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Case study

Behavioural barriers in adoption of smart meters

DRAFT

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Contents

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Theoretical and Contextual Introduction

The transition from fossil fuels to renewable energy such as solar and wind, aimed at mitigating environmental issues, is taking place globally and takes time. Achieving deployment at scale, requires system integration and a level of funding which usually needs to be facilitated by government institutions. Newly built energy systems need to be prepared to integrate energy from renewable energy sources into the electricity grid or district heating/cooling network, such that the grid's capacities are suitable for intermittent renewable sources utilization. This can provide the grid opportunities to control and manage equipment and software to avoid grid overload during peak times of the day when energy demand is high.

Behavioural aspects of energy transition

There are various reasons why the clean energy transition takes time; these involve technical, economic, organizational, regulatory, and human factors. In particular, consumers need time to transit to renewable energy sources in order to get used to new solutions. While some are eager to adopt new technology, others need to overcome psychological barriers first. The identified barriers include (but are not limited to):[1]

1. The experienced cost of change: Changing a habit requires effort, and humans tend to only change their habits when the cost of keeping a habit outweighs the cost/effort of changing their behaviour.
2. Fear of failure: When people are concerned that they may fail or do something wrong, they feel anxious. Their anxiety causes them to continue doing things the way they are used to and makes them less likely to adopt a new behaviour.
3. A focus on either alleviating pains or creating gains: People focus their decision making on either moving away from personal pain or moving towards personal pleasure.
4. Missing intrinsic motivation: When people are intrinsically motivated, their behaviour change is usually deeper and lasts longer, because they want to make the change, instead of feeling that they have to (through extrinsic motivation).
5. Disempowering beliefs: Humans have beliefs about themselves, which can be, but do not have to be true (Stern et al., 1999). These beliefs can both help and hinder humans to achieve milestones and also to make decisions.
6. Actions can have adverse results: When a one-off decision is made for a specific purpose, this can have the unintended consequence for a non-standard or non-generalizable result. This means that the one-time action can change based on future situations such that the intended behaviour change is not put into practice after all.

[1] See: Addressing Behavioural Barriers to Energy Digitalization (ECE/ENERGY/GE.6/2022/5)

7. Negatively formulated goals: Humans have the tendency to focus intensely on where they do not want to go, and the consequence is that they are way more likely to end up just there. Therefore, it is much better to formulate goals in a positive way.

Smart energy networks and regulation of energy consumption

Smart grids are energy networks that can monitor energy flows and automatically adjust to changes in energy supply and demand. Smart grids are the backbone of the digitalization of the energy system.

For example, the deployment of smart grids is one of the 3 priority thematic areas of the Trans-European Networks for Energy (TEN-E)[2], which aims to integrate renewable energy, complete the European energy market design, and allow consumers to better regulate their energy consumption. Hence, investment in the grid infrastructure is important to a successful transition.

Smart meters are one of the technologies important for the energy transition. Smart meters:

- Measure the energy that flows into and consumed from the grid and can provide near real-time information on energy-usage to consumer and suppliers;
- Can enable consumers to actively participate in energy communities, energy savings programs and energy generation (prosumer-model) activities;
- Enable two-way communication between the point of generation and the point of usage and provide actual and historical energy information (e.g., consumption, time, generation, returned, heating temperature, network events and local grid asset health information;
- Support the integration of renewable energy technologies by sending measured data to a display or smart device (e.g., phone or tablet) display in a format that customers can understand. This information lets users see their energy consumption (or generation) and learn how to use energy more efficiently. For customers who have also deployed in-residence batteries, the state-of-charge of the battery can be made available to the customer and the energy provider for demand response and energy arbitrage programs.

To promote the digital transition, the European Union first mandated its member states to roll out smart meters back in 2009. Minimum technical requirements for the meter functionality were given (e.g., consumption levels, varying price tariff responses, data protection and security measures), with the intent that member states were to equip 80% of their end users with smart metering technology by 2020 unless a cost-benefit analysis result was negative (implying that smart meters could be installed 'voluntarily'). By 2019, and 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[3].

[2] TEN-E, 2022, https://energy.ec.europa.eu/topics/infrastructure/trans-european-networks-energy_en, last accessed July 5, 2024.

