technicalities. This combination of sources, methods and

studies will build a solid foundation for the analysis of risk perceptions and smart meters adoption in Europe.

3.2.2 Geographic Distribution

Figure 3: Geographic Distribution of the literature

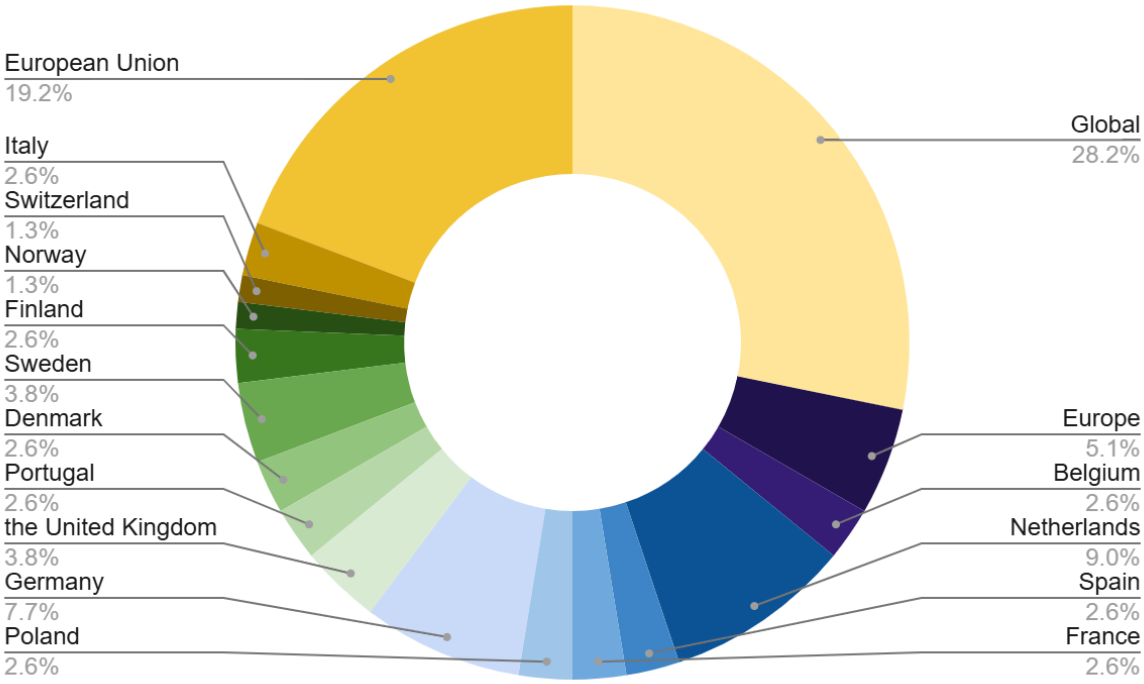


Figure 3 demonstrates the geographic distribution of the literature included in this review. 19.2% of the sources focus on the European Union member states as a whole, while 28.2% adopt a global view including Europe. 5.1% of the studies look at Europe as a whole continent. Together, these sources represent 52.5% of all the literature and allow for comparisons between different countries as well as shared perspectives on policies implemented in Europe like the GDPR or the European Green Deal. On the other hand, they do not include any information regarding local barriers or challenges.

The remaining 47.5% of the literature provide specific cases by country, however some countries are more represented than others, as they are used as case studies to understand consumer risk perception. the Netherlands (9%), Germany (7.7%), Sweden (3.8%) and the United Kingdom (3.8%) take up most of the studies.

The rest of the countries are not as present in the literature, including Poland (2.6%), France (2.6%), Spain (2.6%), Finland (2.6%), Denmark (2.6%), Belgium (2.6%), Italy (2.6%) and Portugal (2.6%). Switzerland makes up only 1.3% of the literature placing it at the lower end.

Figure 4: Country-Level Representation

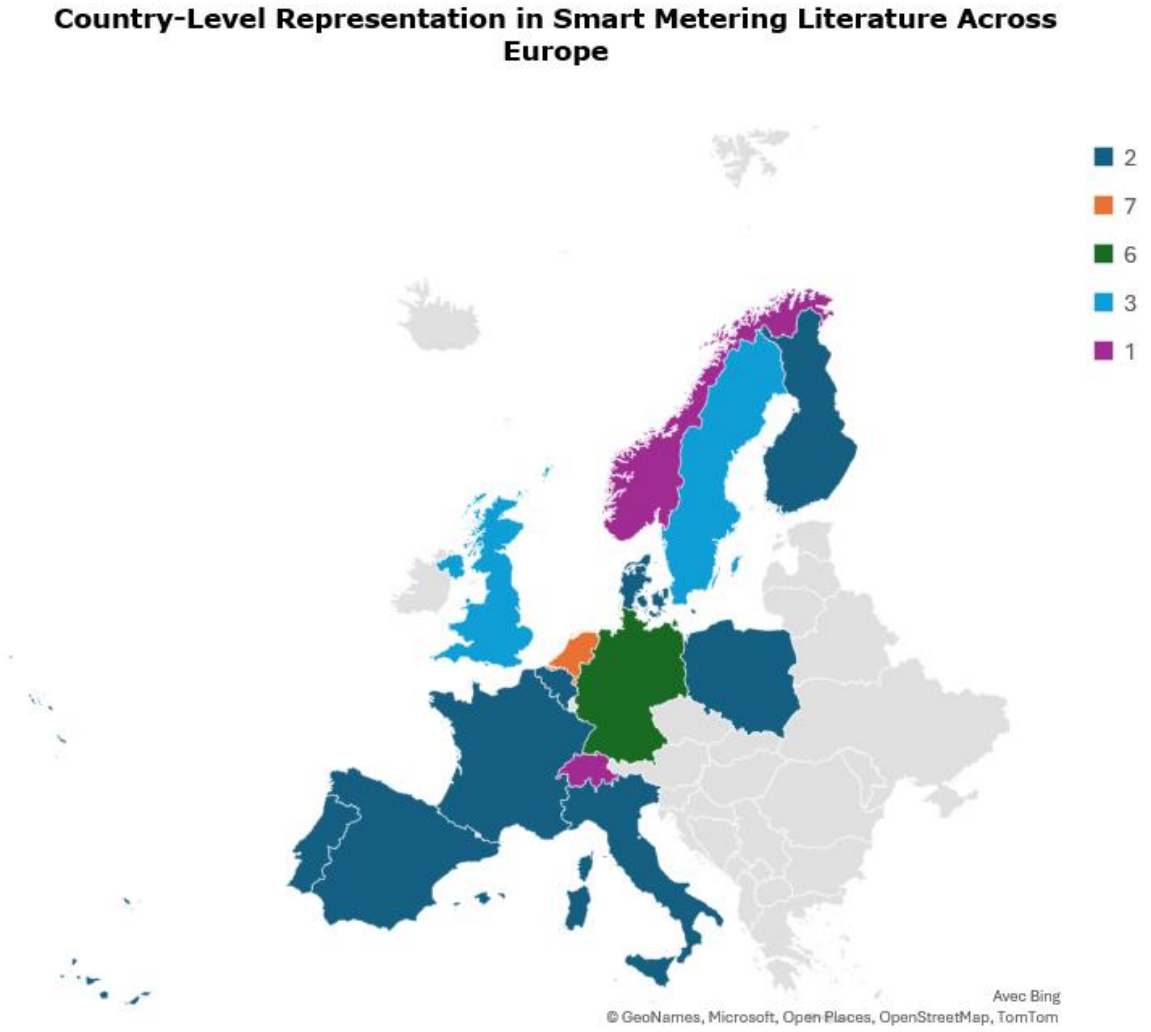


Figure 4 shows that many countries in the East and South of Europe are hardly represented in the literature, these countries include Romania, Bulgaria, Hungary, Croatia and the Baltic states. This unveils a significant geographic gap since Western and Northern Europe get most of the attention compared to the rest of the continent.

3.2.3 Thematic categorization

The 44 peer-reviewed articles retrieved were then grouped into six thematic areas based on their research focus: Adoption & engagement, data privacy & cybersecurity, technology & grid integration, health concerns and lastly financial & cost concerns. Each source provides specific input related to consumer risk perceptions and smart meter adoption in the context of Europe.

Table 3: Thematic Categorization of peer-reviewed articles

Theme	# Of publications	Focus
Adoption & Engagement	21	Consumer readiness, obstacles, challenges, motivations and smart meter engagement
Data privacy & Cybersecurity	8	Privacy concerns, GDPR, current data protections, management of data and cyberattacks
Technology & Grid integration	4	Smart grid control, Machine learning and storage for renewables, system stability and interoperability
Policy & Regulation	8	European Union and national laws, incentives, regulatory gaps and their impact on deployment
Health Concerns	1	Public fears of RF radiation and electromagnetic hypersensitivity and their effect on adoption
Financial & cost Concerns	2	Initial installation costs, willingness to pay and economic valuation of smart meters features

Out of the 44 peer-reviewed articles, the most addressed theme is the adoption & engagement theme making up 21 of the literature. These studies investigate the reasons and motivations behind the adoption or rejection of smart meters in addition to users' engagement and participation with the devices. They examine how users' interactions with smart meters are influenced by behavioral, social and psychological factors. Many areas are examined including digital literacy, institutional trust and communications strategies that affect the adoption of smart meters and how the users are engaging with them. Many studies under this theme used comparative analysis showing how users in different regions react and how they face similar or different challenges. Demographics and emotional factors are heavily used in these studies to uncover users' responses to data usage, while other studies use multiple behavioral experiments and methods to further encourage the use of sustainable energy.

