Pilot Study: Collaboration of Financial Institutions with Academia and Utilities

PCAF PROJECT FINANCING TOWARDS NET-ZERO BUILDINGS

JUNE 2024

PCAF Partnership for Carbon Accounting Financials

Contents

1. Introduction

The Partnership for Carbon Accounting Financials (PCAF) is an industry-led initiative, advising financial institutions (FIs) on how they can measure and disclose the greenhouse gas (GHG) emissions associated with their financial activities. Buildings account for 37% of European greenhouse gas (GHG) emissions. Therefore, decarbonization measures in existing buildings need to increase drastically. At the same time, new buildings need to lead the way towards zero emissions. Funded by the Laudes Foundation, the PCAF project "Financing towards net-zero buildings" addresses the need to mobilize the financial industry to decarbonize their commercial real estate and mortgage portfolios and thus accelerate the transition of European buildings towards net zero by 2050. The project commenced in July 2021 and provides guidance to financial institutions to stay on the required course towards net-zero.

Measuring emissions in the real estate sector poses significant challenges. Unlike industries with well-defined emission sources, real estate encompasses a diverse range of source activities, across residential, commercial, and industrial properties, each with its own unique characteristics and energy consumption patterns. PCAF would like to build on the momentum of measurement and disclosure to offer financial institutions enhanced approaches to increase the precision of financed emission measurement. For the accounting of operational emissions, FIs often rely on average emission factors, energy performance information from Energy Performance Certificates (EPC) and proxy data. Over time FIs should aim to move towards more granular and accurate measurement approaches to increase the precision of financed emissions measurement. To support financial institutions in their emissions measurement journey, PCAF explored pilots on different measurement approaches, that may enable FIs to access actual measured data.

In October 2023, PCAF published an action paper, which documented existing and upcoming approaches that capture actual measured data and could potentially support FIs in improving their measurement abilities by accessing energy consumption data of their buildings portfolio. While access of data to enable actual measurement is still a significant challenge, numerous initiatives attempting to obtain actual or near-actual emissions measurements, across public, private sectors and academia were identified (e.g., digital building passes, digital twin models). Initiatives covered in the action paper included the German savings bank association DSGV, Fabriq, Kamma, Sero, Eliq, Measurabl, Metrikus, Smart Energy Research Lab (SERL) at University College London (UCL), Better Buildings Partnership, Data for Good, Dutch Central Bureau of Statistics and OSB Group.

Subsequently, the initiatives from Eliq and SERL were chosen to develop in-depth data pilots. These two organizations were chosen since they showcase a high level of application maturity and take two separate perspectives within the measurement ecosystem. As a commercial data management system service provider, Eliq deploys a nearest neighbor model to reflect actual measurements for their clients. The UCL initiative collaborates with the UK government to gather smart meter data from UK homes and derive insights for research purposes. The PCAF pilot studies further explored the two approaches and their potential applicability to support FIs in accessing actual measured data for precise GHG measurements.

This strategy report provides the synthesis of the pilot study conducted in collaboration with SERL. SERL was identified a collaboration partner owing to their work on providing researchers with high-quality, contextualized, half-hourly energy data in a secure environment that meets all General Data Protection Regulation (GDPR) and Smart Energy Code requirements. In addition, SERL's involvement in the evaluation of UK government policies like the Green Homes Grant Voucher Scheme (GHGVS) positions them well to bridge collaboration across different actors.

As a collaborator, SERL contributed to this report by sharing insights into their operating model as well as their data supply chain structure. Furthermore, SERL provided insights into their key findings and deliverables which were used as a basis to highlight the relevance of their approach with potential benefits and use cases. PCAF does not provide any commercial recommendation nor any substantiated claim on the quality of the data, information or approach that SERL or any other service provider is deploying. We do not have commercial arrangements nor endorse SERL or any other party as a service provider.

SERL collects household level data as part of a nationally representative Observatory sample, and as part of laboratories that consist of homes which have had a specific intervention, such as a specific technology or policy. The SERL observatory dataset includes 13,000 homes, representative of Great Britain's (GB) population of homes where half hourly gas and electricity data have been monitored since 2019 and linked to tariff data, weather data, Energy Performance Certificates (EPC) data and qualitative survey data to reflect actual energy measurements offering more accurate energy performance estimates of buildings in real-life use compared to normative predictions from EPCs. Throughout this report we collaborated with SERL in explaining their operating model, the expected results and highlighted the potential benefits and relevance for FIs.