[3] https://www.ecologic.eu/sites/default/files/publication/2023/33007-Case-Study_4-German-delayed-smartmeter-rollout.pdf

Rationale for the case study

Previous studies on Distribution System Operator (DSO)[4] suggest that there is generally a positive trend with respect to smart meter installations in European Countries overall. Nearly 50% of DSOs surveyed have started to rollout smart meters. However, not every country has readily adopted this technology. As of 2022, Germany reported 14% smart meter penetration, although this number will likely nevertheless increase as Germany adopted a law in 2023 which makes using a smart meter mandatory from 2025.

A national case study report on smart meter rollout in Germany,[5] identifies a core issue to the delay of the country-wide rollout as a lack of regulatory intervention which created uncertainties among market players. And, while this report acknowledges social acceptance as a necessary reason for successful transformative policy within the context of smart meter deployment, this topic is addresses at a rather high level.

Hence, it is important to look at what is inspiring and holding back the population in Germany from voluntarily adopting smart meters, so that lessons can be learned to help other countries speed up the adoption of smart meters even without regulatory requirements being put in place.

In this document, factors that inspire users in Germany to adopt a smart meter and what determines consumers' behavioural change are discussed. The case study further suggests the ways how the relevant experience can be used in other geographies.

[4] Meletiou, A. Vasiljevska, J., Prettico G., Vitiello, S., *Distribution System Operator Observatory 2022*, Publication Office of the European Union, Luxembourg, 2023 doi:10.2760/778963, JRC132379.

[5] NCS Report #4: Electricity smart meter rollout in Germany, https://www.ecologic.eu/sites/default/files/publication/2023/33007-Case-Study_4-German-delayed-smartmeter-rollout.pdf

Rising Action: Implementing smart meters in Germany

Germany has an advanced energy system with a large part of electricity being generated from renewable energy sources, including local generation from rooftop solar photovoltaics (PV). The share of electricity generation from renewable energy increased from 48% in 2020 to 56% in 2023. Wind power provides the largest amount of electricity, accounting for 32% of the electricity for the public grid, followed by PV systems that generate renewable energy both for self-consumption and the public grid. Other renewable energy sources are biomass and hydropower. Hence, for such a decentralized energy system smart metering is essential.

Introduction of the geography that implemented the action

Germany, nestled in Central Europe, boasts a robust industrial base and high population density, positioning it as one of the major economies globally. This economic strength brings significant environmental challenges, particularly in reducing emissions and transitioning to renewable energy. The nation's commitment to environmental sustainability is underscored by its ambitious energy transition policy ("*Energiewende*"), aimed at reducing reliance on fossil fuels and nuclear energy.

Pre-intervention state of the energy system: challenges and opportunities

Before intensifying its focus on smart meters and renewable energy integration, energy mix in Germany relied heavily on coal, nuclear power, and imported gas. This reliance brought about several challenges: high emissions from coal plants, nuclear waste issues, dependence on the fossil fuel imports, and vulnerability to energy supply fluctuations. Despite these issues, opportunities were present in the engineering sector, widespread public support for green initiatives, and policies favouring investments in renewable energy. These factors collectively laid the groundwork for innovative energy solutions and opened new markets for German technologies, both domestically and internationally.

Plans to decarbonize the economy and reach net-zero targets

Decarbonization strategy in Germany is aiming for net-zero greenhouse gas emissions by 2045. This involves drastically increasing renewable energy to 65% by 2030, phasing out coal by 2038, and enhancing energy efficiency across all economic sectors. Sector coupling is also critical, linking electricity with heating and mobility to optimize renewable energy use.

Challenges in tackling energy efficiency, integration of renewables, and affordability

The integration of renewables like solar and wind presents complex challenges due to their intermittent nature, requiring advanced grid management and significant infrastructure investment. Although the transition intends to reduce energy costs long-term, the initial financial outlay could burden consumers and the Government. Moreover, the rollout of smart meters—mandatory for new PV systems – faces practical hurdles, such as a shortage of installers and delays in installation. While these dual-direction meters are essential for using flexible tariffs and eventually enabling Vehicle2Grid technologies, the higher cost for smart functionality, which reports meter readings directly to suppliers, remains a significant barrier.

Targeting social support

While hurdles such as shortage of installers needs to be overcome, social support is also essential for the success of energy policy. Ensuring public acceptance through transparent planning processes and addressing equity concerns are vital, as is balancing the costs of the energy transition to avoid disproportionately affecting low-income households. Enhancing public understanding through educational initiatives is crucial to foster broad support for the transformation. These strategies ensure that the country not only meets its environmental targets but also serves as a benchmark for pursuing a sustainable energy future in other geographies.