The data privacy and cybersecurity theme group 8 peer-reviewed articles that focus on consumer concerns related to data collection, cybersecurity and the laws protecting their data. Multiple studies use countries like the Netherlands, France, Germany and the UK to compare how different national laws and data regulations are applied and how these laws influence the public trust in the systems behind them. These studies also discuss how direct communication strategies can influence adoption by thoroughly explaining data usage and privacy-by-design models to calm users' concerns. Other studies also examine the technical obstacles that smart meters could potentially face like cyber threats.

The policy & regulation group is composed of 8 papers analyzing the effectiveness of different policies and evaluating different legal frameworks. Many of these papers use national and EU regulations as case studies to examine their influence on consumer risk perceptions and the success of smart meters deployment. For example, research in Belgium, specifically the Flemish side, investigates the national laws and EU directives and contributes to suggesting strategies that encourage trust. Other papers use comparative studies to show how smart meters deployment progress is affected by different policies and institutional frameworks. This theme focuses on looking deeper into the role of user-centric regulations in encouraging consumer acceptance.

Within the technology and grid integration theme, 4 papers examine the role of smart meters in the energy system as a whole. These studies go into details showing the role of smart meter data in the stability of the entire system including the grid and integration of renewable energy. Countries like France and Poland conducted research pointing out how market readiness both from the technological and the institutional sides affect adoption. Other studies focus on evaluating the policies that push forward other technologies or aim to advance further the technology and show how these policies can affect the deployment and the consumers' experiences.

Only one peer-reviewed article covered the theme related to health concerns and this paper examined the reasons behind public resistance related to the effects of smart meter radiation and the social and legal factors that shape these concerns. Specifically focusing on France, this study shows the role that society plays in constructing health concerns which in return leads to legal disagreements and slow down the acceptance and deployment of smart meters even though the study shows that there is little to no scientific evidence validating this claim.

Finally, only two peer-reviewed papers address financial and cost concerns, one paper focuses on users in Germany and how they perceive and assess the value of the different features that come with smart meters. The paper shows that pricing models that use confusing and vague methods to explain cost savings are the same reasons why consumers hesitate to adopt or completely doubt the technology. The second paper also investigates how consumers in Switzerland value the different attributes of smart meters.

The grey literature reviewed here consists of 24 documents, grouped into seven different types. Sixteen documents are reports that evaluate deployment progress, legal frameworks, market readiness and the impact on consumers. Three documents are policy guidance or reviews from official institutions that focus on following up with the strategies to be implemented and the regulatory goals. The documents also include a technical framework setting interoperability standards across the EU,

an international brief discussing consumer trust and digital literacy, a guidance document on GDPR compliance for smart metering systems, a conference proceeding examining the economic effects of metering infrastructure and an international framework presenting a plan for connecting and coordinating different smart energy technologies across the sector.

Table 4: Thematic Categorization of grey literature

Grey Literature	# Of Documents
Report	16
Policy Guidance / Review	3
Technical Framework	1
International Brief	1
Guidance Document	1
Conference Reports	1
International Framework	1

The 24 grey literature documents complement the peer-reviewed articles by presenting input that is built on the current policies, covering regulation and technical requirements in actual practice. All the grey literature is published by official national and international institutions. The European Commission (ec.europa.eu) provides templates like the 2018 Data Protection Impact Assessment (DPIA) for smart energy systems including smart grids and smart meters to support the GDPR and help build the public trust. The European Data Protection Supervisor (EDPS) (edps.europa.eu) annually publishes reports that mainly cover privacy and data concerns as well as proposes improvement in the current strategies to manage data. The International Energy Agency (IEA) (iea.org) gives suggestions on smart grid integration by reviewing energy policies specific to each country. The Council of European Energy Regulators (CEER) (ceer.eu) and ACER report on the progress of smart meter deployment, regularly assess the efficacy of the regulations put in place and examine how users' rights are being protected. National regulators like VREG (vlaamsenutsregulator.be) in Belgium perform research related to the current national regulations and the implemented strategies aimed to increase deployment. Institutions like FfE (ffe.de) provide technical input on the development of smart energy systems infrastructure and the current state of Germany's smart meters deployment.

Most of the grey literature focuses on data privacy and cybersecurity. Many sources offer explanations on different tools that are designed to be used for multiple reasons such as risk assessment, audit governance guidelines and how the data management should be conducted when deploying smart meters. Policy and regulation take up a significant part of the grey literature, offering thorough discussions on how smart meter deployment is being managed in different parts of the EU, and how well aligned it is with the legal frameworks. The content of these documents shows that these factors impact and form the public trust and influence their reactions to new technologies. Other institutions notably the IEA, CEER/ACER and the Heinrich Böll Stiftung, issue reports on how to access information and the support system put in place that can help reduce social influences and help the public transition smoothly. These documents underscore the risks of excluding any sides and encourage inclusion and giving people the chance to take advantage of the transition.

The remaining documents mainly cover the technical side of smart meters and their role in connecting the whole energy system. Most of the documents present the rules that should be followed for the technologies to work together, suggest improvements to face cyber-attacks and propose future plans to the whole energy industry.

This shows evidence that smart meters are part of a bigger and complicated energy system. Some of the documents discuss the different ways people use and react to smart meters. They show that the public needs help to understand the technology which in turn needs effective communication to build trust. Financial and cost concerns are also present, mostly about how the prices are determined and how the costs are clearly demonstrated. On the other hand, health concerns are absent from the reports and documents and are treated to be part of bigger concerns about why the public might resist smart meters.

3.2.4 Thematic Analysis

This section details the different themes covered in the literature review, focusing on how perceived risks and concerns are seen and handled during the deployment of smart meters, by the public, the institutions and the regulators. Across the 68 sources, five main themes emerge: Privacy & cybersecurity concerns, fears related to health, financial and economic risk perceptions, unreliability in policy and regulation and social influence on risk. These issues were present in both the peer-reviewed articles and the grey literature suggesting that these concerns are frequently expressed by the public and are associated with smart meters.

3.2.4.1 Privacy and cybersecurity concerns

The new addition of smart meters in the energy system has shown many improvements and advantages in the whole grid by improving efficiency and enabling tracking the energy use (Kiasari et al., 2024). However, with these benefits come concerns about privacy and cybersecurity. The literature shows that despite the important role of smart meters in improving the energy systems, the public seems to raise many concerns, especially about potential cyber threats and the exposure of their personal data (Rajaguru et al., 2023; Hafner & Raimondi, 2020; Redondo et al., 2020). In the literature, the common issue that is associated with smart meters is cybersecurity risks (Nambundo et al., 2025). Smart meters are the target of many cyberattacks including

eavesdropping, spoofing, man in the middle attacks, denial of service and tampering with data (*European Union*, 2024).

These cyberattacks sometimes succeed due to many weaknesses in encryption, authentication, weak communication channels and irregular software updates (*European Union*, 2024). To address these challenges, the literature suggests solutions that include advanced encryption, blockchain technologies and intrusion detection systems (IDS) (*European Union*, 2024; Nambundo et al., 2025). The European Union (2024), Nambundo et al. (2025), Erkin et al. (2013) and Kiasari et al. (2024) all underline the importance of having multiple layers of security because relying on one isolated and single layer is not enough to protect the system especially that smart grids are connected.

At the same time, user privacy is getting more attention. Given the nature of smart meters, these devices collect detailed energy consumption data that can accidentally give access to sensitive and private information like when people are at home, their daily routines and even the appliances they use (European Commission, 2019; Hafner & Raimondi, 2020). Redondo et al. (2020), Erdemir et al. (2019) and Asghar et al. (2017) deeply explore this and note that smart metres can face significant privacy breaches if there is no proper protection in place. The authors also discuss the different methods to protect privacy, for example, homomorphic encryption, anonymization, data gathering and privacy-preserving computation, however they also state it is necessary for these method to be able to balance between the privacy protection and the quality of the data collected to manage the energy grid.

From a legal and regulatory perspective, the EU's approach to protecting privacy and data plays an important role. (Papakonstantinou & Kloza, 2015) study how the General Data Protection Regulation (GDPR) applies to smart grids while emphasizing on minimizing data collection, obtaining explicit consent and imposing usage limits to specific purposes. Although the GDPR provides a strong framework to protect personal data, the authors argue that its different implementations across EU countries can create difficulties for adhering to the law and applying it effectively, especially as energy systems are becoming more digital and connected to each other.

In order to support data protection, the European Commission (2018) brought in a Data Protection Impact Assessment (DPIA) template specifically for smart grids operators and smart meters. This template provides specific steps to identify, assess and reduce data risks and also emphasize the importance of privacy-by-design and risk and data management practices. Moreover, the Privacy and Security Mirrors (PRISMS) project encourages the participation of regulators and policymakers to collaborate and make decisions involving all stakeholders (European Commission, 2014). The project's objective is to show that balancing protection targets and data privacy regulations is only possible if designs are user-centric, and strategies address those risks.