The report covers the process of collecting smart meter data, its analysis for different case studies and the potential and challenges for accessing data in different countries. Chapter 2 details an illustrative data supply chain using smart meters, from the household to an external end-user. In Chapter 3 the relevance and importance of the provided SERL observatory dataset are highlighted. This is followed by a deep dive into the key requirements for establishing a collaborative approach between academia and FIs. Chapter 4 provides an overview of the replication potential of the SERL approach in different local European contexts. Three European countries, namely Estonia, Germany and the Netherlands were chosen to showcase a range of European geographies as well as local boundary conditions. These countries were then subjected to an assessment of the viability of replication based on 7 key parameters as follows:

- Smart meters penetration rates and future adoption plans.
- Smart meters infrastructure and data management system.
- Final energy consumption and the prevalent heating system.
- Data privacy, data protection laws and the potential of data sharing and access.
- Availability of funding programmes, granting bodies and public-private collaboration opportunities.
- Similar projects and collaborations with smart meters or actual measurements data sharing.
- Availability of EPC repository (central or decentral).

The report ends with conclusions and recommendations in Chapter 5 on how FIs could make use of these findings in their work and how other stakeholders can maximize the benefits of using contextualized smart meter data.

It should be noted that the guidance and recommendations provided in this report do not form part of the PCAF Standard, and there remains no requirement from PCAF nor is this aimed at promoting a particular service provider acting in the name of PCAF. Instead, the guidance is meant for financial institutions who seek to make themselves familiar with the topic.

We would like to express our gratitude towards the Laudes Foundation and its Built Environment Team; the Core Project Team of this project, that includes ASN Bank, ABN AMRO, Carbon Risk Real Estate Monitor (CRREM), Green Finance Institute (GFI), Luminor Bank, Nordea Bank, Deutsche Bank, Erste Group, Federated Hermes, OakNorth Bank and Bank of Cyprus; and the Expert Advisory Group of this project, that includes Alliance for Sustainable Building Products (ASBP), Architecture2030, Center for Climate-Aligned Finance, Climate Safe Lending Network (CSLN), Energy Efficient Mortgages Initiative (EEMI), European Confederation of Woodworking Industries (CEI-Bois), European Insulation Manufacturers Association (Eurima), European Panel Federation, Global Alliance for Buildings and Construction (GlobalABC), Global Buildings Performance Network (GBPN), Green Digital Finance Alliance, GRESB, InnovaWood, Institutional Investors Group on Climate Change (IIGCC), natureplus, Passive House Institute (PHI), Renovate Europe, Science-based Targets initiative (SBTi), UN Environment Programme (UNEP), World Business Council for Sustainable Development (WBCSD) and World Green Building Council (WorldGBC). Furthermore, we would like to thank our project collaborators SERL and Eliq.

2. The data supply chain

The data supply chain is a crucial component in understanding and optimizing building energy consumption data patterns. This chapter provides a brief summary of the passage of data from its initial measurement to its end user application. It explores how data flows through various stages—measuring, collection and transferring, processing, and application—that constitute an energy management system.

In each step of the data supply chain, the chapter focuses on SERL's approach. SERL's methodology highlights the importance of accurate and detailed data collection and its subsequent processing to generate meaningful insights. The brief explanation of the data supply chain in this chapter paves the way for further analysis in the subsequent chapters.

The following Figure 1 provides a schematic overview of a data supply chain with its different components:

