National case study report #4

Germany's delayed electricity smart meter rollout and its implications on innovation, infrastructure, integration, and social acceptance

An ex-post analysis

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Abstract

To achieve climate neutrality by 2050, the EU must digitalise its energy systems and facilitate the electrification of its economies. Smart energy grids combine energy production, storage and consumption and play a key role in this path. Within this smart energy grid, smart metering systems serve as intelligent communication technologies that can empower consumers and energy suppliers by providing valuable data to monitor energy generation and consumption. They have the potential to enable fair electricity prices and increase energy independence. To address the digital as well as the green transition, the EU first mandated its member states to roll out smart meters back in 2009. Today, we can observe a heterogenous implementation among EU countries, with Germany lagging far behind. To investigate the reasons for Germany's delayed smart meter rollout, we conduct an ex-post analysis of the European and German legislative framework in the period of 2009 – 2021, and beyond. In particular, we conduct a process-tracing of Germany's Metering Point Operation Act (*Messstellenbetriebsgesetz, MsbG*), which is the key policy governing the country's smart meter rollout. Moreover, we analyse the policy's transformative character by investigating its implications on innovation, infrastructure, integration, and social acceptance. We find that a lack of regulatory intervention in the early phase, an overregulated market and a weak governmental framework in the later phases delay the German smart meter rollout and that it was not a successful transformative approach. To validate our findings we held five semi-structured interviews with relevant stakeholders in the field.

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List of abbreviations

CBA	Cost-Benefit Analysis
BSI	Bundesamt für Sicherheit und Informationstechnik
EIA	Energy Industry Act
EnWG	Energiewirtschaftsgesetz
EU	European Union
FOIS	Federal Office for Information Security
HAN	Home Area Network
NRW HAC	North Rhine-Westphalia Higher Administrative Court
kW	kilowatt
kWh	kilo-watt-per hour
MHz	megahertz
MPOA	Metering Point Operation Act
MSbG	Messstellenbetriebsgesetz
LMN	Local Metrological Network
SMGW	Smart meter gateway
TAF	Tarifanwendungsfälle (tariff use cases)
WAN	Wide Area Network

Executive summary

To achieve climate neutrality by 2050, the EU must digitalise its energy systems and facilitate the electrification of its economies. Smart energy grids combine energy production, storage and consumption and play a key role in this path. Within this electricity network, smart metering systems serve as intelligent communication technologies that can empower consumers and energy suppliers by providing valuable data to monitor energy generation and consumption. Moreover, they have the potential to enable fair electricity prices and increase energy independence.

To address the digital as well as the green transition, the EU first mandated its member states to roll out smart meters back in 2009. Within its smart meter framework, it requested certain minimum technical requirements such as transparency relating to energy consumption levels, the offering of varying price tariffs, the ability for sector-coupling as well as data protection and security measures.

Today, we can observe a heterogenous implementation among EU countries, with Germany lagging far behind. To investigate the reasons for Germany's delayed smart meter rollout, we conducted an ex-post analysis of the European and German legislative and technological framework in the period of 2009 – 2021, and beyond. Thereby, we use a process-tracing to follow different legislations through time. In particular, we examine Germany's key policy governing the country's smart meter rollout – the Metering Point Operation Act (MPOA) (*Messstellenbetriebs-gesetz, MsbG*) and what factors therein slowed down the rollout.

EU policymaking needs to move from an incremental policymaking approach to one that can achieve a transformation across all sectors – addressing all its technological, economic, political and social implications. To analyse if Germany's smart meter rollout strategy and supporting policies are of a transformative character, we investigate how the key policy impacted the core challenges to transforming our economies: innovation, infrastructure, integration, and social acceptance. The analysis is supported by a systematic literature review and five expert interviews.

We find that a lack of regulatory intervention in the period 2005 – 2012 in Germany's stance at kick-starting its smart meter rollout created uncertainties among market players. In other words, due to both unclear guidelines and standardised technological requirements, the market alone was unable to foster technological diffusion.

In the period 2013 – 2019, the German government finally took action by providing a more precise smart meter framework and introducing supporting regulatory policies. With the aim to meet the EU's minimum technical requirements and data protection measures, Germany opted for a highly complex smart metering system in 2013. As such, it mandated the installation of the smart meter gateway. A smart meter gateway collects energy-related data and ensures secure communication thereof to the relevant stakeholders. Further, the German government would only give the green light for a smart meter rollout, once at least three independent manufacturers developed devices that were in line with the MPOA, i.e. the technical requirements. The analysis shows that this highly complex technical system and stringent regulation took years to be implemented on the ground. Only by December 2019, three market players had managed to develop suitable smart meter gateways. In February 2020, the German smart meter rollout could finally start. This was a late start in comparison to other EU member states. For example, Italy, the Netherlands and France were already in the second phase of their smart meter rollout at that time. Therefore, it seems that overregulation slowed down the German smart meter rollout.

On top of that, in 2021, the High Administration Court of the state Northrhein-Westphalia ruled that the FOIS – the responsible authority for the formal certification process of these technical devices – had unlawfully published the market declaration of three independent manufacturers. The FOIS simplified the standardised technical guidelines as it acknowledged the struggle by market players to implement them. However, it did not have the competency to do so. For this reason, the smart meter rollout was further delayed and only in 2022, the German federal government decided to simplify the technical requirements and adopted an amended MPOA, which came into force on 1st January 2023, in the hope of a re-start of the smart meter rollout.

Moreover, in this case study, we investigated whether the German approach to a large-scale smart meter rollout was transformative within the context of the core aspects of transformation: innovation, infrastructure, and integration. We find that the German government did not design a transformative rollout. For example, for these innovative technologies to become market-ready, a dedicated policy that eliminates uncertainty for market players should have been adopted from the start. We also learn that without the right infrastructures – a smart grid – the installation of smart metering systems becomes less attractive to end users. The analysis of the German legal framework showed that the aspect of interoperability, the technical feature that allows sector coupling and empowers end consumers to participate in the energy transition, was not implemented by smart meter developers. With the rise of renewable energy sources in the system and decentralised energy models such as energy communities, the integration of smart meters into the sectors of mobility or heat and cool provides great potential if we want to reduce fossil-based energy production and reach climate neutrality by 2050.

For future policymaking, we make the following four recommendations. First, to foster technological diffusion, governments should provide clear guidance to relevant stakeholders. In the early phase of the German smart meter rollout, 2005 - 2012, the German government stated that it would soon provide supporting regulation with regard to technical requirements. By promising such legislation, without delivering on it for several years, the German government created additional uncertainty for producers and consumers of smart meters. It created the expectation that legislation was on its way, incentivising producers and consumers to wait for this new legislation, thus, creating a disincentive to innovate.

Second, policymakers should monitor the rollout of transformative innovations more closely and react in a fast and flexible way to signals from the ground. Although the FOIS amended the policy even though it did not have permission to do so, it was only due to the court ruling that the federal government was informed about a needed policy change. Following, it took the central government one year and a half to amend the policy to then announce a re-start of the smart meter rollout on 1st January 2023. To meet the Paris climate agreements, policymakers should react immediately to signals that a rollout of an important technology is not progressing sufficiently fast. Due to the urgency of the issue, a 'wait and see' attitude that leads to unnecessary delays is a luxury that we do not have.

Third, governments should provide a strong governmental framework. Transformative policy often requires inter-governmental cooperation. The ex-post analysis of the German smart meter rollout shows that this aspect was not met. The lack of cooperation between the FOIS and the central government led to an unlawful certification process that further delayed the smart meter rollout.

Fourth, to avoid unnecessary costs and increase social acceptance policymakers should ensure that smart meters that do not yet comprise all technical functions are easily and cost-effectively able to be upgraded. As shown in this study, the inability to implement this feature in practice led to unnecessary costs and a re-certification process – in short, a further delay of the smart meter rollout.

Overall, this case study shows that to achieve the digitalisation of our energy systems and reach climate neutrality by 2050, policymakers must take a truly transformative approach and simultaneously address the core challenges of innovation, infrastructure, integration, and social acceptance. Future research should also include investment needs and the costs that relate to a smart meter rollout, e.g. the digitalisation of our energy networks and the extension of supporting infrastructures.