The European Data Protection Supervisor (EDPS, 2024) underlined multiple persistent difficulties in the implementation of smart technologies. The EDPS research identified that these difficulties were mainly related to obtaining user consent and maintaining both disclosure and responsibility in the

management of smart meter data. To unify practices across all EU countries, it necessitates stricter and more precise regulatory standards (*EDPS*, 2024).

On the social level, the literature reports that consumers frequently voice fears about the collection, storage and use of energy consumption data by external or third parties (European Commission, 2014; Rajaguru et al., 2023). Several research conducted in Germany and Poland investigated these concerns (*BMWK*, 2015; Kochański et al., 2021). The results showed privacy as one of the most frequently mentioned barriers to adoption, with people underscoring fears that their usage data can be misused or shared without their consent. Some studies compare the different legal and regulatory protections across the European Union and noted that even with the presence of protections like the GDPR, the public trust changes depending on the country (Papakonstantinou & Kloza, 2015). Many studies also underline just putting measures in places that do not reduce consumer's concerns because most consumers have little understanding of these measures and how their data is managed (Hoenkamp et al., 2011).

Multiple sources noted that concerns regarding smart meters included technical, legal and social dimensions. In order to address these challenges, the literature argues that solutions need to integrate all these aspects and be flexible to address them all at once (Biresselioglu et al., 2022; (Hoenkamp et al., 2011; Herranz-Pascual et al., 2019; Van Aubel & Poll, 2019). Although there has been a lot of progress in recognizing threats and proposing protections, the literature notes that it is critical to align these three dimensions for future success.

3.2.4.2 Financial and cost concerns

Research done across multiple countries revealed that financial risks and consumer hesitance are significant factors delaying the adoption of smart meters. Consumers who express financial concerns focus mainly on the financial value of smart meters, the fear of unexpected increase in bills or unanticipated charges, and do not fully trust the reliability of the institutions (Kaufmann et al., 2012).

The studies used quantitative methods to understand more about consumers' willingness to pay for smart meters. Complementing these results, the study in Switzerland conducted a choice-based conjoint study with Swiss consumers, and it showed that most important features for smart meter acceptance is feeling financially secure and having clear demonstrations about cost savings (Kaufmann et al., 2012). The conclusions show that when the information received by consumers is imprecise, unreliable or when they worry about unexpected expenses, their willingness to adopt smart meters is significantly reduced. Another example is a study conducted in Germany where data from German households collected by surveys was analyzed and found that trust in both the technology and the regulatory framework plays an important role in influencing willingness to pay (Gerpott & Paukert, 2013). Similarly, choice experiments reveal that many consumers hesitate to adopt smart meters because they are not very sure about the financial benefits of these devices (Gerpott & Paukert, 2013). Both studies underscore that financial risk perceptions are linked to the availability of direct information and trust.

Schleich (2018) also conducted a study in this direction and identified financial uncertainty and the lack of sufficient incentives to be one of the main challenges to the smart meter deployment. Their

conclusions align with the Italy 2023 Energy Policy Review (IEA, 2023), which notes that in some cases, the installation of smart meters resulted in even higher energy bills, as a result increasing consumer doubts about the financial advantages of these technologies. Both sources argue that pricing models that are complicated and fluctuating prices influence the perceptions of financial risk among consumers.

From a regulatory viewpoint, similar issues are noted in Belgium, where regulators underline the importance of clear and understandable pricing models and the importance of measures that especially protect the vulnerable populations from financial burdens related to smart meter adoption (Vlaamse Regulator van de Elektriciteits- en Gasmarkt, 2024). This shows that consumers' perspectives on economic value consider both affordability and how fairly the technology is distributed, and in order to avoid consumers having the full financial burden, these technologies should integrate expense and cost recovery systems.

3.2.4.3 Health concerns

Health concerns related to smart meters are not mentioned as frequently as other concerns and, in some cases, are absent from all official reports and documents discussing smart meters deployment. Reviews and Data Protection Impact Assessments from institutions like the European Commission and the European Data Protection Supervisor mainly address issues of privacy, cybersecurity, and data protection rather than health effects or any concerns related to electromagnetic radiation. This absence reflects consensus in legislative frameworks that as long as smart meters are used under controlled exposure limits, smart meters are harmless to user's health.

However, some independent organizations raised concerns about potential health effects related to smart meters. The Environmental Health Trust (EHT) cautions about the radiofrequency radiation generated from smart meters and raises concerns of possible dangers, underlying symptoms connected to electromagnetic hypersensitivity. The International Agency for Research on Cancer (IARC) classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans, based mainly on studies related to wireless phone use. Although the IARC research does not explicitly say that smart meters could cause any harm.

Among the peer-reviewed articles, Draetta (2018) investigates the social behavior surrounding health concerns related to smart meters in France noting observations saying that even though there is no scientific evidence to back these claims, many fears develop and persist among the public. Draetta (2018) examines the health concerns related to the Linky smart meter through a qualitative social lens, using media analysis, interviews, and discourse analysis to investigate how these concerns became the center debate of the public. Their research shows that the controversy surrounding health risks was a result of public distrust and different interpretations of risk than by scientific evidence. Citizens and activists reported symptoms such as headaches, fatigue, dizziness and sleep problems that they linked to electromagnetic hypersensitivity, although no conclusive medical link to smart meters was confirmed.

The study also reveals that the public was not informed properly and the institutional communication was weak, making the public feel that they are forced to adopt smart meters without their involvement in the decision-making, and these factors further fueled the debate. Local government resistance, including bans or complete rejection of Linky meter installations in some areas, reflected bigger conflicts between national energy policies and local governance. Draetta (2018) concludes that health fears are deeply connected to political, cultural and social contexts that influence how risks are perceived and how public acceptance of new technologies develops.

3.2.4.4 Customer engagement and participation

Many of the studies in the literature argue that active consumer participation is important for smart meters to effectively be implemented, however, the desired level of engagement is not achieved yet. The literature shows that although smart meters have strong functional capabilities, many users are not yet prepared or involved, which limits the full potential of smart meters affecting the whole grid system (Batalla-Bejerano et al., 2020; Chen et al., 2023).

The research across multiple European countries reveals that consumer engagement is usually neglected or underestimated during smart meter deployments. For example, Hoenkamp et al. (2011) used interviews and policy reviews to analyze the Dutch smart meter deployment and describe the "neglected consumer" issue, where poor communication and a lack of inclusion and public involvement result in public distrust and resistance. This study emphasizes that engagement necessitates more than just providing information, it needs actual and continuous participation.

Supporting this, Chawla & Kowalska-Pyzalska (2019)'s study about Polish social media users, investigated public awareness and acceptance of smart meters. They found that false information and doubts were frequently present in social media conversations. To address these issues, the authors suggested that engagement platforms should be developed and communication methods should be more direct.

More research further underscores the importance of consumer involvement and engagement in smart energy systems. Biresselioglu et al. (2022) conducted a review of the readiness of the public to engage smart energy systems and showed that engagement efforts are more successful when consumers receive incentives, feedback on their energy consumption in real time and opportunities to participate in decisions related to energy. These conclusions are consistent with Gangale et al. (2013) who suggested that consumers should be included early in the process as this inclusion further encourages their participation.

In addition, according to the most recent reports in literature, consumer engagement and participation do not stop once the technology is adopted, it also involves considering users to be part of the energy market and be treated as partners. The 2024 Market Monitoring Report by ACER and CEER underline that energy models should advance and include offers that encourage consumer engagement, dynamic tariffs, demand side response and personalized services. Hafner & Raimondi (2020) initiated a research on sustainability, more specifically on public readiness for smart energy transitions and it uncovered that social and psychological aspects are causing a readiness gap. Consumer participation is one of the first steps to remove sociocultural challenges and encourage sustainable behavior.

3.2.4.5 Uncertainty in policy and regulation

Another recurrent theme in the literature is that many policy communications have an optimistic narrative which presents the deployment of smart meters as an inevitable and entirely beneficial step towards efficiency and environmental objectives (CERRE report, 2020). Although these advantages are recognized, the literature also argues that framing this perspective in this way, might seem to be predetermined to the public without their input included which results in consumer feeling isolated and their concerns about privacy, cost and health risks unheard (Zhou & Brown, 2016).

In contrast, models that encourage engagement and participation receive favorable attention in the literature. Multiple studies show that involving local communities and stakeholders in the planning and deployment phases encourages acceptance and trust (Sovacool et al., 2021; Gangale et al., 2013). Having direct communication, flexible options and tools for continuous feedback also support this. These strategies help align smart meter implementation with local needs and values, reducing resistance and encouraging engagement by demonstrating that institutions are listening and willing to adapt rather than imposing policies (CERRE report, 2020).

The literature also underlines that in order to encourage consumer assurance and resolve regulatory fragmentation it is critical to propose legal frameworks that increase trust on both the national and European Union level (Orlando & Vandevelde, 2021;Hafner & Raimondi, 2020). The literature underscores that uniform rules that clearly show who is responsible for consumer rights, data protection and technical supervision help reduce uncertainty and improve institutional accountability (Inderberg, 2015). A similar structure would increase consumer trust in the smart meter ecosystem and provide them with more channels for a source of help.