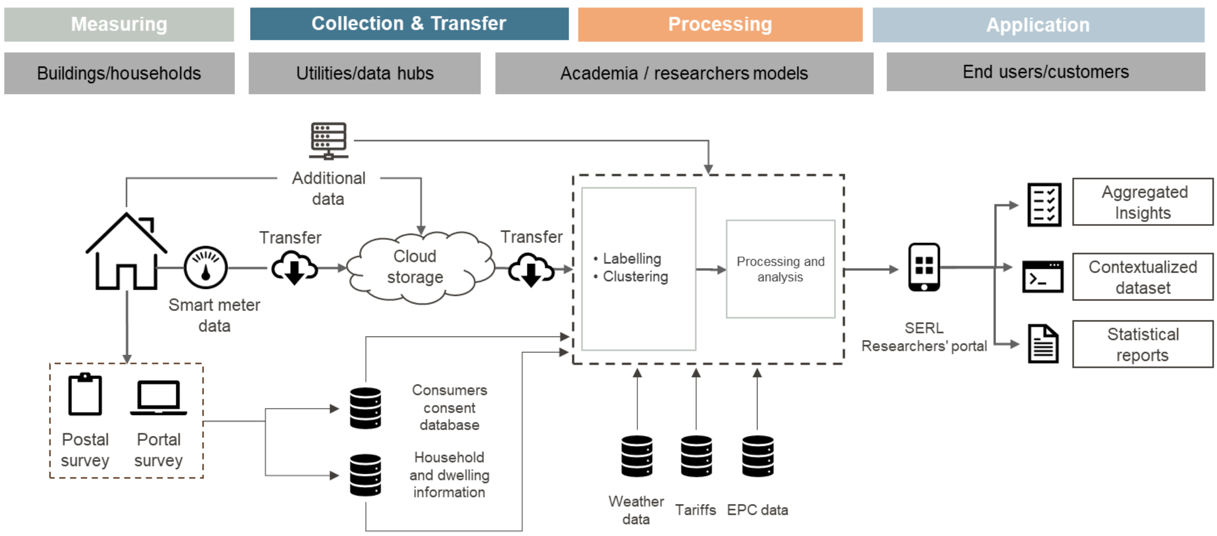

Figure 1: Example data supply chain of smart meter data flow (Source: own illustration based on SERL operating model)

Figure 1 illustrates the data supply chain for smart meter data, highlighting the roles of energy consumers, data hubs, and service users as follows:

- **Energy Consumers**: Represented by households equipped with smart meters for electricity and gas. These meters record energy consumption data and transmit it via a communication hub.
- **Data Hubs/DSOs** (Distribution System Operators): Serve as intermediaries that provide communication between smart meters and service users. They store data in the cloud, facilitating its transfer and ensuring it is accessible to authorized parties.
- **Data management system providers**: represents the entity responsible for processing the data prior to proceeding to final application (e.g. SERL system).
- **Service Users**: Include energy suppliers, electricity and gas network operators, academia and research centers (e.g., SERL researchers), and other users like businesses. These entities utilize the data for various purposes, such as improving energy efficiency, conducting research, and optimizing network operations.

The value of the smart meter data is then enhanced by linking it to contextual data about the building, its occupants and the weather.

2.1 MEASURING

The first step in the data supply chain is the measurement of the energy consumption of residential and non-residential buildings. Energy consumption in buildings originate from different unregulated and regulated household fittings and equipment, where heating and cooling are examples for regulated energy, while external lighting, electric appliances and IT equipment are examples for unregulated energy (BREEAM 2016).

The actual amount of energy consumed is dependent on fixed and variable factors. Fixed factors like the building envelope, level of insulation and others can only be impacted by considerable efforts in the design, construction, and renovation phases of a building (Asdrubali and Desideri 2019). Variable factors concern the actual use of energy, impacted by demographic, technological and behavioral factors (Abrahamse and Steg 2011). Therefore, the more information is available on an individual building/household, the more accurate data processing and insight generation can be.

The methods used to measure energy consumption depend on the type of energy source being monitored. These methods can range from intrusive technologies, such as smart plugs that provide detailed usage data for individual devices, to centralized smart meters that track overall consumption in real time (Ridi et al. 2014). Additionally, aggregated information from energy bills offers a broader view of energy usage but lacks the granularity provided by more advanced monitoring tools. Smart meters offer a high potential for detailed, real-time energy monitoring without being intrusive, enabling a continuous and scalable approach to energy assessments (Fraunhofer 2020). Smart meters can break down overall energy use into specific categories, providing valuable insights that can drive efficiency improvements and behavioral changes.

Smart meter roll-out in European countries is usually conducted by Distribution System Operators (DSOs), which are supervised by regulators. In most cases, DSOs continue to own and operate the smart meter after installation (European Commission 2021).

In the case of SERL, smart meter data was accessed by recruiting participants who provided informed consent, collecting data through the Data Communication Company (DCC) Gateway[1], adhering to strict data governance and ethical protocols, processing and analyzing the data for quality, and making the data available to accredited researchers in a secure environment. This means that energy insights are generated based on ***primary data*** provided by installed smart-meter technology, contextual data provided by self-completed questionnaires by occupants and additional linked ***secondary data***, that captures detailed information about the dwelling and weather.