1. Introduction

Energy efficiency means using less energy for the same or even increased output (UNEP, 2023). In today's climate and energy crises, reducing energy consumption is becoming ever more prominent. It is also one of the key drivers for the European Union (EU) to reach its ambitious climate targets and to become the first climate-neutral continent by 2050 (European Commission, 2021).

In 2006[1], the European Union (EU) first acknowledged the potential of smart metering systems within the context of energy savings. With the aim to liberalise its energy markets[2], the EU mandated its member states to conduct a smart meter rollout to at least 80% of consumers by 2020 unless a cost-benefit analysis (CBA) was negative. In 2019[3], with the adoption of the New Green Deal, the European Parliament and Council passed a revised directive that made a full deployment of smart metering systems in the Member States mandatory.

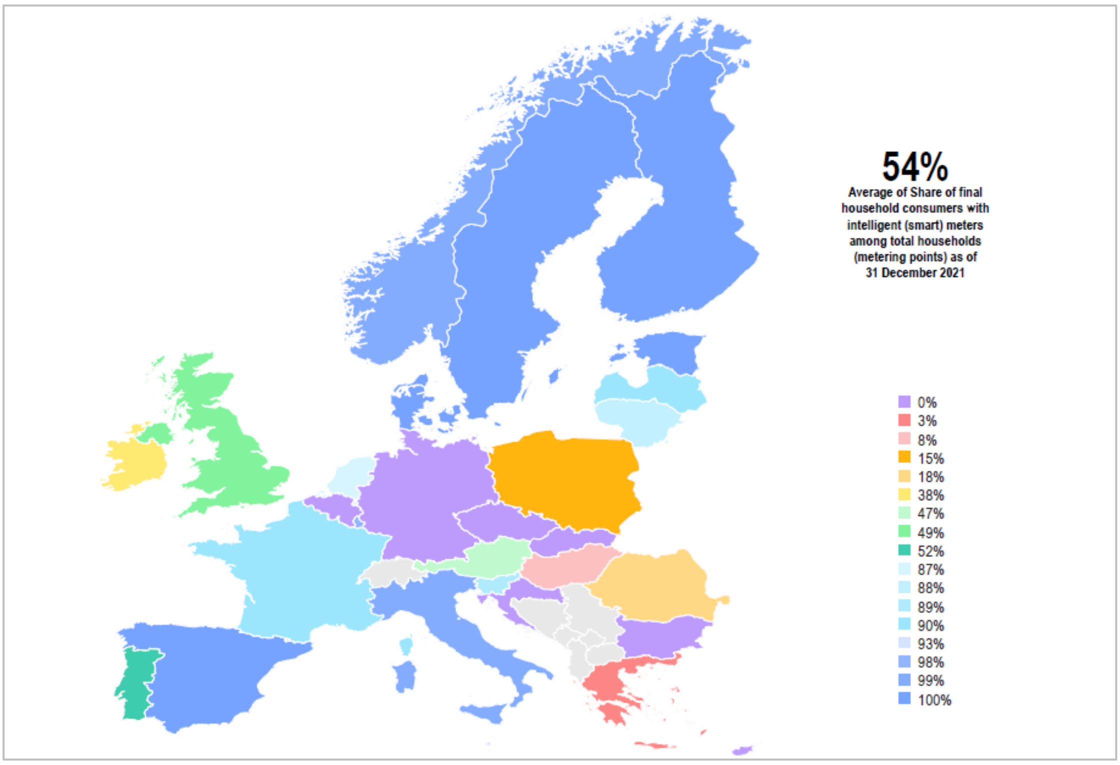

Figure 1 Status quo of the rollout of electric smart meters at the end of 2021
Source: ACER CEER 2022 - Annual Report on Monitoring the Internal Energy Retail Markets and Customer Protection Measures in 2021.

Current analyses show that there is a heterogenous smart meter rollout in Europe (ACER CEER, 2022). For example, in 2021, eleven member states reached a roll-out rate of 80% or higher.

[1] European Union Directive on Energy Efficiency 2006/32/EC.
[2] European Union Directive Common Rules for the Internal Market for Electricity 2009/72/EC.
[3] European Union Directive on Common Rules for the Internal Market for Electricity (EU) 2019/944

Figure 1 shows that this was achieved by the countries of Denmark, Estonia, Finland, Italy, and Spain. For Germany, on the contrary, the data shows a less favourable outcome: Only a small fraction of consumers are currently equipped with smart metering systems (Ibid.). Bergsträßer (2022) finds that in 2020, Germany had only reached a smart meter rollout of 0,057%, the year the EU had envisioned for its member states to reach a smart meter rollout of 80% if it was feasible. So why has the rollout been such a slow affair in Germany?

To investigate the reasons for the delayed smart meter rollout in Germany and to uncover how transformative the country's approach has been within the context of innovation, infrastructure and integration, we assess the following two research questions:

I. **What main factors delayed the smart meter rollout in Germany?**

II. **What are the implications of the delayed rollout on the 4i-dimension[4]: innovation, infrastructure, integration, and social acceptance?**

   a. How has the German approach impacted innovation in terms of technological diffusion, the creation of new business models and policy innovation?

   b. How has the German approach impacted the establishment of new infrastructures?

   c. How has the German approach impacted integration into the electricity network?

2. Case study design, method and data sampling

To answer the first research question, we conducted a qualitative ex-post analysis covering the period 2009 – 2021 and beyond of Germany's smart meter rollout. Looking back enabled us to find factors that caused a delayed implementation process of the EU's strategy for an EU-wide smart meter rollout at the national level. Thereby, we took a three-step approach. First, we analysed the European and German legal frameworks that supported Germany's smart meter rollout. This was supported by an extensive literature review. Second, we conducted a within-case study by evaluating Germany's key policy that paved the way for the country's smart meter rollout. Third, to validate our findings, we held five semi-structured interviews with relevant experts in the field.

To answer the second overarching research question, we added another dimension of analysis. We investigated the transformative aspects of Germany's approach within the context of

[4] In line with the 4i-TRACTION project, the four core challenges to transformative climate EU policy are innovation, investment & finance, infrastructure and integration.

innovation, infrastructure and integration. We provide further information on the methodology and sampling in the next sections.

2.1 Legal analysis of EU and German framework

To uncover how effectively EU policy (smart meter rollout) was implemented at the national level (Germany), we first analysed the European framework for the installation of smart metering by focusing on governance and technological aspects. In particular, we investigated the following EU legal documents: EU Internal Market Directive 2009/72/EC, the Energy Efficiency Directive 2006/32/EC, the Energy Efficiency Directive 2012/27/EC and the Measuring Instruments Directive 2004/22/EC, Commission Recommendation of 09 March 2012 on preparations for the roll-out of smart metering systems (2012/148/EU), which formulates minimum requirements for smart meters.

2.2 Within-case study: Germany's key supporting policy

After identifying the European legal framework and its objectives, we examined the German governance framework. In 2016, Germany passed its key policy that supported a national smart meter rollout – the Metering Point Operator Act (MPOA) (Messstellenbetriebsgesetz (MsbG)). The aim of the MPOA was to create a technical infrastructure for the energy transition by introducing smart measuring devices and systems. By process-tracing Germany's approach, in particular the MPOA, we found key factors that posed a challenge and hence slowed down the country's smart meter rollout. An extensive literature review of academic articles, legislative documents, technical reports, and news articles supported the analysis.

2.3 Transformative aspect of Germany's approach to roll out smart meters

For the EU to become climate-neutral by 2050, transformative policy needs to impact all sectors, our economies, governance frameworks and societies over the coming decades (Görlach et al., 2022a). To achieve this, four key criteria must be met: First, policymakers must think backwards from the end. Second, we must design policies that overcome existing and future path dependency and lock-in risk. Third, transformative policy must support the development of institutions that are capable of delivering transformative change. Fourth, policy must foster integration across sectors and embed technical changes in a broader political and socio-economic process. Without societal support for these aspects, the transformation will be hard to achieve. Therefore, policy must also address social aspects such as changes in behaviour, routines and processes (Görlach et al., 2022a).

To understand if Germany designed a smart meter rollout of a transformative nature, we investigated the country's strategy on the following three aspects: innovation, infrastructure and integration. A key challenge in this task was the limited availability of data. Since the German smart meter rollout has only recently gained some traction, reporting and evaluation studies are still an ongoing process. We, therefore, supported our analysis with desk research of academic literature, articles and technical reports. We also included insights from other member states, e.g. Italy, Sweden and the Netherlands. In the next sub-chapters, we outline how we define these in this study.