The comparative studies conducted across different European countries showed that for smart meter policies to be effective, the deployment should not only rely on technicalities but also on the quality and clarity of these policies in addition to considering the social factors when developing them (Zhou & Brown, 2016). Countries with more inclusive and flexible governance approaches, such as the Netherlands and UK, report higher consumer engagement and easier adoption processes, while those with more strict and top-down strategies experience higher public resistance and slower deployment (Geels et al., 2021).

3.2.4.6 Risk and social dimensions

Numerous studies in the literature underline how demographic characteristics can influence consumer behavior towards smart meters. Biresselioglu et al. (2022) argues that characteristics like income, region and education should be considered when implementing deployment strategies as they affect how open the individual is to adopt a new technology. (Chawla et al., 2020) also supports this by adding that these characteristics should also be included when developing communication strategies in order to reach the entire population.

Digital literacy also emerges as one of the main factors affecting the adoption of smart meters. Stieglitz et al. (2023) explore how digital nudging using smart home applications can encourage

environmentally friendly behaviors. Their conclusions suggest that although digital nudges can motivate behavior that helps save energy, the success of similar strategies depends largely on users' ability to understand and interact with digital interfaces, underlining the important role of digital competence for actual participation.

Institutional trust greatly differs across regions and has a strong impact on consumer acceptance of smart meters. Boda & Medve-Bálint (2014) note that people in Western Europe generally have higher levels of trust in institutions than those in Eastern Europe, which can be explained by their willingness to participate in smart metering initiatives. Complementing this, case studies identify mistrust in institutions and concerns over privacy and data security as the main obstacles that contribute to consumer resistance or hesitation toward adopting smart meters (Orlando & Vandevelde, 2021; Kochański et al., 2021).

Income also significantly influences consumer perceptions toward smart meters. Research by Gerpott & Paukert (2013) shows that lower-income households are hesitant to invest in smart meters and that is mainly due to financial constraints and doubts about the promised financial benefits. For these groups, smart meters were occasionally reported as being perceived as additional financial burdens.

Psychological factors including behavioral factors, attitudes, social influence also play important roles in smart meter adoption. Guerreiro et al. (2015) explain that positive attitudes toward new technology and social norms encourage its use and individuals' confidence in their ability to use the technology increases the adoption. Supporting this, Chawla & Kowalska-Pyzalska (2019) found that peer influence and social acceptance improve consumer engagement with smart meters.

3.3 Current risk management strategies

Many strategies have been implemented by the EU alongside governments to address multiple risks and aspects of the smart meter deployment.

3.3.1 Enforcing new cybersecurity measures

In March 2024, The EU Cybersecurity Certification Framework's latest development introduced the first ever EU Network Code on Cybersecurity for the Electricity Sector. This code "aims to establish a recurrent process of cybersecurity risk assessments in the electricity sector." (*European Union*, 2022). The main goal of these assessments is to identify any entities that might impact the electricity flow, their cybersecurity risk and what measures could be needed to face those risks (*European Union*, 2022). Under this code, member states, relevant authorities and system operators are required to establish security measures that can assess any weaknesses (*European Union*, 2024). The first priority of these measures is to protect the systems from external cyberattacks and be able to detect malfunctions (*European Union*, 2024).

In addition, Directive 2022/2555, also known as Network and Information Systems Directive (NIS2) replaced the previous Directive 2016/1148 (NIS1) that protected network and information systems (NIS) and their users, and any involved individuals from cyberthreats. The new directive set new standards and reinforced the system "through a wider scope, clearer rules and stronger supervision tools" (*European Union*, 2022). This means that smart meters are now part of the whole cybersecurity

framework. All member states are responsible for supervising their energy industry regularly and making sure it is following the new measures. The European Union also has created The European Union Agency for Cybersecurity (ENISA) since 2004 that is dedicated to help Member States and EU bodies by offering technical instructions (*The European Union Agency for Cybersecurity*, n.d)

Under the NIS Directive, The Network and Information Systems Cooperation Group was established and its main role is to facilitate and support information exchange among Member States, the European Commission and the EU Agency for Cybersecurity (ENISA) (*European Union,* 2022). This sharing also includes information about risks and cyber threats. In the same context, the European Energy Information Sharing and Analysis Centre (EE-ISAC), established in Belgium, facilitates sharing information between private and public sectors, by conducting joint threat analysis, solving problems and creating solutions, to improve security the of the European energy infrastructure (*Energy Information Sharing and Analysis Centre*, n.d).

3.3.2 Promoting 'Privacy by Design' and consumer control

Smart meter's main feature is the collection of detailed data related to the household's energy consumption. Because of the sensitivity of this information, data protection is one of the EU's main priorities. One of the initiatives established by the European Commission is the General Data Protection Regulation (GDPR) (*European Union*, 2016). Smart meters systems are, therefore, required to comply with this framework. While the GDPR offers the foundational rules, the European Commission also added tools that are specifically designed for the energy sector.

The first tool is the Data Protection Impact Assessment (DPIA) Template for Smart Grids and Metering Environments. This template is developed for smart grid operators and those responsible for the smart grid architecture infrastructure and the main goal of this template is to establish data collection rules and assess and reduce any risks targeting data protection (*European Commission*, 2014). It also clarifies the proportionality of data collection, its storage, usage and its purpose. These templates must be completed before any deployment of smart meters as these information are sensitive (*European Commission*, 2014).

The GDPR also gives the right to individuals to access, consult and obtain all the information related to their collected personal data as well as inform them clearly how their data is being processed (*European Union*, 2016). Under this regulation, regulators are required to impose on energy providers to offer their users easy interfaces that allow them to access their information and track how and where their data is being used (*European Commission*, 2014). When these tools restrict the total exposure of data information, users feel that they have a sense of control and can see directly where their data go.

3.3.3 Encouraging consumer engagement

For smart meters deployment to succeed, data protection measures and legal policies are not enough if public trust and engagement are low. The European Commission alongside local governments have been working extensively to address these challenges. The European Commission's first step is to promote the digitalization of the energy system, supporting the objectives of the European Green Deal. This digitalization affects the whole energy chain from the provider to the user. It will allow consumers to engage with their energy providers in a new way and will help energy providers offer

better services (*European Union*, 2022). The EU is also working closely on this topic and is developing the Common European Energy Data Space (CEEDS) which is a space that facilitates data sharing, allows users to access and manage their data (*European Union*, 2023).

The International Energy Agency is also focusing on initiatives that target vulnerable populations like elderly, low-income households and people with disabilities that are usually neglected (The International Energy Agency, 2023).

3.4 Gaps in the Literature

Although smart meters are gaining more attention and are more and more present in research, there are still many areas that have not been covered or do not get much attention in the current literature. These gaps do not only include the topics that are discussed but also reflect how thoroughly each topic is being investigated, how different regions are represented and how each method shows the actual concerns of the users. In order to increase adoption rates, these gaps must be filled for policymakers and institutions to improve the technology and help the public benefit from its advantages.

The first noticeable gap is the lack of research related to health concerns. The public frequently raises concerns about the fears of the radiation generated from smart meters, however a very few literature discuss these concerns separately. Most of the studies and sources dismiss these concerns and rarely discuss them, however this will only add more issues. The absence of research that is specifically dedicated to studying this area shows that there is little understanding of how these concerns emerged, whether the reasons behind it were misinformation, past experiences, lack of trust or lack of explanations from authorities. In order to develop strategies that are tailored and actually address the public's concerns, these understudied areas should be explored more.

Financial concerns are not as present in the literature although many studies have mentioned public hesitance related to costs and the economic burden that comes with smart meters. Whereas many sources mention that people are worried that their bills will increase or their pricing systems seem to be complicated, only 2 peer-reviewed articles thoroughly investigate how these concerns influence customer's decision making related to smart meters. This is especially concerning because many households feel that even small increases in their bills can be risky. This is an important part, because without understanding how people react to financial changes, it is hard to design effective pricing strategies and test if they are actually helping or harming smart meter adoption. Consumers are especially prudent when they do not notice any immediate benefits or cannot see any improvements that might come in the future. Therefore, more research should be conducted to understand how financial implications influence decision-making.

Another noticeable gap is the uneven representation of some regions in Europe. Countries like Germany, France and the Netherlands seem to be the main focus of many studies in the literature and this is mainly due to their strong digital infrastructure, regulations and the public trust in their institutions which as a result placed them as the examples of the industry standards. On the other hand, the Eastern and Southern parts of Europe are left uncovered despite their difference in public reactions and architectural conditions compared to Northern and Western Europe. These regions face lower institutional trust, less digital resources, have different cultures and experiences that might

create specific challenges to smart meter adoption. Therefore, the lack of research in these regions might not reflect the seriousness of these issues and might negatively affect the strategies proposed. If the institutions only rely on a generic strategy that is mostly based on Northern and Western European data, these regions will be left behind.

From a methodological point of view, most of the research lacks comparative and long-term studies. Researchers mostly focus on using surveys to look into consumer's opinions at a specific point in time. This might help show general themes and patterns, however it does not show the changes that might occur in people's attitudes towards smart meters after a long period of use, and it does not investigate if people's initial excitement about the technology stays or diminishes once it is installed. This is especially important because if users' behavior is not followed for a long period of time, it is hard to determine if consumers actually benefit from smart meters or if their lack of engagement affects the full potential of the technology. On the same note, very few studies conduct regional or community comparisons. These comparisons are not only necessary to understand the different consumer behavior but also to assess how effective policies and strategies are and help design them to adapt to different settings. Long-term and comparative studies could help provide suggestions and guidance for deployment strategies to adapt to different populations.