2.2 COLLECTING & TRANSFERRING

In many European countries, energy consumption data from smart meters is collected either by utilities or by (retail) data hubs, which are entities with the specific purpose to provide access to and exchange meter data often for billing purposes (European Commission 2021).

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[1] For premises, the physical infrastructure by which a connection is (or is to be) made between that premises and the Data Communications Company Systems (and each Data Communications Company Gateway Connection shall form part of the Data Communications Company Systems)

The frequency of meter readings varies across Europe as measurements can be as granular as minute to hourly readings and can span back several years (EURELECTRIC 2013). As depicted in Figure 2, the data can be collected and transferred via a smart meter communication port (P3), which serve the DSOs mainly for meter readings, power quality and outage measurements. Data collected from the P3 port can also be accessed via the P4 port, which is the gateway for energy suppliers and internet service providers (ISP). Through this port, energy consumption data is accessed by third parties and stored in data hubs. In cases where consumption data is not proactively stored in a central data hub and is only stored in the smart meter, energy suppliers or ISPs have to submit requests to gain access to this data (van Aubel and Poll 2019).

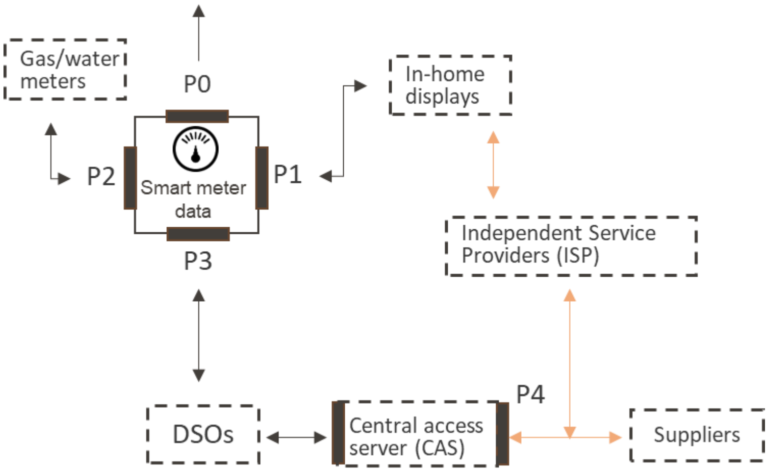

Figure 2: Smart-meter ports and processing, (source: adapted from van Aubel and Pol (2019))

(Retail) data hubs are centralized data centers that enable the exchange of electricity consumption information between market parties. These hubs help secure equal access to data from smart metering and increase efficiency in the communication between market parties, especially between network operators and retailers for billing and switching purposes (van Aubel and Poll 2019).

To date, several European countries have implemented national data platforms that cover different Business Use Cases (BUCs)[2] and System Use Cases (SUCs)[3]. For example, data platforms in countries like the Netherlands and Estonia are end-consumer oriented, while platforms in Belgium and Italy are more focused on suppliers and Balancing Responsible Parties (BRPs)[4]. Generally, data platforms are owned and operated by Transmission System Operators (TSOs) and DSOs (European Commission 2021).

In European countries such as Germany, where central data hubs are not (yet) used, smart meter gateways are used to receive and store data from meters and communicate retailer energy consumption data with external market participants (BSI 2024). Each consumer can define which market party has access to their smart meter data, resulting in a decentralized data management system (Buchmann 2017).

For UCL's SERL operating model, the primary data and secondary data are collected separately. Primary energy data was collected via the Data Communications Company (DCC)

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[2] BUCs are business services for a commercial end-user outside of the energy system.
[3] SUCs are use cases for the development and regulation of the energy system.
[4] BRPs are organizations that are responsible to invoice energy consumption per household/party.

Gateway, a centralized system that allows approved users to query smart meters for data. SERL sent data requests to participants' Communication Hubs (Comms Hubs) via the DCC Adaptor Service. The Comms Hubs, located within participants' homes, store smart meter data for up to 13 months.