2.3.1 Innovation

In this study, we understand innovation as technological innovation and business model innovation. These innovations can bring solutions to enable climate neutrality. Within technological innovation, the focus is on technologies that are ready for the market but still require (accelerated) market mainstreaming. This also includes new market creation, e.g., business models, products, processes and services. Innovation also includes policy and governance innovation (Görlach et al., 2022a). This can either happen via diffusion (the spreading of a novel policy instrument or governance mechanism from one jurisdiction to another) or via invention – the creation of an entirely novel instrument/mechanism (Görlach et al., 2022a).

In the case of smart meters, a rollout establishes a new market for new technologies and products as analogue devices are replaced with digital metering systems. As a result, there is a need for a new modus operandi. Only when markets and the way we handle energy demand and supply adjust, can they enable technological diffusion (Grubb et al., 2013).

2.3.2 Infrastructure

Infrastructure is also an enabler to transition from fossil to renewable energy sources. However, without supporting infrastructure, new low-carbon technologies cannot be mainstream. In the mobility sector, this applies to electric vehicles, which are dependent on a widespread infrastructure of charging stations (Grubb et al., 2013).

Infrastructure needs to enable communication between relevant actors so that we can transport, monitor and assess electricity demand and supply. Thereby, a digitalised energy network needs to be expanded and strengthened to support changing patterns that come with the transformation of our energy systems (Görlach et al., 2022a).

As such, the rollout of smart meters plays a key role in the digitalisation of the energy sector by establishing a whole new system of communication and information between numerous entities at different levels. The case study can help to identify both pitfalls and possible success stories in complex infrastructure projects. The German case provides useful lessons in the challenges of upscaling innovations while their development is still ongoing, and on the trade-offs that policymakers have to navigate through.

2.3.3 Integration

To transform the energy sector we need to take a holistic approach. This comprises addressing all energy fuels, technologies, infrastructures, governance mechanisms and new modes of energy production and consumption. Sector coupling – when new technologies interconnect sectors that used to employ their own specific energy carriers, e.g. links between power and transport (through electric vehicles), power and heating (through heat pumps and power-to-heat) and power and industry (through electrolysers and other power-to-x technologies) – is an important example of transforming our systems as a whole. For instance, solar power produced on the roof of a building can be used to charge an electric car nearby (Görlach et al., 2022a; Olczak and Piebalgs, 2018).

The rollout of smart meters has the potential to foster the implementation of combined photovoltaic systems, heat and power systems or other controllable energy-consuming or energy-providing appliances (e.g. systems of electromobility) and thereby contributes to the integration of the sectors of electricity, heating (or cooling), transport and industry.

2.3.4 Social acceptance

Transformative policy will induce structural change. As we need to change the way we behave, this transformation can be perceived as a disruption of our 'business as usual'. Social acceptance is seen as a crucial prerequisite for the success of the energy transition (Görlach et al., 2022a).

This case study provides valuable insights into the interplay of legislative processes and social acceptance of the energy transition.

2.4 Semi-structured expert interviews

In the third and last step, we held five semi-structured interviews with relevant experts to validate our findings. Table 1 provides an overview of the interviewees. The experts were purposively sampled to guarantee data provision. We contacted the experts by email. Four interviews were conducted by video/ telephone online tool, took around 30-40 minutes, and were not recorded. One questionnaire was answered in writing. Table 4 in the Annex lists the six open-ended interview questions. To increase our understanding, we slightly adjusted or asked additional questions when appropriate (Eisenhardt, 1989).

Table 1 List of interviewees by member state, organisation, type of actor, market role.

No.	Member State	Type of actor	Market role
1	Italy	Academia	Research
2	Germany	Industry	Consultancy Smart Meter and Grid
3	Germany	Industry	Energy provider
4	Germany	Industry	Energy provider
5	Germany	Government	Regulator

3. Background: Smart meters

In this section, we explain the role of smart meters in the transition of our energy systems.

A smart meter is a technical device that runs on a digital system and collects and transmits data about energy supply and demand. Smart meters are seen as a key lever in the energy transition as they provide valuable data on how we consume and produce energy. For example, smart meters can measure and monitor electricity usage more accurately and frequently. This can induce more efficient and cost-effective energy behaviour (European Commission, 2023; Knayer and Kryvinska, 2022). On average, smart meters provide savings of €270 per year for electricity per metering point (distributed amongst consumers, suppliers, distribution system operators, etc.) as well as an average energy saving of at least 2% and as high as 10% based on data coming from pilot projects (European Commission, 2023).

By integrating smart meters into the electricity network, they also enable the monitoring of electricity feeds into the grid and electricity usage from the grid. Energy providers are able to offer load-dependent tariffs to which a smart home system can react, once the smart meter receives the information. In other words, end users can use their electrical appliances, such as the washing machine, when electricity is the cheapest.

To managers of the grid, smart meters provide valuable information on the quantity of power supplied from renewable energy sources. This enables them to stabilise the network by better planning their investments and being able to respond to the requirements of their customers. This also reduces costs for network operation and maintenance (European Commission, 2023).

Moreover, smart meters empower end users to become active in the energy transition. Electricity production from for example domestic photovoltaic and attached batteries enables end users to sell excess energy by providing it back into the grid or sharing it within their energy community.

With increased renewable energy sources and the digitalisation of our buildings and transport sectors, smart meters can also offer the potential for sector coupling when connected to the smart grid. This not only lowers energy bills but also increases energy independence (JRC, 2021).

4. Results

In this section, we demonstrate how the lack of regulatory intervention in the early phase of Germany's smart meter rollout did not kick off technological diffusion (section 4.2.1). We also show how technical complexity as a consequence of technological requirements lead to overregulation that hindered technological progress (section 4.2.2), and how institutional failure lead to a halt of the German smart meter rollout (section 4.2.3). Moreover, we find that due to these factors, the German smart meter approach cannot be classified as a successful transformative policy within the context of innovation (section 4.3.1), infrastructure (section 4.3.2), integration (section 4.3.3), and social acceptance (4.3.4).

4.1 European legal framework provides leeway to member states

The analysis of the European legal framework shows that several legislative measures form the basis for a smart metering deployment in Europe (Figure 2). By providing a minimum set of technical specifications, member states were given leeway on how to implement European legislation for smart metering into domestic legislation.

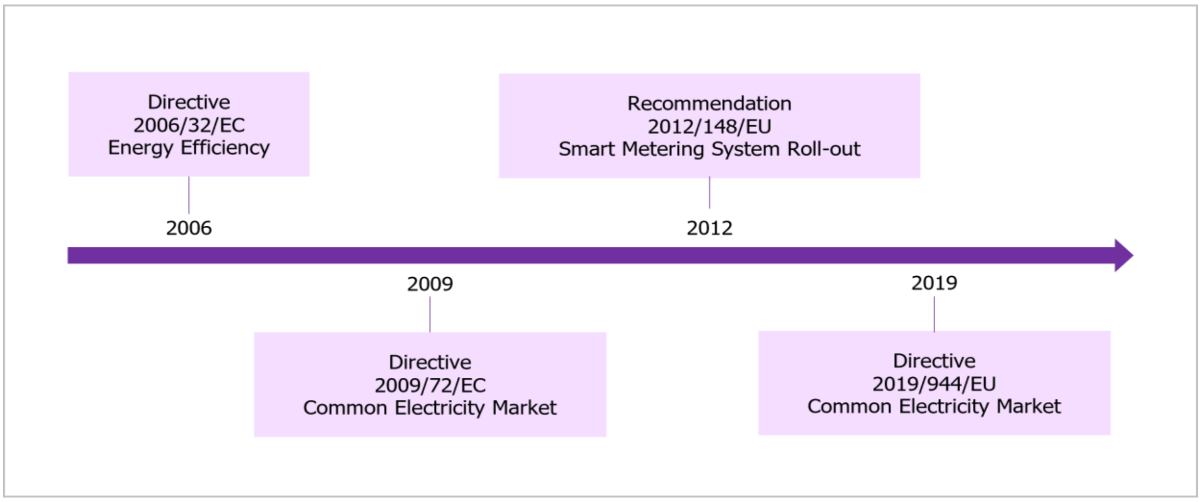

Figure 2 Timeline of key EU smart metering legislation
Source: European Commission, own visualisation.