Another important topic that needs more attention is communication. The literature often mentioned the importance of communication but lacks thorough investigation on the topic. Poor communication plays a big role in pushing for public resistance, however the literature does not dig deeply into the kinds of messages people receive, how these messages are written or if they adapt to different and specific groups. How the messages are written and delivered should be carefully examined and tested using different formats, framings, languages and media and should not be addressed as general statements. In addition, one-way communication is not effective anymore. The public wants to interact with energy providers, regulators and institutions in a two-way communication, they want to ask questions, get feedback, be part of the process and have a space that allows them to understand the technology, thereby increasing trust and giving people a sense of control.

Many of the literature in this paper uses qualitative methods including surveys and experiments. Although these methods gather important data, they miss the human side and emotions that motivate the public's hesitance to accept new technologies. Few studies use interviews, comparison groups or participant observations to closely look at how people are actually experiencing smart meters in their daily life. Such qualitative methods can decode that data and reveal individuals' or households' habits, if their engagement with smart meters is affected by their habits, how and where they get their information from, the role of their experiences with technology and their backgrounds in their decision-making. Only qualitative research can give these conclusions without excluding the most important side, which is the public.

Some studies consider digital and financial literacy as an indirect link with smarts meters. This is surprising seeing how these factors are how people decide the level of risk and compare it to the benefits. People will eventually lose trust and be confused by complicated price models or infrastructure that do not facilitate access to their data. There is an obvious lack of attention towards this topic that can be considered one of the main aspects of smart meters adoption.

4 Discussion

This section will go deeper into the sources and will analyze and evaluate the conclusions identified in the results sections.

4.1 Privacy and cybersecurity Concerns

This review revealed that one of the biggest challenges of smart meter adoption is addressing privacy and cybersecurity concerns. Although there are many strict laws to protect the consumer's data, like the GDPR, these concerns persist. Users are especially worried that their personal data, their habits and routines might be exposed and used for other purposes and not just billing. These concerns are raised in different countries in Europe.

This persistence is quite surprising as the European Union has put in place numerous laws and legal protection dedicated to this issue. Institutions like the European Union and European Commission assume that systems that support encryption and data anonymization are enough to show the public that their data is safe and therefore reduce their concerns, however this review proves that to be wrong. These reassurances are not enough for the public to trust these systems and believe them to be effective. This can be explained by the nature of how people view these concerns. These technical protections do not address the public's emotional and social concerns related to being watched or exposed. This aligns with The Institutional Trust Theory that states that these types of technologies represent something deeper for consumers and trigger fears about loss of control and surveillance. Unlike the different institutions under the European Union who have assumed that privacy concerns can be resolved if technical communication was better.

This review also revealed that the level of these privacy concerns varies from one country to another. It was found that countries with a history of political surveillance or corrupt institutions, trust in official institutions are lower which results in concerns being more intense. And this is especially shown in parts of Eastern and Southern Europe. (Boda & Medve-Bálint, 2014) supports this claim and argues that Northern and Western countries demonstrate higher levels of institutional trust compared to the Eastern and Southern regions. This claim is also supported by the PRIvacy and Security MirrorS (PRISMS) that found in a study conducted in 2015, that there is a link between privacy concerns and historical mistrust and these concerns are not based on lack of understanding alone. These two studies support the Institutional Trust Theory that suggests that the public's trust is formed not just by the current laws but is also formed by previous negative experiences and collective memory.

In contrast, there are countries, where smart meters are also deployed, that demonstrate lower levels of privacy concerns, like Sweden, the Netherlands, Denmark and Finland. This might be due to the level of the public's trust in their institutions and how much has the public been involved in the deployment process (Zhou & Brown, 2016). These differences show that in order for the legal frameworks to support and ease the public's concerns, the public should first be able to trust those institutions and their initiatives.

This review also found that the public has many misunderstandings about what smart meters are for and what they can do. For example, many users believe that smart meters can possibly allow other external entities to know when they are at home, risking them to be burglarized, how many occupants there are or even the appliances they use. This is especially present among older users and people who are not very familiar or comfortable with technology in general. Rajaguru et al. (2023) do support this claim, that poor communication and digital exclusion fuel similar misconceptions, however this review argues that these misunderstandings are not the full problem. Even when the public is well informed about the actual role of smart meters, whether it was by statistics, regulations or informational sessions, many users still express fears and discomfort. This is in line with one of the principles in Risk Perception Theory that suggests that knowing the facts alone is not enough for people if they feel they are losing control.

When it comes to privacy and cybersecurity concerns, this review reports different conclusions that the earlier studies presented, related to how consumers respond to new technologies. Multiple sources in the literature have underlined the constant improvements and upgrades in security systems and the strict laws and regulations set by the European Union to protect personal data and protect systems from cyber threats (European Union, n.d; European Commission, n.d). However, this review found that these enhancements and upgrades did not really have a strong effect on the public perception. In reality, many consumers do not even understand these systems or how they work, and therefore they do not really reassure them. And this is where the gap between expectation and reality emerges and shows that emotional responses to data privacy are real and should be addressed.

The main conclusion, related to data privacy and cybersecurity, of this review states that these concerns are much more affected by the level of the institutional trust and the public's emotional responses than the actual technical risks. It also supports research that puts smart meters as more than just devices to improve energy efficiency but more of technologies that might integrate into people's lives and change how they feel and operate (Chawla & Kowalska-Pyzalska, 2019). This review also reveals that data privacy and cybersecurity concerns decrease significantly when the public trusts their institutions and feel included in the process of smart meter deployment. This conclusion is reinforced by the International Energy Agency that underlines in its 2023 report the importance of including all stakeholders and especially users when deploying smart meters (*Energy Efficiency* 2023, 2023).

In order to address these concerns, policymakers must change the way they approach the public in relation to smart meters. The first step is having direct and inclusive communication that does not only address the technical protections available but also how they would work in everyday terms. The public sees smart meters as devices that will take away their control. This sense of control is much more important to the public than it seems. Policymakers and energy providers should provide their users with features that leave them a space to have options. For example, data sharing customization or having a choice to withdraw from using smart meters for a period of time. These options will help users feel much more in control and less forced to just accept what is offered. In addition, assuming that all users have the same levels of digital literacy affects the effectiveness of

the strategies implemented to encourage adoption. Policymakers and energy providers should offer support to those who are less knowledgeable and are less familiar with the technology. These practices fall under the principles of Risk Perception Theory and Institutional Trust Theory that emphasize the importance of inclusion and empowerment to reduce public resistance.

In conclusion, this review refutes the arguments that state that data privacy and cybersecurity concerns can be fixed by implementing the latest and the strongest security systems. It is clear that public trust and their emotional responses are the source of these concerns and not the protections that are already in place and in order to address them and encourage smart meter adoption, policymakers should take into account how people understand the technology and what they feel about it.

4.2 Financial and costs concerns

Another significant concern that was revealed in the thematic analysis is financial and cost concerns that many consumers expressed all over Europe, and more particularly, by people who come from low-income households and vulnerable communities. This concern was not as present in the literature as the data privacy and cybersecurity, however it was frequently mentioned in the literature but not in detail. The public was especially concerned about their bills getting higher, facing any unexpected fees and charges, confusions regarding time of use pricing and cost savings (Gerpott & Paukert, 2013). This supports the Risk Perception Theory that states financial insecurity influences how people assess risk, as they consider the potential loss more than what they are uncertain to gain especially when the benefits are not immediately noticeable.

This is in line with what Rajaguru et al. (2023) presented, saying that poor communication about the advantages of smart meters financially are the reasons that might create this confusion and therefore increase the public's concern. However, Rajaguru et al. (2023) argues that this problem can be solved if better communication is implemented to inform the public and reduce their fears. This review questions this claim because throughout the literature it is clear that communication alone is not enough to address this issue. In fact, this review supports (Energy Efficiency 2023, 2023; Schleich, 2018; Biresselioglu et al., 2022) that says there are deeper social issues that are linked to these concerns. When the public has had previous experiences where they had to carry the cost of utility if they ever go higher or if they get no help from their governments and institutions, it is understandable that they would be skeptical and doubtful and not just misinterpret or misunderstand. The literature suggested many viewpoints about the origin of these financial concerns, and whether it was because of lack of information or because of previous experiences. This review shows that while these two factors could be at play, there are other social factors like trust that fuels these concerns.

Another noticeable theme across the literature is that the public seems to see smart meters as devices that threaten any predictability related to households' finances and do not see them as tools that would help with their bills or their energy use, even when models like dynamic pricing are present, consumers prioritize what they could lose over what they might gain (Gerpott & Paukert,

2013). This is mainly due to consumers not being able to accurately estimate how much smart meters will help them save, even though they might acknowledge that using energy in off-peak times can help them reduce their bills. Even further, regions with low institutional trust face these challenges even more, which is aligned with the Institutional Trust Theory that says when the public doubts the intentions of the institutions, they tend to avoid engagement with their incentives even if the benefits are real and available.