In addition, Participant Recruitment and Consent was collected directly from occupants alongside contextual data about the occupants through a self-completed questionnaire and linked to secondary data (e.g., weather, EPCs, location data). Participants were recruited in three waves using a stratified random sampling approach based on region and Index of Multiple Deprivation (IMD) quintile. Participants provided informed consent for their smart meter data to be collected and linked with other relevant datasets. This consent was obtained through a participant portal or postal questionnaire to not disadvantage occupants who were not connected to the internet, where they could sign up and complete a survey (Webborn et al. 2021). The user sign-up SERL survey of around 40 questions included a variety of questions covering the following 4 key areas:

- **Dwelling Information**: dwelling type, number of rooms/bedrooms, heating system, temperature settings etc.
- **Household demographics**: number of occupants, age and gender, employment status, educational qualifications, etc.
- **Energy related behaviors and attitudes**: energy-saving behaviors, financial wellbeing, consideration of energy upgrades (renovation), etc.
- **Additional contextual information**: thermal comfort, any other additional information.

Figure 3 provides an overview of the datasets that comprise the SERL Observatory dataset covering the buildings' contextualized energy use data for the entire sample. The SERL observatory dataset, its uses and relevance to FIs are explained in detail in Chapter 3.

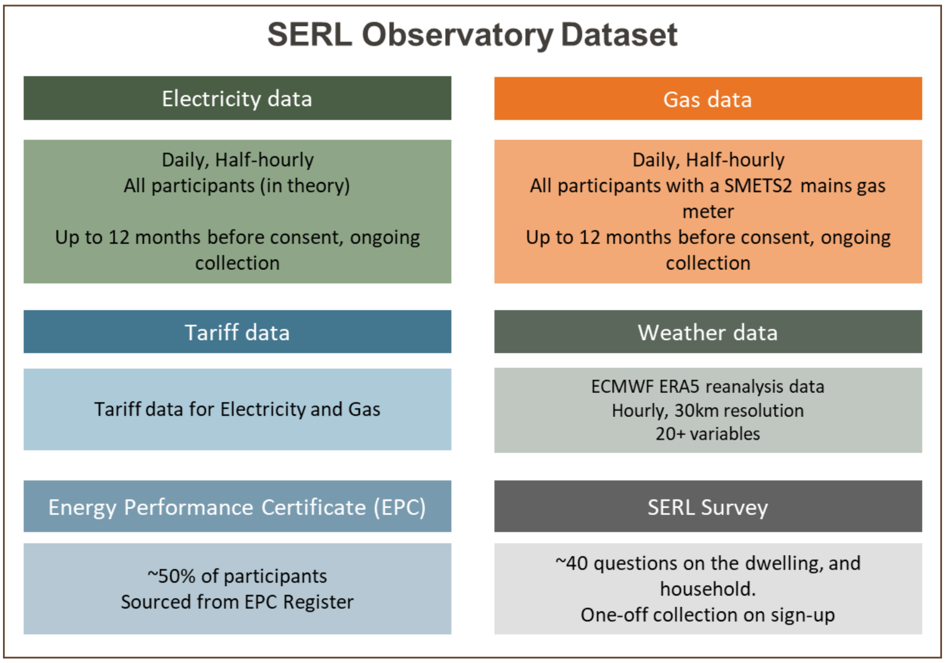


Figure 3: SERL Observatory Dataset components. (Source: Adapted from (Webborn et al. 2021))

2.3 PROCESSING

After receiving the primary and secondary data from households, utilities and clients, the service provider processes the data within a data safe environment. This step in the data supply chain requires specific attention, as it is crucial to translate energy data into meaningful outcomes, but also introduces subjective data analysis steps that depend on the decisions and set-up of the deployed modes.

In SERL's case, the collected primary data, which includes half-hourly and daily electricity and gas readings, are stored in an Online Transaction Processing (OLTP) database and linked with other contextual datasets at the participant level using a pseudo-unique property reference number (PUPRN). Then it undergoes a processing and quality analysis/error flagging by the SERL team. For example, daily electricity data are split by year, and half-hourly data are split by month to manage file sizes.

The energy use data for the entire SERL Observatory dataset, comprising ~ 13,000 homes, is then presented, along with a breakdown into different categories. The analysis first distinguishes homes by heating system type, separating gas-heated homes from electrically heated homes. It also identifies homes with photovoltaic (PV) systems. Further segmentation is based on key contextual variables, including location-based factors (region and Index of Multiple Deprivation (IMD) quintile), ranges of mean external temperature, Energy Performance Certificate (EPC) variables (energy efficiency rating and floor area), and survey variables (building type, building age, central heating system, number of occupants, and electric vehicle (EV) ownership).