The use of smart metering systems (then "intelligent metering systems") was first mentioned in the EU's directive 2006/32/EC (European Parliament and Council, 2006). With this directive, the EU aimed to improve the security of the energy supply, reduce the end-use of energy by increasing energy efficiency and foster the promotion of renewable energy production. Thereby, these digital energy-saving technologies were seen as a lever to boost technological innovation and competitiveness. While the EU did not prescribe any technical requirements in this directive, it mandated member states to ensure that final customers were provided with meters that informed about real energy consumption levels at the actual time of use. At the time, the installation of smart metering was voluntary with the exception of new buildings and buildings that underwent major renovation (European Parliament and Council, 2006).

In its 2009 directive for a common internal electricity market[5], the EU became more precise by making the use of smart metering mandatory for all in case of a positive outcome of a cost-benefit analysis (European Parliament and Council, 2009). Member states were to equip 80% of their end users with smart metering technology by 2020. The EU's countries had to conduct a CBA by 2012 and repeat it every four years in case of a negative outcome or more frequently in line with technological and market developments. Also in this directive, the EU did not set any specific technical requirements but mandated member states to develop and publish technical safety criteria for the technologies' design and operational functions so that they directly connect to the consumers' equipment and the power generating and distributing network. However, in line with appropriate standards, member states or the designated authority were obliged to consider the aspect of 'interoperability' when developing smart metering systems. This function allows for several energy types to connect to sectors that would usually not interact. In other words, it enables sector coupling.

With the increasing digitalisation of our energy systems, smart grids play a key role in improving energy production, energy efficiency and security. At the same time, they also pose new security and privacy risks as they connect various actors and systems, and share information and data. It is therefore not surprising that the European Commission put great emphasis on data security, protection and management in its 2012 recommendations for a large-scale smart meter rollout in Europe (European Commission, 2012). Thereby, it introduced the *'data protection by design'* principle which demands that member states build data protection and information security features into smart metering systems before they are rolled out. To test whether the technological devices meet these requirements, member states were to conduct data protection assessments prior to the rollout. Noteworthy, in these recommendations the European Commission provided member states with guidance by, for the first time, defining smart metering systems:

> "'*smart metering systems means an electronic system that can measure energy consumption, adding more information than a conventional meter, and can transmit and receive data using a form of electronic communication*'" (Recommendation 3, b).

The European Commission also prescribed a set of ten mandatory common technical requirements taking into consideration the sides of the customer, the metering operator, commercial aspects of energy supply, security and data protection and distributed generation:

1. Provide readings directly to the customer and any third party designated by the consumer.

[5] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 repeals Directive 2003/54/EC. It sits under the EU's 2008 Energy Package that addresses the reduction of greenhouse gas emissions, renewable energies and energy efficiency.

2. Update the readings frequently enough to allow the information to be used to achieve energy savings.
3. Allow remote reading of meters by the operator.
4. Provide two-way communication between the smart metering system and external networks for maintenance and control of the metering system.
5. Allow readings to be taken frequently enough for the information to be used for network planning.
6. Support advanced tariff systems.
7. Allow remote on/off control of the supply and/or flow or power limitation.
8. Provide secure data communications.
9. Fraud prevention and detection.
10. Provide import/export and reactive metering.

Seven years later, in 2019, the European Parliament and Council adopted the amended version of the EU's Internal Market Directive for Electricity (Directive (EU) 2019/944). Thereby, it translated the European Commission's recommendations on technical requirements for smart metering systems. While these had not changed, the EU focused on the role of smart grids and the integration of renewable sources in the internal energy market (European Parliament and Council, 2019). Member states and regulatory authorities were mandated to facilitate cross-border access for new suppliers of electricity from different energy sources as well as for new providers of generation, energy storage and demand response. Moreover, the directive allowed citizen energy communities to become distribution system operators by ensuring easy market entry, operation and exit to all categories of entities. No regulatory restrictions should exist when applying information and communication technologies – smart metering systems – to share electricity produced among communities' shareholders. Smart metering systems were seen to provide valuable information to network operators and reduce maintenance costs. In terms of an installation timeline, the directive stipulated that smart metering systems that had already been installed before this directive entered into force may remain in operation. However, in case of non-compliance with the pre-described requirements, they shall not remain in operation after 5 July 2031 (Ibid.).

4.2 German legal framework

The analysis of the German legal framework shows that a lack of regulation and clear guidance through for example standards can hinder technological innovation. By analysing the different phases of the German smart meter rollout, we also show that overregulation can slow down and even hinder technological diffusion. Figure 3 provides a timeline and overview of key German legislation for the country's smart metering rollout.

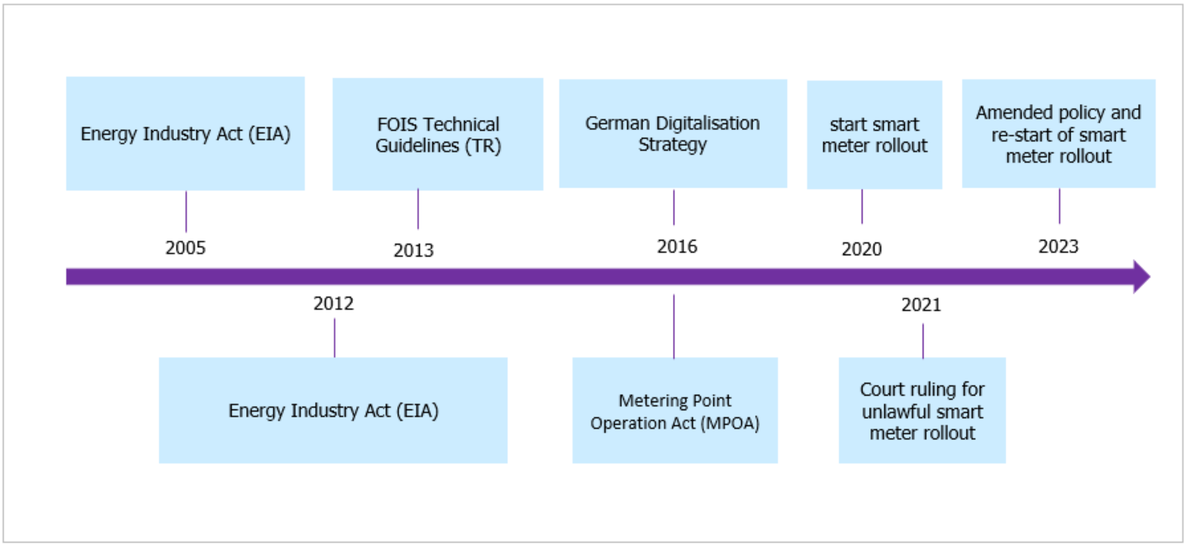

Figure 3 Timeline of key German smart metering legislation

Source: Own analysis, own visualisation.

4.2.1 2005 – 2012: Lack of regulation leaves technological diffusion to the market

Although the German government translated EU regulation into national law early on, the lack of a dedicated national policy delayed the country's large-scale rollout of smart meters. In its 2005 Energy Industry Act (EIA) *(Energiewirtschaftsgesetz – EnWG),* the German government mandated the introduction of smart metering systems that offer load-variable and time-based tariffs under the premise of data protection and data security. The legislation did not define what exactly smart metering systems would need to look like and stated that national standardised technical requirements would be developed and published in a separate regulation (German Federal Government, 2005)

In 2011, an amended Energy Industry Act provided more guidance by outlining a mandatory installation of smart metering systems for the following cases, in line with energy consumption levels and the type of building:

- Buildings that have newly been connected to the network,
- buildings that have undergone renovations with total costs of 25% of the building's value or the renovation comprises 25% of the building envelope
- the energy consumption is higher than 6000 kWh per year,
- buildings that co-create heat and power, through for example a rooftop solar panel, with an installed capacity of more than 7 kW.

This was only necessary as long as the installation would be technically and economically feasible, underwent an official certification process, and would ensure interoperability. No specific technical requirements for the devices were given (German Federal Government, 2011). Technical feasibility was met as soon as the technologies were ready to enter the market. Economical feasibility was met in that end users would not be charged for the installation of the devices. However, yet again, the legislation did not stipulate any specific technical requirements for the devices as such but informed again about the future development of a separate supporting regulation (Energy Industry Act 2005, §35, 1, (12)). Electricity end users that did not fall into the above-mentioned categories were mandated to install modern meters (Energy Industry Act 2011, §118b) (German Federal Government, 2011).