Belgium and Poland are examples of countries that face these misconceptions. ACER-CEER (2024) Retail Market Monitoring Report found that the public suspects the real purpose of smart meters saying that these technologies will only help to improve the efficiency of the energy system and therefore help the institutions to reach their goals, but it might be less beneficial for the average consumer. The Institutional Trust Theory addresses this claim that the institutional motives, fairness and credibility all play a role in shaping the consumer's view of whether the technology is going to help them or exploit them. The public seems to have a perception of who will benefit more and when these types of perceptions are present, rejection grows.

The study that was conducted in Poland used a social media analysis to understand more the public perspectives, more particularly, social media users (Chawla & Kowalska-Pyzalska, 2019). This study showed that users linked smart meters with instability, manipulation and unexpected fees. However, this is quite surprising as in reality these concerns did not really match the pricing models that were put in place. There was a clear inconsistency in what people perceive to be the reality and the actual reality. This shows that when there are gaps in communication and credibility, distrust fills those gaps and increases the perception of risk, a claim that is supported by Risk Perception and Institutional Trust Theory.

This is not only present in certain countries or regions. Even when there are strong protections implemented, for example in Germany, there are still communities that remain wary about the financial implications, and its mostly older and low-income consumers (Gerpott & Paukert, 2013). CERRE (2020) supports this as it found that even when the market is regulated, there are always groups that perceive smart meters as threatening to their financial stability especially when they do not immediately see the financial benefits or do not have access to information. A similar case is Switzerland, where consumers are still hesitant towards smart meters, even though there is strong infrastructure (Kaufmann et al., 2012), which further proves that institutional candor can influence consumer perceived risk more than the cost-benefit calculations.

A study conducted in Spain shed light on another perspective related to financial concerns. It linked financial concerns to social fairness. This study shows that groups such as shift workers, retirees and households with fixed routines find difficulties adapting to the dynamic pricing models as they have different working hours and health conditions (Herranz-Pascual et al., 2019). These groups feel more disadvantaged as they cannot really benefit from the services that make these systems what they are. It also gives them the perception that unless the user has flexible time and is digitally comfortable with the devices, they will not benefit from it and be excluded. This is a claim that is present in the Institutional Trust Theory saying that if the technology is not equally accessible to

everyone and seems to benefit some more than others, resistance increases and political opposition arises.

Financial concerns do not only impact the adoption but they also impact their engagement. If consumers are not engaging with the system, not only are the devices not reaching their full potential, but this lack of engagement also impacts the overall objectives of improving the grid efficiency and integrating renewable sources. From the Risk Perception Theory perspective, if the financial benefits are not visible and immediate, resistance to change grows. When consumers do not see any reward after changing their habits and behavior, they cease to stay engaged. This proves that even though smart meters will help with the long-term energy efficiency and the improvement of the whole energy system, consumers are more motivated by the short-term benefits and the immediate results.

This analysis revealed a few gaps that are present in the literature. Many studies focused on the perspectives of consumers regarding financial concerns but did not verify the results. This is especially important because if the research does address these issues, it will be hard to differentiate between resistance that is influenced by social dimensions and resistance that emerged from actual financial harm. This lack of longitudinal data weakens the recommendations and strategies to address this issue.

One of the gaps noticed in the literature is the lack of geographic and demographic diversity. Most of the studies focus on Western Europe leaving the Southern and Eastern European countries unstudied. In addition, the research does not categorize their conclusions based on demographic characteristics like age, income, education or digital skills although these are one of the main drivers for consumer decision-making. There is also little attention to financial literacy that has a significant influence on how people understand their pricing models and the systems and features that help them save money. This area should be further explored because if people do not understand how smart meters help them reduce their bills, the benefits might not be as evident as regulators and energy providers assume they are.

In light of these conclusions, few recommendations are suggested. First, communication must not contain general statements and should in fact be targeted to different demographics considering their background, region, culture and experiences. Communication does not only come as messaging but also as support and guidance through customized tools and in person interactions, this way people actually see the impact of smart meters on their bills and not just theoretical numbers. Second, policymakers should offer assistance to these groups, whether it was an incentive or an option to choose their models, this would help significantly reduce financial perceived risks and build trust in institutions as these groups will feel less excluded and involved in the strategies.

In conclusion, research has extensively shown that smart meters have significant benefits and are technically strong and effective. This review reveals that the actual drivers of consumers acceptance or rejection is trust, directness and fairness. Unless financial concerns are properly addressed, these issues will continue to affect smart meter deployment and adoption.

4.3 Health Concerns

Although smart meters have been confirmed to be safe to use, the public still raises concerns related to health risks especially regarding radiofrequency (RF), and these concerns seem to be one of the many concerns that influences smart meter adoption. The World Health Organization and IARC (2011) has constantly confirmed that the electromagnetic fields (EMFs) that smart meters generate do not exceed the safety limits that are internationally set. Supporting this, the Environmental Health Trust (2023) confirmed that smart metres generate less radiation compared to devices that are more used like Wi-Fi routers and smartphones. However, this concern persists in some countries more than others. An example would be France where many local protests were held that delayed the deployment of smart meters and in some cases even blocked it completely (Draetta, 2018).

Across the literature, some studies supported the claim that if the technicalities and functions of smart meters are explained, then the public concerns will be reduced. Some official documents also stated that as long as the public is well informed of the safety standards then their fears would ease. However, the previous example contradicts these arguments and shows that technical reassurances cannot address the emotional aspects of these concerns. In fact, this review supports the claim made by many studies and follows the principle of Risk Perception Theory that says risk perceptions are formed by trust and feelings. This means that even if the risk is low and the science and evidence does not back it up, people would still consider it a valid risk especially if they do not understand it and feel forced to accept it.

One of the examples that demonstrate this discrepancy is electromagnetic hypersensitivity (EHS). The World Health Organization does not directly state that there is any relation between EMFs and EHS, however, it does recognize that people who suffer from the symptoms are actually experiencing real discomfort. However, not much research is done to take a closer look at these experiences making the public feel unheard and resist even more. This conclusion is in line with the Institutional Trust Theory that says when individuals feel that their voices are not being heard and their experiences are not validated, they tend to doubt their institutions and in some cases form a negative image of the whole system. Even with the absence of scientific proof, it is critical to understand and recognize the social aspect of health concerns to prevent the emergence of opposition.

This is the case of the Linky meters deployment in France that faced many oppositions from the public. The research shows that this opposition was mainly due to the personal stories and experiences that the public was sharing about the lack of sleep and headaches that they linked to the Linky meter (Draetta, 2018). These stories had a huge influence even though there was no medical evidence confirming this link. This is proof that public rejection is motivated by a lack of institutional trust more than doubt in science.

The literature also shows that health concerns are related to much deeper emotions and feelings and not just to the technology alone. In the case of France, the country operates under strict laws and the public has options to stop using the technology, however, people still fear RF exposure. Risk Perception Theory argues that people assess risk based on how much their daily life would change

and not on data and statistics. And this is clearly evident because even with strong protections implemented, fear does not diminish because people do not just want to kept safe, they want to be part of the decision-making to relay their feedback and fears and make sure that their concerns have reached those in control.

This review also revealed that who delivers the message is also important. The study about the Linky meters shows that when independent organizations, like doctors and researchers, are included in the delivery of the messages, the public seems to receive those messages positively contrary to when they receive it from the government or the energy providers (Draetta, 2018). And that is mainly due to the fact that the public usually does not understand or trust these messages unless independent sources explain them clearly using terms that feel relatable and detailed. The institutional Trust theory fully supports this argument because it argues that what builds relationships and connection is trust and not facts alone.

Health concerns are not spread equally among the public. Some individuals are more wary about these concerns than others. For example, people living in rural areas, older adults or people who are not really comfortable with the technology are more concerned about EMFs. This can be explained by referring to the Risk Perception Theory that says when people feel that they are losing control or do not fully understand the technology, they seem to assume that the technology is more risky than it actually is. This is also supported by the Institutional Trust theory arguing that people who feel that they are excluded from the benefits of the technology or that the system is focusing on the more privileged, tend to distrust the messages and dismiss them.

Although this issue is very important for the public, not much research was done to uncover more about it. Out of the 44 peer-reviewed articles included in this review, only one article directly addressed health concerns. Documents from the grey literature either do not address any attention to this issue or treat it as a minor problem. This absence of research shows a gap that might have significant impact on smart meter adoption that policymakers are not aware of and might explain why some concerns only grow over time and do not go away.

In order to address these issues, our analysis suggests that governments and energy providers should engage the public with an empathetic and validating approach. They should collaborate with independent health experts who would explain thoroughly RF exposure, by comparing smart meters with other daily used devices and also show the different choices people have. This is a method that is supported by the Institutional Trust Theory saying that inclusion and honesty build trust, and also by the Risk Perception Theory which argues that messages need to match people's understanding and feelings.

On a more technical level, energy providers should offer their users options and choices and let them decide what they want to choose, for example, offering wired meters or integrating features that can allow users to adjust RF settings. These features might not be needed for the functionality of smart meters however they are an important step that shows users that institutions are taking their concerns seriously and are willing to adjust their practices and be more flexible and respect people's

preferences. The Linky smart meter case in France is a good example showing that even small changes can completely shift the outcomes. Smart meter deployment plans should include spaces like public forums for the people to ask questions, share their stories and experiences and input their feedback in order to build lasting trust.