The intervention and the changing factor

To investigate the acceptance of smart meters of users in Germany,[6] researchers asked 346 potential users between the ages of 18 and 69 whether they intended to adopt a smart meter based on different benefits, such as whether people feel a smart meter: is helpful to them; makes daily life easier; is entertaining technology-wise; and makes their homes more secure.

The first factor that inspires users to adopt smart meter technology is hedonic motivation, the pleasure that a user experiences when using a technology. This motivation is probably triggered by the interaction users can have with this technology. For example, it is possible to see how much electricity is generated by solar panels on the roof in real time; or a graph shows how much electricity is used throughout the day. Other smart devices, such as smart thermostats that only offer automation without providing feedback, do not trigger hedonic motivation. The interaction triggers pleasure because it allows users to control, monitor, and analyse energy use.

The second factor is social influence, in a sense that other people and media can trigger interest in this technology. This means that the social environment is very important for influencing whether this technology is spread and adopted more often. This influence can be applied directly and indirectly. A direct influence means that other people or media inspire new users to start using a smart meter. An indirect influence means that people are inspired to, for example, install solar panels, which in turn requires the installation of a smart meter. For example, advertisements for smart meters use various techniques, such as persuasive language, emotional appeals, and social proof, to influence consumer behaviour and encourage smart meter adoption. Also, social influence of people, deciding to start using a smart meter, can inspire others to do the same.

The third factor is the local environmentalism. Although hedonic and social influences are stronger, environmentalism means the concern about the environment and actions to protect it. This influences the willingness to install a smart meter to reduce energy consumption based on the device's feedback: for example, switching off devices completely as opposed to stand-by.

[6] Große-Kreul, F. (2022). What will drive household adoption of smart energy? Insights from a consumer acceptance study in Germany. Utilities Policy, 75, 101333, https://epub.wupperinst.org/frontdoor/deliver/index/docId/7902/file/7902_Grosse-Kreul.pdf.

Important to note about this study is that it is limited in a sense that a stated motivation does not mean a practical implementation (i.e., buying a smart meter). In many jurisdictions, including Germany, the rollout of smart meters is typically orchestrated by DSOs, not purchased individually by consumers. DSOs incorporate the deployment of smart meters into their infrastructure development plans, which must be approved by national regulators. In Germany, this is overseen by the Federal Network Agency (*Bundesnetzagentur*), which ensures that the deployment aligns with national energy policies and regulations.

Smart meter connection process in Germany

The process for connecting smart meters in Germany involves several key steps, as follows:[7]

1. **Regulatory framework and mandates:** The German regulatory framework mandates the rollout of smart meters based on specific timelines and criteria set by the Federal Network Agency. These criteria often include energy consumption thresholds; for instance, households consuming more than a certain amount of electricity per year may be required to have a smart meter installed.
2. **DSO planning and deployment**: Once the regulatory requirements are established, DSOs integrate smart meter installation into their operational plans. These plans detail the logistics of the rollout, including the procurement of smart meters, scheduling of installations, and communication with customers.
3. **Installation and activation:** The actual installation is conducted by technicians authorized by DSOs. After installation, smart meter must be activated and integrated into the grid's operational network, allowing it to communicate usage data back to DSO and, potentially, to the consumer.
4. **Consumer interface and data management:** Consumers typically access their consumption data through an online platform, or a digital interface provided by DSO. This data can be used by consumers to manage their energy usage more efficiently.
5. **Ongoing maintenance and upgrades:** DSOs are responsible for the maintenance and any necessary upgrades to smart meters to ensure they continue to function correctly and benefit from advancements in technology.

In sum, consumers psychological barriers may fall into three main categories:[8]

1. **Motivation:** This category involves whether the behaviour is desired by an individual and whether they are intrinsically motivated (as opposed to extrinsically motivated),

[7] For detailed, authoritative information on the implementation of smart meters in Germany, the Bundesnetzagentur's official (website https://www.bundesnetzagentur.de/DE/Home/home_node.html) and their annual reports provide comprehensive insights. These documents outline the regulatory policies, progress reports, and future plans concerning smart meter technology in Germany. By understanding these aspects, one can appreciate the organized and regulated nature of smart meter rollout in Germany, which is quite distinct from consumer-purchased models prevalent in some other markets.