Table 2 provides a comparison of technical functions between modern meters and smart metering devices. The main difference is that modern meters can only receive information on for example data consumption. The device visualises consumption-related data on an in-built screen, it cannot send the information to the energy provider or network operator (German Federal Government, 2011).

Table 2 Comparison of technical functions between modern meters and smart meters

	Modern meters	Smart metering systems
Digital	Yes	Yes
Applicable for energy usage of	<6000 kWh	>6000 kWh, and >7 kW installation
Measures and visualises actual energy consumption	Yes	Yes
Offers load tariffs	Yes	Yes
Transmits data to third party actors	Needs technical upgrade	Yes
Connected to a smart grid	Needs technical upgrade	Yes
Interoperability	Needs technical upgrade	Yes

Source: FOIS, own visualisation.

After not providing guidelines on technical requirements for five years, the German government decided to take a market-led approach to the diffusion of smart metering systems. As outlined in section 4.1, at the time, EU regulation also only formulated broad specifications, with yet a missing definition of smart meters and smart metering systems. Di Nucci (2014) states that in countries with an advanced smart meter rollout, regulatory intervention outweighed market forces. For example, in Sweden where the enforcement of monthly electricity readings induced a smart metering rollout had accomplished a near-full smart meter rollout by 2014.

Di Nucci (2014) finds that the EIA framework did not provide any incentives either from the market or regulatory side. Although the number of utilities offering smart metering products in Germany had risen from 15 in 2010 to 101 in 2011, Hierzinger et al. (2012) find that most of these only offered a two-category price tariff – a high and a low price - even though 101 variable tariffs existed. The authors add that the difference between the high and low price tariff was not significant enough to make an installation of these minimum functional smart meters economically attractive for end users below an annual energy consumption of 6000 kWh/a.

Moreover, utilities held back until the German government conducted its cost-benefit-analysis relating to a large-scale smart meter rollout, as prescribed by EU regulation in 2009 (Hierzinger et al., 2012). Only in 2012, the Federal Ministry for Economic Affairs led the country's first CBA. The results were presented one year later in 2013, showing a negative outcome for a large-scale rollout until the year 2020. Yet again, Germany was not obliged to start a large-scale smart meter rollout (EY, 2013). If we look at other EU countries, France carried out its first CBA in 2006 and presented a positive outcome in 2007. It is therefore not surprising that France quickly became one of the frontrunners in smart metering in Europe (Hierzinger et al., 2012).

In 2012, an amended version of the Energy Industry Act finally provided a definition of smart metering systems (§ 21d para 1). However, still, no precise technical requirements were provided.

4.2.2 2013 - 2019: Overregulation leads to technical complexity and paralyses large-scale rollout

As outlined in section 4.1, member states were given leeway to implement the EU's mandate for a large-scale smart meter rollout. In Germany, the Federal Ministry for Economic Affairs mandated the Federal Office for Information Security (FOIS) *(Bundesamt für Sicherheit in der Informationstechnik – BSI*) to develop national standardised technical requirements for smart metering systems (Energy Industry Act 2011, §21c 1-3). As such, in 2013, the FOIS published its certification policy for smart meter technologies -*Technische Richtlinie BSI TR-03109* - thereafter TR or technical guidelines (Federal Office for Information Security, 2013).

To meet the feature of interoperability and the high level of data security and protection measures, as prescribed by the European Commission in 2012, the FOIS opted for smart metering systems based on smart meter gateway technology. The smart meter gateway (SMGW) serves as a communication tool that connects modern meters to the electricity network. Thereby, these devices become smart metering systems. The main function of the SMGW is to securely collect data and communicate it to external parties such as the energy provider and network and distribution operators. The technical devices also ensure restricted data access and the privacy of inhabitants and facility owners (Federal Office for Information Security, 2013).

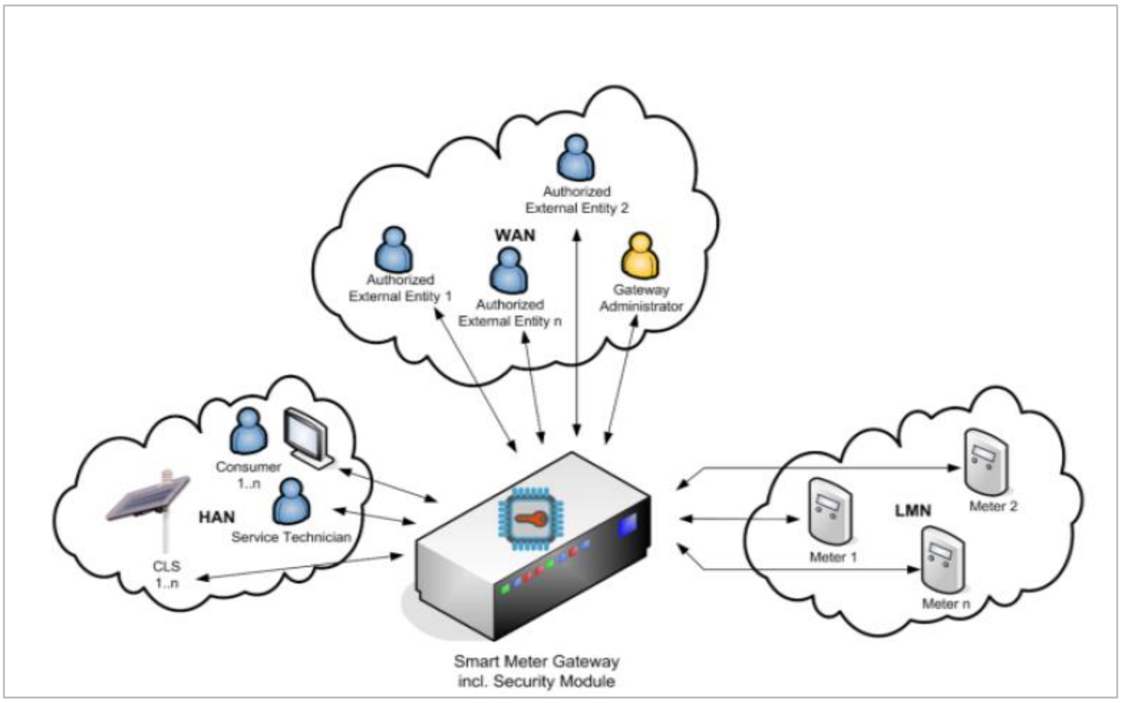

Figure 4 Smart meter gateway architecture
Source: FOIS, 2013.

Figure 4 visualises the architecture of the German smart meter technology. The gateway connects the following three network areas and stakeholders:

- **Home Area Network (HAN):** This network area is for the communication between the SMGW and controllable local systems (CLSs) such as controllable devices, i.e. other smart meters
- **Local Metrological Network (LMN):** This network area is for the communication between the SMGW and modern or smart meters.
- **Wide Area Network (WAN):** This network area is for the communication between the SMGW, the associated energy provider and network operator and the SMGW administrator.

The smart meter gateway is therefore the central communication tool, which receives and stores data from meters, and processes this for consumption by market players (Federal Office for Information Security, 2013). However, the SMWG architecture is subject to challenges and limitations introduced by mandatory specifications in official technical guidelines, the TR. Figure 5 shows that the TR consisted of six modules: specific requirements for the smart meter gateway, a security model, cryptographic specifications to ensure secure data transmission, smart metering connection to the network and smart metering infrastructure, other system-relevant specifications (yet to be stipulated), and smart meter gateway administration (Federal Office for Information Security, 2013).