Alongside the energy use data, normalized energy use statistics are also provided. This includes energy use by household's floor area, and per occupant. Additionally, local weather data is provided alongside the energy data for each household to allow adjustments for local weather, for example normalizing by degree day. All weather metrics are calculated per household using the same time periods as those used for the energy statistics. The smart meter data is then presented in kilowatt-hours per day (kWh/day) and mean kilowatt-hours per hour (mean kWh/h), which effectively represents the power rating.

2.4 APPLICATION

The processed data can be used for different BUCs and SUCs. The use cases most relevant to FIs are described in more detail in the subsequent section.

3. Collaboration use cases for financial institutions

The SERL database aims to provide high-quality, longitudinal, contextualized, half-hourly energy data for a representative sample of GB households. By providing detailed and high-resolution energy consumption data, the dataset supports various research areas, including network load management, consumer demand profiling, and fuel poverty detection. It also ensures data security and compliance to GDPR and the SEC.

3.1 RELEVANCE AND POTENTIAL BENEFITS

Such contextualized datasets can have noticeable relevance and potential benefits to FIs. Some of them are as follows:

3.1.1 ACCURATE INSIGHTS ON ENERGY CONSUMPTION PATTERNS

The SERL Observatory dataset analysis includes detailed information on energy consumption parameters that can be used to increase FIs' understanding of the average energy consumption of their mortgages and commercial real estate portfolio. This knowledge can be utilized to calculate the emissions related to the building energy use to enable financed emissions reporting, as described under the PCAF standard "The Global GHG Accounting and Reporting Standard for the Financial Industry - Part A Financed Emissions" (PCAF 2022).

Energetic data obtained from EPCs have been one of the most commonly sourced data accounting for energy performance of buildings. However, EPCs in principle are not intended to give a prediction of the actual energy use of a particular home as they assume normative consumption but should nonetheless provide a reasonably accurate measure of the regulated energy use. Research has shown that the accuracy of the reported EPC of a building can diverge significantly from its actual energy use in the operational phase and there have been several recent European papers exploring the difference between metered and modelled energy use according to local EPC processes (for compliance with the Energy Performance of Buildings Directive (EPBD)). Numerous examples across Europe were listed in (Few et al. 2023) which include analyses in Belgium, Ireland, The Netherlands, and Poland.

The potential cause of such differences include:

- Differences between real and assumed modelled occupant behavior and weather.
- Regulated energy use calculations differing in scope from metered information, e.g., ignoring appliance energy use.
- Shortcomings or inaccuracies in the quality of data input into calculations, e.g., assessor error and lack of availability of detailed data for new buildings that are difficult to measure accurately in existing buildings.
- Difficulty in appropriately accounting for aspects of energy use not included in the metered energy use. Increasingly, homes have energy generation, for example by Solar PVs, that is self-consumed in a home, and not metered as export, or metered energy that is not used in the home, e.g., electric vehicles. Also, some forms of energy are very difficult to meter such as wood for burning.

SERL used the Observatory Dataset for GB households and compared modelled energy using EPCs with metered energy data in which both were converted to Primary Energy Use Intensity (PEUI) to allow for a like-for-like comparison. Figure 4 highlights the methodological approach for the comparison process.

SERL found that EPCs significantly over-predict the PEUI compared to actual metered energy use in most homes. This over-prediction increases as the EPC rating worsens (e.g. A → G); for example, the gap widens from −26 kWh/a/m^2 (−8%) for EPC band C to −276 kWh/a/m^2 (−48%) for bands F and G.

Therefore, FIs could explore collaborations with private, public or research entities that provide actual emissions measurements through models based on smart meter data. This additional data layer could augment or replace the current reliance on EPCs by generating more accurate measurement models for emissions measurement.