[8] Gerald Schweiger, Lisa V. Eckerstorfer, Irene Hafner, Andreas Fleischhacker, Johannes Radl, Barbara Glock, Matthias Wastian, Matthias Rößler, Georg Lettner, Niki Popper, Katja Corcoran,

Active consumer participation in smart energy systems, Energy and Buildings, Volume 227, 2020, 110359, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2020.110359.

experience little cost of change, and installing a smart meter alleviates a pain or creates a gain.

2. **Ability:** This category involves whether an individual can comply with the behaviour requirements. This involves not only being able to buy a smart meter but also being able to overcome the fear of failure and they have empowering beliefs about their ability.
3. **Environmentalism:** This category involves whether an individual's behaviour is facilitated or prompted by the state of environment. This means that their goals related to smart meters should be positively formulated and that their decision should be consistent over time.

The effects and lessons learned of the case study

Considerations of the action performed

The initiative of the Government of Germany to integrate smart meter gateways into the national electricity grid was a visionary component of the energy system transformation towards renewable energy. The ambitious programme was intended to retrofit the energy infrastructure with advanced technology, fostering the integration of renewables while promoting energy conservation and efficiency among consumers. The modernized grid was anticipated to be more responsive and capable of handling the fluctuating nature of renewable energy sources, such as wind and solar power, which were becoming a larger part of the country's energy mix. The importance of this initiative escalated as energy imports have recently been affected by supply uncertainty. Electricity prices increased dramatically and the country had to temporarily open decommissioned coal plants.[9]

Yet, despite its promising objectives, the smart meter implementation encountered a series of barriers that highlighted the gap between policy formulation and its execution. Technological hurdles emerged in the form of integrating new devices into existing infrastructures,[10] while regulatory frameworks were not sufficiently agile to accommodate the fast pace of technological innovation.[11] Societal acceptance posed another significant hurdle, as public apprehension towards new technology and data security concerns became apparent.[12,13,14]

Positive direct and indirect effects of the policy (technical, economic, social perspectives)

The technical benefits of the smart meter policy were poised to be substantial. The grid operators would gain the ability to manage energy demands in real-time, optimizing the flow of electricity

[9] https://www.smart-energy.com/regional-news/europe-uk/germany-to-make-smart-meters-mandatory/.

[10] https://www.smart-energy.com/industry-sectors/smart-meters/re-energizing-the-future-the-next-german-smart-meter-rollout/#:~:text=According%20to%20statistics%2C%20smart%20meter,(End%202022).

[11] Ibid.

[12] https://www.power-technology.com/features/eu-smart-meter-optimism-dampened-by-slow-uptake/?cf-view.

[13] https://iot-analytics.com/smart-meter-adoption/.

[14] https://www.cleanenergywire.org/news/electricity-smart-meters-become-standard-german-homes-2032.

and enhancing the overall stability and efficiency of the power system.[15] This was also essential for the accommodation of renewable energy sources, whose intermittent nature required more sophisticated control and distribution methods. This also fostered consumer behaviour change in using household appliances in non-peak hours.[16]

Economically, the ripple effects of the policy were expected to be significant. Operational efficiencies were predicted to lead to cost reductions for both energy providers and consumers. Grid operators would benefit from cost reductions in billing and metering operations such as modifications of contracted power, change of tariff plan and connection/disconnection actions. The implementation of smart meters would facilitate dynamic pricing models, giving consumers the opportunity to adjust their usage in response to real-time pricing data, potentially lowering their energy costs and incentivizing energy efficiency.

The social impact of the smart meter initiative was multifaceted. The policy was anticipated to drive a societal shift towards empowered, energy-efficient consumers, and align individual consumption habits with broader net-zero goals. This shift was expected to promote a culture of responsibility, where consumers could actively engage in managing their personal energy use and their carbon footprint.