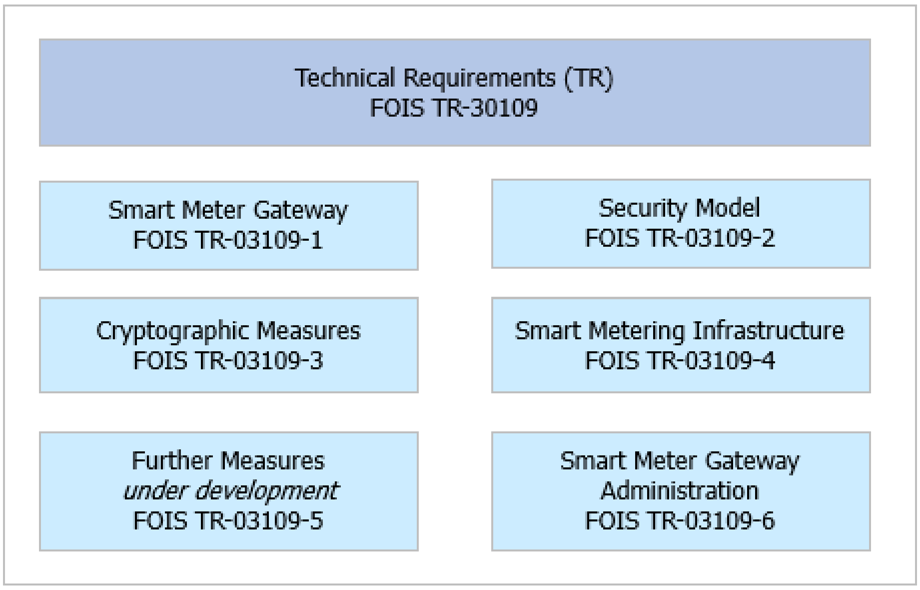

Figure 5 Overview of technical requirements laid out in the TR-30109 by modules

Source: FOIS (2013), own visualisation.

This overview demonstrates their complexity and that the German government treated the EU's emphasis on data protection with great importance. Interviewee 2 confirms that overregulation took years to implement on the ground. To be precise, together these documents make up around 500 pages with mostly further detailed specifications in Annexes. The first module TR-03109-1, 132 pages long with Annexes of 74 pages in total, stipulates that a SMGW must provide at least three physical interfaces and fulfil a variety of functions for these interfaces like recording, time stamping, the transmission of measured values using evaluation, pseudonymisation and firmware updates. The requirements for these functionalities are stipulated in line with certain application cases that regulate what type of data can be collected, and communicated via the smart meter gateway, how often and at what price - in short the tariffs (TAF). For example, TAF 3 enables the use case where the supplier flexibly bills the end consumer for consumption at different prices based on the specific load incurred. Technology developers must integrate all 14 TAFs that are outlined in the TR (Federal Office for Information Security, 2013).

The module on security measures, 169 pages long, requires the use of a certified safety module that supports the gateway especially in signature creation and verification as well as in key and random number generation. To make it more palpable, the installation of smart meters must follow a strict personalised identification number (PIN) mechanism. Interviewee 2 underlines that the PIN mechanism could only be used once and in case of being wrongly entered, the smart meter gateway could no longer be used.

It is evident that the technical complexity as a consequence of technological requirements slowed down the German smart meter rollout. While Sweden had achieved a near-complete rollout in 2014, Germany was still in the phase of carrying out pilot projects to gain insights into the technical and economic issues of smart metering systems (Hierzinger et al., 2012; Di Nucci, 2014). Di Nucci (2014) states that the Swedish government had introduced 'less smart' devices that would primarily be able to collect data consumption levels more frequently and hence provide more accurate meter billings. We can observe the same approach in Italy, where the government also opted for 'less smart' technologies with the aim to provide customers with transparency about their energy consumption behaviour (Interviewee 1). The government decided that the simpler version would suffice as it still met the EU's minimum technical requirements (Interviewee 1; ACER CEER, 2022).

With the aim to accelerate its energy transition and to put a greater focus on the role of smart grids and smart metering systems therein, the German government published its digitalisation strategy in 2016 (German Federal Government, 2016). Within the framework of this policy, the legislature adopted the Metering Point Operation Act (MPOA) (*Messstellenbetriebsgesetz - MsbG*), which serves as a key policy to regulate the governance of the installation of smart metering systems (German Federal Government, 2016). The MPOA stipulates three mandatory regulatory requirements:

- The FOIS must conduct annual assessments of the market readiness of the technologies, and publish them through a 'market declaration' .
- To ensure a competitive market, at least three independent developers of smart metering technologies must be certified by the FOIS and thereby meet the technical requirements as laid out in the TR.
- The economic feasibility must be guaranteed. For this, the law provides price caps for several cases.

Once all requirements are met a rollout is declared and metering point operators – these are mostly the energy providers - are obliged to equip end consumers that fall into the energy consumption or production categories as laid out in the EIA with smart metering systems. At the same time, the law also prohibits the installation and usage of metering systems that do not meet the technical requirements stipulated in the MPOA. In case of a breach, fiscal sanctions would apply.

4.2.3 2019 – 2021: Unlawful certification halts rollout

The analysis of the German legal framework identified another barrier to Germany's smart meter rollout. In December 2019, the Federal Office for Information Security (FOIS) certified the third smart meter technology developer for meeting the required technical criteria and security standards. In line with the MPOA, the FOIS published the 'market declaration' on 31 January 2020, which gave the green light for a large-scale rollout of smart metering systems. As outlined in section 4.2.2, this also meant that any other smart metering systems were no longer allowed to be installed or used. Already installed modern meters were to be upgraded so that they were able to connect to the smart meter gateway and the smart grid. In 2019, around 5,8 million modern meters were installed (German Federal Network Agency, 2019).

However, shortly after the official start, the German rollout was put on hold due to an unlawful certification process. In March 2021, the Higher Administrative Court of the state of North Rhine-Westphalia (HAC NRW) found that the FOIS certification process was not in line with the MPOA legislation. The court stated that the certified smart meter gateway devices would not meet the required technical criteria as laid out in the TR-03109-1, in particular the aspect of interoperability (Higher Administrative Court NRW, 2021).

Without the interoperability character, operators of power generation plants, for which the installation of smart metering systems was mandatory due to their energy consumption levels, were unable to install the devices and support sector coupling. The unlawful start of the German smart metering rollout also meant that already certified metering technologies that had been installed since the official rollout was no longer certified devices. Instead, they were illegal and developers were forced to reconfigure the technologies and undergo a re-certification process (Higher Administrative Court NRW, 2021).

A second reason for the ruling of an unlawful certification process was that in January 2019 the FOIS had without proper permission simplified the standardised technical requirements as it acknowledged the struggle by manufacturers to meet the standardised technical requirements (Higher Administrative Court NRW, 2021). To be precise, it had amended the technical guidelines (TR) by making TAF10-14 optional. But it was exactly these TAFs that lay out the requirements for meeting a devices' interoperability. As this aspect was a prerequisite in the EIA but also the EU legislative framework, the certification process was void. The court claimed that the FOIS had simplified the TR as implementation on the ground did not take off, with the result of a non-rollout of smart metering systems (Higher Administrative Court NRW, 2021). The court also stated that according to the MPOA, the FOIS does not have the capacity to make 'corrections' of the technical guidelines (TR). Only the federal government can do so (Higher Administrative Court NRW, 2021).

As a result of the court's judging, the FOIS had to retract its market declaration and the smart meter rollout was put on hold in 2021.

4.2.4 Beyond 2021: An amended policy to accelerate the rollout

To re-start the smart meter rollout, the German government adopted an amended MPOA policy on 1st January 2023 (German Federal Government, 2023). One of the key amendments is the so-called three-manufacturer rule, according to which the FOIS first had to certify three smart meter gateways from different manufacturers to ensure a sufficient market supply was dropped as this was not required under the EU legal framework. In the future, the pace will therefore be set by the most innovative manufacturer.

Among other amendments, the segmented approach was extended. The new policy mandates a mandatory installation of smart metering systems for consumers up to 100.000 kWh and producers up to 25 kW, even if not all technical functions can yet be enabled. For consumption of up to 6.000 kWh and generation plants between 1 and 7 kW, smart meters are to remain optional for the time being. Additional functions such as control and switching could be made available successively by means of smart meter application updates. From the ministry's point of view, this would give the industry the opportunity to build up processes and practice controlling via smart meter gateway in a 'warm-up phase' before the mandatory rollout becomes mandatory for all (German Federal Government, 2023).

Moreover, the government also envisions simplifying the up-to-now highly secure supply chain, which should make the installation process easier and more cost-efficient.

4.3 Transformative character

In this section, we reflect upon the smart meter rollout within the context of the three core challenges that underpin transformative climate policy: innovation, infrastructure, integration, and social acceptance.