In conclusion, this review supports the claim that health concerns are more than just unfounded reactions, they actually reflect more complex social cues. It is not only about not matching the science, but more about trust and being heard.

4.4 Findings

After analyzing the different concerns that are frequently expressed by consumers related to smart meter adoption in Europe, whether it was data privacy and cybersecurity concerns, financial and cost concerns or health concerns, it seems that there are patterns that emerged with them. These patterns do not just appear alongside these concerns but seem to influence how people make their decisions and also seem to be the reason behind their existence in the first place. Throughout the content of the sources reviewed, three main themes keep appearing in different ways: How much the public trusts their institutions, how is the communication and information delivered to the public and whether the public feel included in the process of the deployment. These are the factors that the public consider when assessing risk and when deciding whether to accept the new technology or reject it.

This analysis clearly shows that institutional trust plays an important role in how the public perceive risk. When consumers feel that the institutions behind smart meters are not trustworthy or credible, be it policymakers, energy providers or the governments, they assume that the initiatives coming from them are more harmful than helpful. This is even heightened in cases when the public already experienced unreliable institutions or corruption in the past and are now more doubtful and cautious. This shows that in some cases, the public does not reject the technology itself but the institutions behind it and always question whether they are honest and reliable. This proves that consumer's risk perception is formed not only by what the public knows but also by what they believe to be the intentions of the institutions and systems involved.

The analysis also shows how communication can change what people think about smart meters and how they view the risks associated with them. The public does not want communication that is vague, focusing only on the functional side of smart meters or one-way communication as this kind of messaging usually does not answer the questions that the public is actually asking and consider the concerns and fears that they have in mind and this only increases the confusion that is already present. However, when the communication is using easy and understandable terms, and are delivered by trusted sources, the public receives it positively. The conclusion of this analysis shows that as much as the content of the message is important, the way of the delivery and the sources delivering it matter as well.

Another pattern that seems to also have an impact on how consumers perceive risk is if they feel they are part of the conversation. Meaning, if they are involved and included in the decisions related to smart meter deployment. This feeling of lack of involvement comes in different ways, whether the user feels that they do not have a choice in the type of meter they want to use, if they feel confused about the pricing models or if their health and safety concerns were ignored. The people who do not feel involved in the process express concerns about smart meters even more, and view risks related to them to be more intense as they start to associate these technologies with loss of autonomy and vulnerability. Including and involving the public does not only mean fairness, it also means using and incorporating their viewpoints and their input in the process.

Based on these three patterns we can picture the actual reasons behind the public's concerns and how consumers perceive risk. This review concludes that risks are not just associated with the technology itself but actually consider how that technology was introduced and how the public experienced it. Consumers' acceptance of smart meters relies mainly on whether they trust the systems introducing it, whether they receive messaging that is inclusive and direct and whether they took part in the deployment process. These three dimensions are important and if one of them is missing, consumer risk perception increases and people would be more cautious and might reject the adoption. This can help explain the difference in smart meter adoption rates in some countries that operate under the same policies and laws.

The conclusions of this analysis are directly linked to this review's research question. They reveal that there are many drivers and dimensions that affect consumer's risk perceptions besides technical facts and personal beliefs. Trust, context, past experiences and relationships all play part in forming those perceived risks. These conclusions also suggest ways to improve current strategies and go beyond just improving the design or enforcing additional laws, to advance and push for smart meter acceptance. In order to address the challenges associated with risks, policymakers need to rebuild trust, improve the communication and make sure to involve the public in the beginning of the process and not just inform them of the decisions that have been made.

In addition to addressing this review's research question, this analysis was also able to answer the guiding questions about the different concerns expressed by the public, how these concerns are shaped and how they influence their decision-making. Public concerns are not illusions and are in fact present in the real world. Previous experiences, media narratives or discomfort with technologies are all part of bigger social and behavioral factors that form these concerns and do not only mean that the public is simply misinformed but shows that the institutions are not filling all the gaps. In order to change the direction of risk preference and push it towards acceptance, there should be more focus on those factors and not only on the technology.

The conclusions of this review clearly demonstrate that the public's decision to accept or reject smart meters is not random but actually follows patterns that are built on their experiences, their level of trust and if they feel important. This being said, risk perceptions are indeed profound and rooted in the public's mind, however with the right approaches and strategies, these perceptions can change.

5 Recommendations

This section will be presenting some recommendations addressed to policymakers to help improve smart meter adoption. It will also suggest what future literature needs to focus on in order to the cover the complex and human side of smart meter deployment.

5.1 Future Strategies

Addressing consumer's risk perception does not stop at improving the functional aspects of smart metres and should not be a top-down approach taking only the policymakers' perspective into account. Risk perception is more complicated than that and to understand it, it is critical to consider the emotional, cultural and social aspect to approach it. People's perceived risk should not be seen as just a lack of understanding or knowledge, it has a complex relationship with their values, their conditions, where they live and most importantly how credible they think the institutions are. Users are unique and strategies should consider their differences to be able to address their specific concerns and especially avoid generic approaches.

Based on the literature and on the conclusions of this review, it is clear that including the public early in the process proves to be one of the most effective ways to decrease perceived risk. Whether it was the planning phase, the testing phase, design phase or the deployment phase, when people feel included and important for the success of smart meters, they tend to trust the technology and the institutions behind it more. The public does not only want to be on the receiving end, they want their energy providers and regulators to take their feedback and perspectives and incorporate it from the start. These institutions would benefit from community meetings or citizen panels that deliver input from the public, raise awareness on specific concerns and provide a space where people can ask questions and feel heard.

This review also suggests that top-down communication is no longer effective. In order to reduce risk perception, more attention should be given to how the information is delivered and how to encourage more trust in that information. Authorities assume that information shared by them will automatically be received positively by the public, and this is far from the reality especially when the communities do not even trust that authority. Institutions should switch their approach and include other entities that seem to convince the public more easily. These entities can be NGOs, independent organizations, local energy activists and groups that feel closer to the public and can deliver messages that make the public feel they have their best interest in mind. Not only is the delivery of these messages important but also their content should be adapted to the unique local needs and should be easy to understand using different formats and languages. Also, these messaging are the first connection between users and smart meters, so their content should not be general information, should actually address what people might be afraid of and be able to provide answers to their questions.

Additionally, to reduce consumer's risk perception, the public needs to be reassured that institutions can be accountable. Meaning that if energy providers or governments seem to be unsupervised or have absolute freedom, people are more suspicious and disregard any reassurances coming from them. To address this issue and build trust, policymakers should involve external experts and perform

independent audits of smart meter programs and make assessments related to data protection available to the public.

Privacy concerns are the biggest concern for the public, and institutions should continuously evaluate and improve privacy and data protection measures. Not only should data security be a priority, the type and amount of data collected should also be restricted. Energy providers should only collect data that is necessary for billing and managing the system, and they should always make sure that the users have given their full consent. Energy providers should also facilitate users' access and control over their data. This can be achieved through dashboards that use easy and clear language and have features that guide users, regardless of their level of digital literacy, to understand and see clearly what type of data has been collected, who sees it and uses it and in what manners it is being used. Users should also have the choice to limit or stop their data from being shared, or in extreme cases, withdraw completely from participation, this could give users a sense of control.

Another important point that should be prioritized is the inclusion of all stakeholders, making sure that every user has access to the same benefits. Users like the elderly, migrants, renters, low-income households and other vulnerable groups perceive risk differently and that is mainly due to the challenges they face whether regarding the functionality of the technology, the costs that might come with it or security issues. These groups should receive much more attention and help from institutions and this help can be in the form of subsidized or free installations, online and in-home guidance and overall support for the users to familiarize with the technology. From an engineering perspective, smart meter designs should be universal and should use large fonts, voice control and easy settings that can be easily used by any and every user.

Smart meters offer a generic system that assumes all households are the same. This cannot be true because every household has their own routines, habits, schedules and members. Therefore, these systems should be more flexible and consider the different needs of each household. Users should be given the choice to adjust their smart meter system, whether it was the time of installation, the use of specific features or how they prefer to receive feedback. This flexibility should also be reflected in the pricing models because different households prefer different options. Energy providers should offer their users different plans like prepayments, fixed rates or dynamic pricing and let them choose what they feel is the best option for them. This way, users can have more control over personalizing their choice and this would help them plan for any future costs.

And lastly, community plays a big part in consumer's risk perceptions and is usually overlooked by regulators and policymakers when they address the public. People share their stories and experiences with their communities and social groups. The public puts great importance in these discussions because they reflect what is actually happening. These communities can have different individuals that come from different groups who can share their unique experiences, stories and testimonials from early users making people feel closer to them and showing them that smart meters helped them change their consumption, reduce their energy use and decrease their bills and that these devices are for everyone.

5.2 Future Research

There has been considerable research done on smart meter adoption, however there are still some limitations and gaps that still need more attention. To provide a better understanding of this topic, a couple of suggestions for future research will be mentioned in this section.

It is important for future research to delve deeper into the real reasons and motivations behind consumers' decision-making. It is critical to approach this topic from a consumer's perspective by investigating their engagement, their expectations, their experiences whether related to the technology itself, the regional context, or their individual characteristics. This is especially necessary as the connection between smart meters, institutions and consumer perceptions is a complex one.