Potential negative effects

Initially conceived as the Metering System 2020 (MS2020), the smart metering approach in Germany involved the adoption of a gateway technology that connected various elements of the energy supply chain. The smart meter gateway was the interface between the energy provider and the consumer, which had the ability to communicate with digital meters in the house such as the digital electricity meter, and digital meter connected to the solar system. With a unique approach, and the country was charting new territory without the guidance or reference of other established international frameworks. The path forward was marked by complex negotiations and often conflicting interests among stakeholders, including device manufacturers, utility providers, regulatory bodies, and consumer protection agencies. Standards were set by the Federal Office for Information Security for smart meter gateways and because of the disagreements, the standards had to be revised more than once. Yet, these requirements introduced many complexities including logistical challenges that drastically slowed deployment and provoked public concern.[8]

Added to this, media reports frequently discussed other potential challenges, such as the susceptibility of smart meters to hacking and the possibility of them losing smart functionality, leaving consumers with expensive, non-functioning meters. Such media scrutiny and public concern came at a time when the smart metering system benefits were yet to be fully realized and understood by an average consumer. The reports of potential security breaches and loss of functionality created a climate of mistrust and doubt. The complexity of the implementation, compounded by these fears, led to a delay in adoption rates and a hesitant engagement from the

[15] 2015 :https://energy.ec.europa.eu/publications/study-cost-benefit-analysis-smart-metering-systems-eu-member-states_en.

[16] https://publications.jrc.ec.europa.eu/repository/handle/111111111/27878.

public. These societal factors highlight the need for transparent communication and robust education campaigns to dispel myths and showcase the technology's advantages.

This backdrop of technological challenges, regulatory wrangling, and media scrutiny resulted in a hesitant adoption among consumers. All this has led to Germany being almost a decade behind in implementing smart meters than many other countries.

Adjusted long-term plans for decarbonization

The country’s ambition to become net-zero by 2045 necessitated a recalibration of strategies following the early challenges faced by the smart meter rollout. With the recognition that the initial goals were overly optimistic, the Government revised its approach, outlining a more practical and staggered strategy that extended the full deployment timeline to 2032.

This adjusted strategy sought to address the complexities of the initial rollout through incremental installation targets and a new pricing structure. The proposed ‘agile rollout’ would enable the swift deployment of certified smart meters in homes and businesses, ensuring that the adoption would effectively contribute to decarbonization efforts of Germany. The plan of the Government included capping the metering fees and requiring energy suppliers to offer dynamic contract offerings by energy suppliers, reinforcing the country’s commitment to a holistic and sustainable energy system. By mandating a progressive rollout – 20% by 2025, 50% by 2028, and 95% by 2030 for residential and small business consumers up to 100,000 kWh (and optional for those below 6,000 kWh) and generators up to 25 kW (and optionally 1-7 kW). For large users over 100,000 kWh and generators over 100 kW, these targets are extended respectively to 2028, 2030 and 2032. The strategy aimed to facilitate a smooth transition with stringent requirements for data protection and cybersecurity, reflecting a commitment to consumer rights in an increasingly digitalized energy landscape.

The legal framework also recognized the importance of flexibility and choice for consumers, encouraging the energy market to adapt and offer diverse contract options. The stipulation for all energy providers to offer dynamic tariffs from 2025 was indicative of a broader shift towards a more consumer-centric and environmentally responsible energy landscape.

These changes were designed to not only address the immediate challenges of rollout but also to anchor the long-term vision of a decarbonized energy system.

Outcomes, findings, and advantages derived from the mass deployment of smart meters

Despite the slow start, the mass deployment of smart meters holds the promise of significantly reshaping energy consumption patterns in Germany. By providing real-time data to consumers, these devices enable more informed decision-making, allowing for an optimization of energy usage that contributes to efficiency of the national grid. The implementation of dynamic tariffs presents an opportunity for consumers to benefit financially from off-peak energy consumption, leading to a reduction in the necessity for high-cost peak power production.

In the context of energy transition goals in Germany, smart meters are expected to be indispensable. They are considered key to creating a grid that is both flexible and resilient, capable of integrating the variable generation patterns of renewable energy sources. The

broader deployment of smart meters is anticipated to streamline the process of balancing energy supply and demand, facilitating a more responsive and sustainable energy system.

The experiences gleaned from smart meter initiative in Germany, offer a wealth of information and insight. As the country continues to refine its approach to energy policy, the understanding gained from the successes and setbacks of the smart meter rollout will shape future energy strategies. These lessons are not confined to the German context; they hold valuable insight for other countries navigating similar transitions, providing a framework for effective policymaking and technology adoption.

The example of Germany in establishment of a comprehensive smart metering system is reflective of the broader global movement towards digitalization and sustainable energy. It is a narrative not only of technological innovation but also of the adaptive, responsive policymaking that is required to steer such a significant transformation with a commitment to an intelligent, resilient, and environmentally conscious energy infrastructure. Although other countries, including Italy, Sweden, Denmark, are at the forefront of smart meter roll-out with percentages exceeding 90%, Germany represents an example of resilience and policy adaptability that has been able to overcome the initial barriers.