4.3.1 Innovation

4.3.1.1 Technological innovation

While a market-led approach can foster technological diffusion for relatively mature technologies, it is less suited to incentivising breakthrough innovation (Görlach et al., 2022b; Grubb et al., 2013). Standards and direct regulation provide guidance to market players and allow for technological improvements and innovation (Ibid.). The German approach to the country's smart meter rollout is a good example of this. As outlined in section 4.2.1, the market alone did not manage to drive smart meter diffusion in the early years. The lack of clear technological standards for smart metering systems created uncertainty among market players (Smart Grids-Plattform Baden-Württemberg e.V., 2021).

The analysis also shows that data protection concerns can slow down the greening of our energy systems can hinder technological innovation. Geels et al. (2021) call this the tension between technological learning and a coordinated push. In our case, an overregulated market in line with the 'privacy by design' principle in the years 2013-2019 led to a six-year-long development phase of smart metering systems. Developers are faced with highly complex devices, which require specialised technical knowledge that not all energy companies have, especially since it's a novel technology. As outlined in section 4.2.2, German smart metering systems need to be configured in a certain way, comply with wireless data transmission standards, be compatible with a variety of software programmes, be equipped with in-home-displays that enable consumers to measure real-time data, which makes the development of such devices challenging. Interviewee 2 confirms that overregulation leads to a high level of technical complexity that took years to implement on the ground.

Data shows that in countries where less stringent technological requirements were set, such as Italy, a smart meter roll-out rate of 80% was achieved in 2020 (ACER CEER, 2022). Interviewee 1 confirms: "To accelerate a smart meter rollout, Italy opted for less smart [*with fewer technological functions*] meters". With the objective to provide customers with transparency about their energy consumption behaviour, the government decided that the simpler version would suffice as it still met the EU's minimum technical requirements (ACER CEER, 2021; interviewee 1). Another case shows how a simpler version of smart metering devices can ensure a fast smart meter rollout. In the Netherlands, the Dutch government went beyond the EU's minimum technical standards and mandated a rollout of smart metering devices that enabled two-way communication with the energy network. As a result, the Dutch Consumer Association argued that these digital devices would not ensure sufficient data protection. As a result, the smart meter rollout was put on hold in 2008 and restarted in 2011 with a rollout of 'less smart' metering systems (Cuijpers and Koops, 2013).

4.3.1.2 New business models

Smart meters provide transparency about energy demand and supply. In line with other sources of data such as weather conditions, this enables energy providers with sufficient data to create time-based tariffs and attractive pricing packages (Krüger and Teuteberg, 2015). These functionalities are especially important in view of increased renewable energy production and the volatility that comes with it. Customers need to be able to react to price signals (Di Nucci, 2014).

In theory, the smart meter gateway technology is able to control energy production from solar or power-to-heat facilities through the establishment of TAFs 9 and 10. However, based on a survey of energy providers in 2020, in practice, no new market processes such as the design, exploitation and development of new sales models entered the market (EY, 2021).

With emerging energy communities in Europe and Germany, smart metering systems receive more attention as these serve as a communication tool between consumers of the community. The digital devices also measure possible surplus of electricity which provides valuable information to the energy provider who regulates the network. This creates great potential for energy savings and climate mitigation. Jendrischk (2022) states that prosumers can reduce their energy consumption by up to 65 per cent. However, in 2022 two thirds of 50.8 million metering systems were still analogue meters. Out of these, every fifth photovoltaic-based energy producer had a smart metering system installed, that's 3% out of 10,8 million prosumers in Germany (Ibid.).

Di Nucci (2014) states that it is not just a matter of introducing smart metering systems but, instead, also considering the development of a smart market. Feasible business models need longer timeframes for the return on the investment. To eliminate uncertainty and provide guidance, the right regulatory setting must be in place (Ibid.).

4.3.1.3 Policy innovation

The Federal Ministry for Economic Affairs' mandate for the Federal Office for Information Security (FOIS) to develop national standardised technical requirements for smart metering systems created new governance structures. The FOIS was responsible for the creation of the technical guidelines as well as the certification process. Moreover, a dedicated policy – although not introduced at the moment the EIA's stipulated a smart meter rollout – was adopted in 2016. Within the framework of the innovation dimension (see section 2.3.1), these two aspects classify as policy innovation and therefore as a transformative approach.

4.3.2 Infrastructure

The electricity grid was originally designed to allow a few large producers to feed into the grid and distribute the energy from there to many decentralised consumers. With the liberalisation of electricity markets, the digital age and the introduction to renewable energy sources, our energy networks have been pushed to become more efficient and reliable. Smart grids also open the door to new actors that are connected to the grid, such as prosumers (Orlando et al., 2022). Decentralised energy production from for example photovoltaic systems on buildings and the irregular feed-ins poses challenges to the grid because it does not have storage capacity. It is only stable if as much electricity is fed into the grid as is simultaneously drawn from it. Smart metering systems provide the necessary information about supply and demand that helps to maintain grid stability (Orlando et al., 2022). However, without a suitable infrastructure, innovative technologies – in our case smart metering systems – will not move from the pilot phase to becoming mainstream. A good example of this is the smartphone. Without the internet infrastructure, customers would have had no use of this device and it would have not become mainstream as we see it today (Grubb et al., 2013).

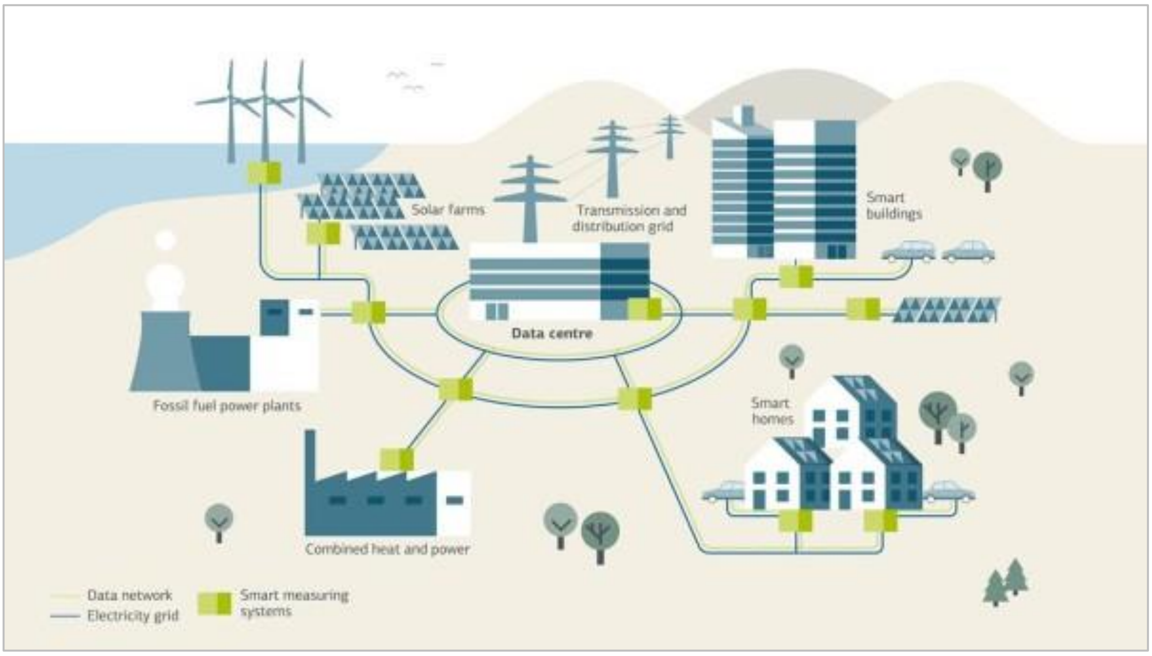

Figure 6 Overview of smart power grid and smart data grid

Source: Höfling and Koschel, (nd)

Figure 6 provides an overview of the smart power grid and smart data grid and the number of networks it connects. Within this process, they face a series of challenges from the protection from cyber attacks and data fraud, the high costs for infrastructure development (Orlando et al., 2022), and increased power outages driven by extreme weather conditions (Starn, 2021).