Firstly, there is a need for further investigation of longitudinal studies that follow consumers from the point of installation to how their behavior changes towards smart meters after time. In the literature reviewed, studies rely on data from before or directly after installation and connect that data to acceptance rates and perceived risks, missing completely that habits and behavior can change over time, be it months or years. This is why following users over a long period would reveal more about the consumers, if their engagement and participation with smart meters diminishes or increases over time, if their trust in institutions stays the same and if new concerns might emerge.

Not only will these studies help understand consumers' viewpoint, it will also be helpful for policymakers to evaluate the policies, incentives and tools that are put in place and are available to users in order to support long-term sustainable behavior.

Consumer behavior is not the only driver for decision-making. Region and culture play a big part in forming that behavior, it also influences their opinions about these technologies therefore impact consumer's risk perceptions. Although investigating Europe as a whole can give a general image about smart meter adoption, it does not show differences that are specific to each country. For example, some countries, like Switzerland, Germany and Sweden, have a higher level of institutional trust and view smart meters as the important next step for sustainability, and this result is a faster and more effective smart meter deployment. However, in other regions like in Eastern and Southern Europe, that experienced political conflicts and unstable governments, the public is very wary of any initiative coming from authorities, including smart meters technologies, which in turn affects their deployment and adoption rates.

Identifying these differences can give future research a new point of view that does not only compare countries with each other, but actually understand the differences within those countries like the economic standing of each region, urban and rural differences, and minorities. Qualitative methods can be used to reveal such differences, investigating culture, history, politics, media, and social norms that have proven to influence consumer's views and provide a start point for policymakers to design policies and strategies that take these differences into account.

Additional research is also needed to evaluate the Advanced Metering Infrastructure (AMI) and assure that the infrastructure is accessible to all sides and does not exclude any stakeholder because how the information is laid out can be easier for some more than others and can neglect the diversity of the people receiving it. Not all users are comfortable with technology and understand it easily, and this is where smart meter designs seem to be lacking, assuming that all users are the same. Elderly, people with disabilities, illiterate people or those who face language barriers might not approach smart meters like the rest.

Future research should focus on this angle and investigate how changes in smart meters to include bigger screens, visual and audio instructions, different languages, and different layouts can make participation for these users easier and improve their understanding and engagement. This can be tested by observing how different users interact with different designs and would help in designing an infrastructure that is inclusive. It can also be helpful to include these vulnerable populations early in the process to get their feedback that would help create solutions that directly address their needs. Smart meters are now becoming a big part of smart energy systems and will be part of every home, therefore there is an urgency to address these gaps and make sure that smart meters will not exclude any user.

In addition, the literature would benefit from research that studies how intermediaries and trusted third parties can be beneficial to communicating smart meters. Research mainly focuses on the relationship between consumers and energy providers, governments, institutions, and regulators, not mentioning the role of intermediaries in influencing and changing people's views about any topic, and especially in this case, smart technologies. The public seems to trust information coming from these groups and have higher relational trust, that the governments and official authorities do not have, and this trust is even lower in regions that had previous bad experiences with institutions. Investigating how these intermediaries can build trust and influence the public opinion would be beneficial and could help different governments decide the best ways to include these groups in the deployment process and build policies that support them. This approach could help identify what kind of resources are needed for these groups to help address problems that the official institutions are struggling to solve.

Intermediaries are not the only external entities that form the public' opinions and views about smart meters. Family, friends, neighbors and even online groups influence people's viewpoints. Understanding their connections and interactions can help show how communities talk about trust and acceptance and influence each other.

6 Conclusion

At the end of this paper, this review was able to give a thorough and unbiased view of the challenges that smart meters face and the barriers that are affecting its adoption in Europe. Our conclusions found that even though the sources show that smart meters are supported by strong technical foundations combined with strict policies, they can only reach their full potential if the public accepts and adopts these technologies. One of the first conclusions is that smart meter adoption relies on

consumer's opinions and feelings about it as much as the performance of the devices. This is where risk perception, trust, regional differences and communication comes in. The first concerns discussed in the review are privacy concerns. People fear their data could be used for ulterior reasons. This concern seems to be present even when protections like GDPR are in place. The second concern is financial and cost concerns, these mainly include fear of unexpected charges, confusing saving models, that especially low-income households and disadvantaged communities seem to base their decision-making on. And this is where misinformation and low customer engagement further fuel those fears. And this is also the case for health concerns that are not backed by any scientific evidence but persist in the public, especially concerning electromagnetic emissions.

Our second conclusion is that social norms, institutional trust and feelings form the different opinions and perceptions consumers have related to smart meters. Consumers do not just choose the technology, rather they rely on their feelings and experiences to form their opinions about it before adopting it. The public can still refuse to adopt smart meters even if they prove to be effective and secure. Another conclusion derived mainly from studies comparing different countries is that we can see the importance of institutional trust and communication. Germany and the Netherlands were an example of successful and higher deployment and adoption rates because people feel involved and informed. Other examples show the opposite, in countries like Poland where there is weak communication and misinformation is circulating, the risk of rejection is high. This is the reason for switching to two-way communication that includes and supports all sides. Our conclusion shows that the behavioral and social issues will not be solved only by upgrading the technology.

Despite the various topics and methods used in the sources reviewed in this paper, some important gaps were noticed. The first gap is the absence of studies about health risks and how it also influences consumer's decision-making. Research seems to miss this part even though these concerns are expressed frequently on social media and by consumers and play a part in the slow smart meter deployment. This absence does not only make the research about smart meters incomplete but also can be a blind spot for policymakers and a weakness that might affect the effectiveness of their strategies. Research also does not investigate deeper the financial side of the adoption. Only a few studies covered the topics of pricing models, savings and how that impacts specifically low-income households. Another gap is that most studies do not follow the progress in a long period of time. If they cannot compare the initial data with the results overtime, they might not be able to define the real reasons behind these concerns. There is also the uneven representation of European countries, as most research relies on data from Western and Northern Europe and the EU, excluding the Eastern and Southern regions that have completely different policies, experiences, consumer habits and culture which are important to compare risk perceptions between different countries. The last gap noticed in this review is the limited research on trust and communication that does not conduct actual experiments and tests that might help design future strategies.

This paper argues that risk perception has a significant role in smart meter adoption, it even surpasses technical flaws and gaps in regulation. The presence of legal protections alone is not enough for people to feel certain and trust the technology and the institutions. Statistics and facts do not replace emotions, social norms, trust, control and privacy, factors that seem to influence risk perception and are much more impactful than they seem. The public might perceive smart meters

as a threat to their finances, health, privacy and autonomy which in result leads to resistance or even rejection of the technology. However, when people feel seen, for example being included in the process, and their concerns heard and used to develop strategies that address their fears, perceived risk slowly decreases and people are more probable to adopt the smart meters. Therefore, understanding the multiple aspects of risk perception will benefit policymakers to build trust and long-term engagement.

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8 Appendices

Focus theme	References
Adoption & Engagement	(Batalla-Bejerano et al., 2020)
	(Sun et al., 2023)
	(Hafner & Raimondi, 2020)
	(Biresselioglu et al., 2022)
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Health Concerns	(Draetta, 2018)
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Source	Link
European Union	https://european-union.europa.eu/index_en
European Commission	https://commission.europa.eu/index_en
International Energy Agency	https://www.iea.org/
Vlaamse Regulator van de Elektriciteits- en Gasmarkt	https://www.vlaamsenutsregulator.be/nl
Bundesministerium für Wirtschaft und Energie	https://www.bmwk.de/Navigation/DE/Home/home.html
European Committee for Standardization & European Committee for Electrotechnical Standardization	https://www.cencenelec.eu/
Forschungsstelle für Energiewirtschaft	https://www.ffe.de/
Environmental Health Trust	https://ehtrust.org/
International Agency for Research on Cancer	https://www.iarc.who.int/
Council of European Energy Regulators	https://www.ceer.eu/
Agency for the Cooperation of Energy Regulators	https://www.acer.europa.eu/

Abbreviation	Definition
SEM	Smart Energy Systems
ICT	Information and Communication Technologies
EGD	European Green Deal
FF55	Fit for 55
GDPR	General Data Protection Regulation
IEA	International Energy Agency
BMWK	Bundesministerium für Wirtschaft und Energie
CEER	Council of European Energy Regulators
ACER	Agency for the Cooperation of Energy Regulators
EDPS	European Data Protection Supervisor

DPIA	Data Protection Impact Assessment
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
VREG	Vlaamse Regulator van de Elektriciteits- en Gasmarkt
FfE	Forschungsstelle für Energiewirtschaft
IDS	Intrusion Detection Systems
PRISMS	The PRIvacy and Security MirrorS
EHT	Environmental Health Trust
IARC	International Agency for Research on Cancer
CERRE	Centre on Regulation in Europe
NIS	Network and Information Systems
ENISA	European Union Agency for Cybersecurity
EE-ISAC	European Energy Information Sharing and Analysis Centre
CEEDS	Common European Energy Data Space
RF	Radiofrequency
EMFs	Electromagnetic Fields
EHS	Electromagnetic Hypersensitivity
NGO	Non-governmental organisations
AMI	Advanced Metering Infrastructure