As Germany forges ahead with its ambitious energy policies, the lessons learned from the smart meter rollout are likely to influence not just future deployments within the country but also serve as case studies for other nations embarking on similar transformative energy projects.

Conclusions and policy recommendations for other geographies

The case study of adoption of smart meters in Germany, including overcoming psychological barriers, provides a comprehensive insight into the factors that can facilitate or impede the integration of renewable energy technologies into a national grid. Drawing conclusions from this intervention and considering the implications for other geographies, it is evident that policy recommendations must be context-specific yet guided by broader principles that have universal applicability.

Conclusions from the intervention

The proactive approach exercised in the case of Germany towards the adoption of smart meters, highlights the importance of combining technology with targeted policy measures to accelerate the transition to renewable energy. Key conclusions from the case study include:

- **Legal and regulatory environment:** The key component which opens the window for the wide scale deployment of smart meters requires that the legal and regulatory environment should be in place. In Germany, the situation typically revolves around several regulatory and legal aspects. To foster a conducive environment for the deployment of smart meters, it is essential that the legal and regulatory frameworks are robust, transparent, and aligned with the interests of all stakeholders involved. Enhancements in legislation regarding tariffs, opt-out policies, and the mandatory nature of installations are critical components that need thorough review and possible revision to ensure smooth deployment and operation.

- **Technological readiness:** The successful integration of smart meters is contingent upon the existing technological infrastructure and the readiness for a wide scale deployment of the technology. To avoid unnecessary costs and to increase social acceptance, the technological evolution of smart meters must guarantee smooth and cost-effective upgradeability. Meters also need to provide data granularity, i.e. consumption and generation at asset level and not just net metering.
- **Consumer engagement:** Active engagement with the community through educational programmes and real-time data access empowers consumers, making them active participants in energy management. This happens only if the tariff structure or other means are implemented.
- **Behavioural insights:** Understanding the psychological barriers to adopting new technologies is crucial. In Germany, addressing these barriers through motivational and social influence strategies was essential to increase adoption rates.

Recommendations for implementation in other geographies

Based on the experience from Germany, other regions considering similar technological deployments could benefit from the following strategies:

- **Tailored communication strategies:** Develop communication plans that resonate with local values and norms. Use local influencers and community leaders to promote technology adoption, ensuring the message aligns with regional environmental and economic priorities.
- **Regulatory frameworks:** Implement supportive regulatory frameworks that mandate the adoption of smart technologies while ensuring that these mandates are feasible given the local economic and technological landscape. Such regulatory frameworks must reduce the uncertainty of stakeholders, enabling an innovation-looking environment.
- **Infrastructure investments:** Invest in upgrading the energy infrastructure to support the seamless integration of renewable technologies. This involves enhancing grid capacity and stability to handle increased renewable inputs.

Potential limits for "importing" the best practice

While the case of Germany offers valuable lessons, there are inherent challenges in applying these practices universally:

- **Diverse starting points:** Countries vary significantly in their current energy infrastructure, technological advancement, and renewable energy adoption rates. Policies must be designed to accommodate these starting points, possibly requiring phased, piloted, or tiered implementation strategies.
- **Socio-economic variability:** Economic disparities can influence the feasibility of adopting new technologies. In regions with limited financial resources, large-scale investments in technology might not be immediately practical without substantial external support or innovative financing models. Communities can be engaged through workshops, demonstrations, and open fora where benefits and operations of smart meters are discussed with a panel of brokers or qualified consultants.

- **Cultural and social barriers:** Cultural perceptions and the social fabric of a region can affect the acceptance of new technologies. Tailored strategies that consider local beliefs and practices are essential for successful adoption.
- **Long-term sustainability plans:** The alignment of technology adoption with long-term sustainability and climate goals may vary. Some regions might prioritize immediate economic benefits over long-term environmental sustainability, necessitating a balance between short-term gains and long-term goals. As smart meters are rolling out across various regions, renewable energy projects should be considered in with a ‘success by design’ methodology. In other words, a series of actionable measures for the purpose of renewable integration, potentially bespoke to the region, need to be developed and then be included as part of both the roll-out of the smart meters as well as the installation of renewable sources.