The lack of a regulatory framework and focus on technological progress delayed the development of needed smart grids. In its cost-benefit analysis in 2009, the EU stipulated that a large-scale rollout must be supported by network improvements (European Union, 2009). In Germany, the focus has been on data protection and the development of the technological function of smart meters (Gährs et al., 2021). Because of this, it is no surprise, that today the infrastructure is still under heavy development (Kroener et al., 2020). In fact, it was only in 2020 that the Federal Network Agency reallocated the licence for the 450 Mhz network to the critical infrastructures of energy, and water. This frequency network is designed to ensure the decentralisation and digitisation of the energy supply as well as fail-safe communication (BNE, 2020). It also addresses the frequent lack of cellular coverage in low-voltage basement areas (450 alliance.org, 2014; Bergsträßer, 2022). Erlinghagen et. al (2015) state that in Europe meters are usually installed inside buildings, often in cellars where internet coverage is scarce.

4.3.3 Integration

In section 3 we learned that smart meters are a key component of the electricity grid as they empower end users to participate in the energy transition by monitoring and controlling their energy consumption levels. Heilscher et al. (2019) find that smart meters and smart meter gateways are the essential new elements of the German smart grid, especially in view of the increasing share of decentralised energy systems such as through photovoltaic installations, battery storage systems, e-mobility charging stations or power-to-heat applications. In 2019, Germany registered more than one million solar electric power systems, however, the lack of secure and standardised communication measures with solar electricity inverters remained (Hielscher et. al, 2019). Without guaranteed interoperability, it is difficult to implement cross-system and cross-actor solutions with lower integration costs on a broad scale (Bergsträsser, 2022).

The analysis of the EU and German legal frameworks show that both of these gave great emphasis on the aspects of interoperability. Although the possibility was given through TAFs 9 and TAFs 10, we also learn that interoperability was not a feature of the smart meter gateways that the FOIS certified in 2019. Bergsträßer (2022) finds that without guaranteed interoperability, it is difficult to implement cross-system and cross-actor solutions with lower integration costs on a broad scale.

4.3.4 Social acceptance

The smart meter rollout focuses on technological diffusion. However, without social acceptance, the mainstreaming of innovative technologies is difficult (Grubb et al., 2013). Classical economics assumes that we make rational choices. In other words, our decisions to change behavioural patterns are motivated by money and future savings. While this might be correct to some extent, social norms, public debate, considerations of fashion and procrastination also influence individual decision-making (Geels et al., 2021).

While the segmented approach as prescribed in the EIA 2012 allows for technological progress, it creates uncertainty among small-scale end consumers. Although the installation rate of modern meters as prescribed in the EIA 2012 rose from 2.5 in 2018 to 5,8 million installations in 2019, small-scale end customers were hesitant to pursue an installation. Interviewee 4 reasons that in theory modern meters can be upgraded to be connected to the smart meter gateway, thus, the smart grid. However, in practice, this is not possible. This has the following implication: To avoid unnecessary costs, households do not install modern meters but instead wait until smart metering systems that can immediately be connected to the network becomes mandatory for them. Further, in case end users want to switch energy providers, it is necessary to also change their metering system, which incurrs additional costs. Moreover, as previously stated, most smart metering systems in Europe are installed in the cellar, because of which users do not directly see their energy consumption, which makes the transparency on energy consumption not attractive for end users (Interviewee 4).

If we look at Italy, we find that in both the first and second phase of the country's smart meter rollout some hesitation among end users existes. In the first phase of the rollout, the 'not so smart' metering systems did not display energy consumption levels directly on the device (Interviewee 1). Instead, customers had to log into an online platform to be able to monitor their energy consumption levels. In the second phase when the new smart meters featured a display, most end customers did not have knowledge about how to use these digital devices. To address this issue, the Italian government mandated that the new rollout needs to take place in a more inclusive way through public hearings and knowledge-sharing between energy providers and end users (Interviewee 1).

5. Conclusion

In this study, we investigate the factors that contributed to the delayed German smart meter rollout by conducting an ex-post analysis of the European and German legal framework for a smart meter rollout, for the years 2005-2021 and beyond. Although a single case study is insufficient to draw general conclusions, we make the following observations.

We demonstrate that the German government took a market-led approach to technological diffusion but that the market alone could not foster a large-scale smart meter rollout. The lack of regulatory intervention during the early years of Germany's smart meter rollout, 2005 – 2012, did not provide guidance to market participants and technology developers.

We also uncover that in the later years, 2013 – 2019, technical complexity as a consequence of technical requirements that were hard to meet by developers was a key factor in Germany's delayed smart meter rollout. It took nearly six years to implement the technical requirements on the ground. This suggests that legislation should have followed innovation rather than the other way around. Although the EU gave leeway to its member states by only setting minimum technical requirements for the development of smart metering devices, Germany took the 'design by data protection' to heart. The examples of the Italian and Dutch approaches show that the introduction of 'less smart' metering systems – with fewer technical functionalities – can pave the way for a smart meter rollout. This fosters not only technological development but can serve as a starting point for emerging new business models and can increase social acceptance, which are key aspects in achieving the mainstreaming of new technologies.

Moreover, in this case study, we investigated whether the German approach to a large-scale smart meter rollout was transformative within the context of the core aspects of transformation: innovation, infrastructure, integration, and social acceptance. We find that the German government did not design a transformative rollout. For example, for these innovative technologies to become market-ready, a dedicated policy that eliminates uncertainty for market players should have been adopted from the start. We also learn that without the right infrastructures – a smart grid – the installation of smart metering systems becomes less attractive to end users. The analysis of the German legal framework showed that the aspect of interoperability, the technical feature that allows sector coupling and empowers end consumers to participate in the energy transition, was not implemented by smart meter developers. With the rise of renewable energy sources in the system and decentralised energy models such as energy communities, the integration of smart meters into the sectors of mobility or heat and coal provides great potential if we want to reduce fossil-based energy production and reach climate neutrality by 2050.

For future policymaking, we make the following four recommendations. First, to foster technological diffusion, governments should provide clear guidance to relevant stakeholders. In the early phase of the German smart meter rollout, 2005 - 2012, the German government stated that it would soon provide supporting regulation with regard to technical requirements. By promising such legislation, without delivering on it for several years, the German government created additional uncertainty for producers and consumers of smart meters. They created the expectation that legislation was on its way, incentivising producers and consumers to wait for this new legislation, thus, creating a disincentive to innovate.

Second, policymakers should monitor the rollout of transformative innovations more closely and react in a fast and flexible way to signals from the ground. Although the FOIS amended the policy even though it did not have permission to do so, it was only due to the court ruling that the federal government was informed about a needed policy change. Following, it took the central government one year and a half to amend the policy to then announce a re-start of the smart meter rollout on 1st January 2023. To meet the Paris climate agreements, policymakers should react immediately to signals that a rollout of an important technology is not progressing sufficiently fast. Due to the urgency of the issue, a 'wait and see' attitude that leads to unnecessary delays is a luxury that we do not have.

Third, governments should provide a strong governmental framework. Transformative policy often requires inter-governmental cooperation. The ex-post analysis of the German smart meter rollout shows that this aspect was not met. The lack of cooperation between the FOIS and the central government led to an unlawful certification process that further delayed the smart meter rollout.

Fourth, to avoid unnecessary costs and increase social acceptance policymakers should ensure that smart meters that do not yet comprise all technical functions are easily and cost-effectively able to be upgraded. As shown in this study, the inability to implement this feature in practice led to unnecessary costs and a re-certification process – in short, a further delay of the smart meter rollout.

Overall, this case study shows that to achieve the digitalisation of our energy systems and reach climate neutrality by 2050, policymakers must take a truly transformative approach and simultaneously address the core challenges of innovation, infrastructure, integration, and social acceptance. Future research should also include investment needs and the costs that relate to a smart meter rollout, e.g. the digitalisation of our energy networks and the extension of supporting infrastructures.

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Annex

Table 3 List of interview questions

No.	Question
1	What is the status quo of the smart meter rollout in the country of your expertise?
2	What have been from your point of view the most enabling factors for this success?
3	What have been hurdles to the implementation process?
4	If you could change the existing policy in the country of your expertise in only one point – what would that be?
5	What are the technical requirements set by law that the smart meters need to fulfill?
6	What main technological features must the "standard" smart meter bring with, especially regarding interoperability?

About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a ClimaTe-neutral European UnION

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

Project partners

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