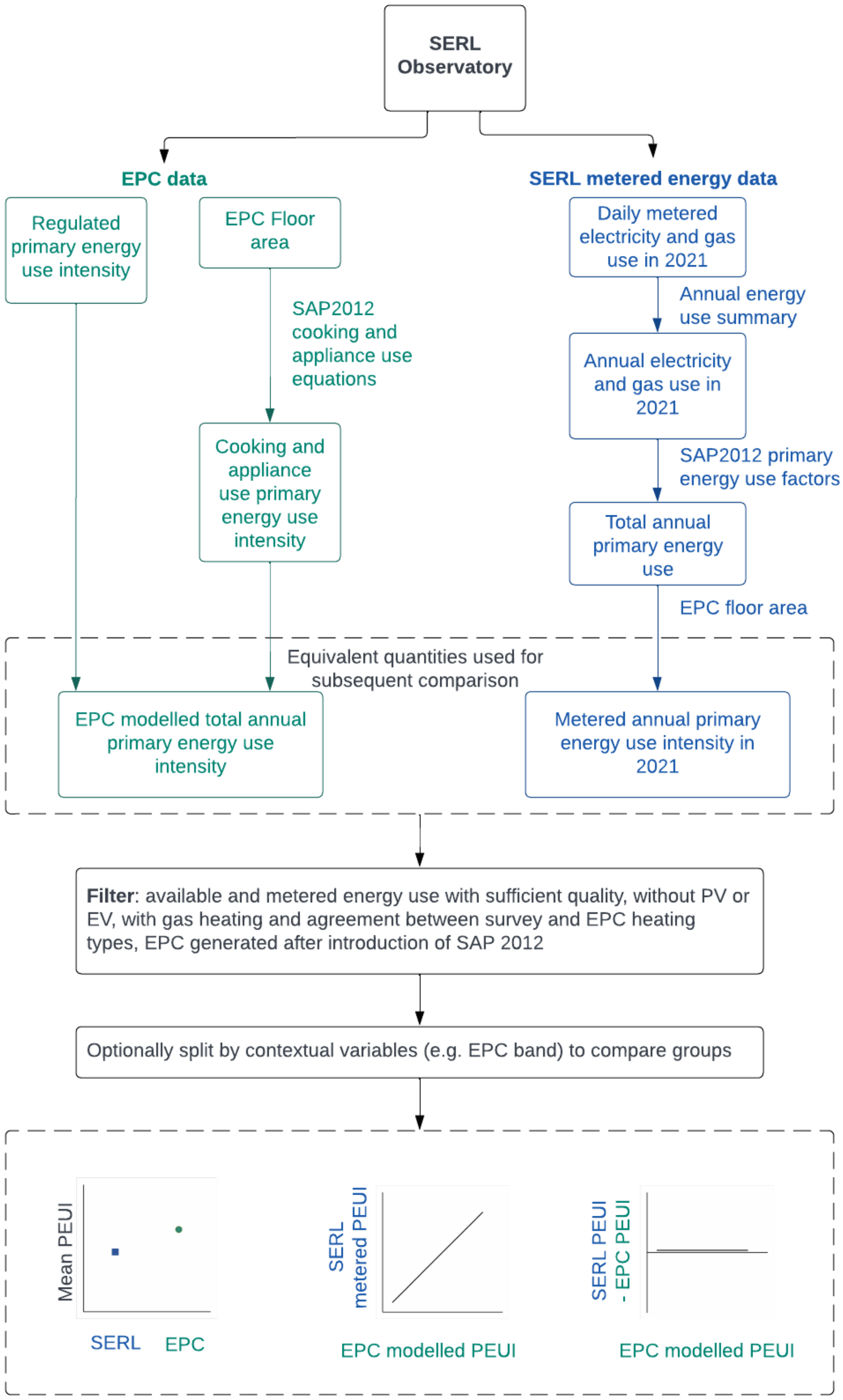


Figure 4: SERL methodological approach for the comparison of EPC and metered energy data

Source: (Few et al. 2023)

3.1.2 STRATEGY SUPPORT AND IMPROVEMENT OF FINANCIAL PRODUCTS AND SERVICES

Contextualized datasets based on actual energy measurements (electricity and gas) from smart meters can result in a better understanding of consumers behavior as well as the extent of impact from external factors.

SERL's analysis of their observatory dataset includes several areas, from general trends (e.g. annual energy use, building type effects, etc.), to more detailed assessments (e.g. regional differences, impact of heating system, etc.). Furthermore, it provides insights into estimated impact of other external factors on consumption behavior (energy price increase, subscription to variable electricity tariff "spot prices", COVID-19, etc.). Figure 5 provides an overview of the analysis type of expected results extracted from the *SERL statistical report: Energy use in GB domestic buildings*.

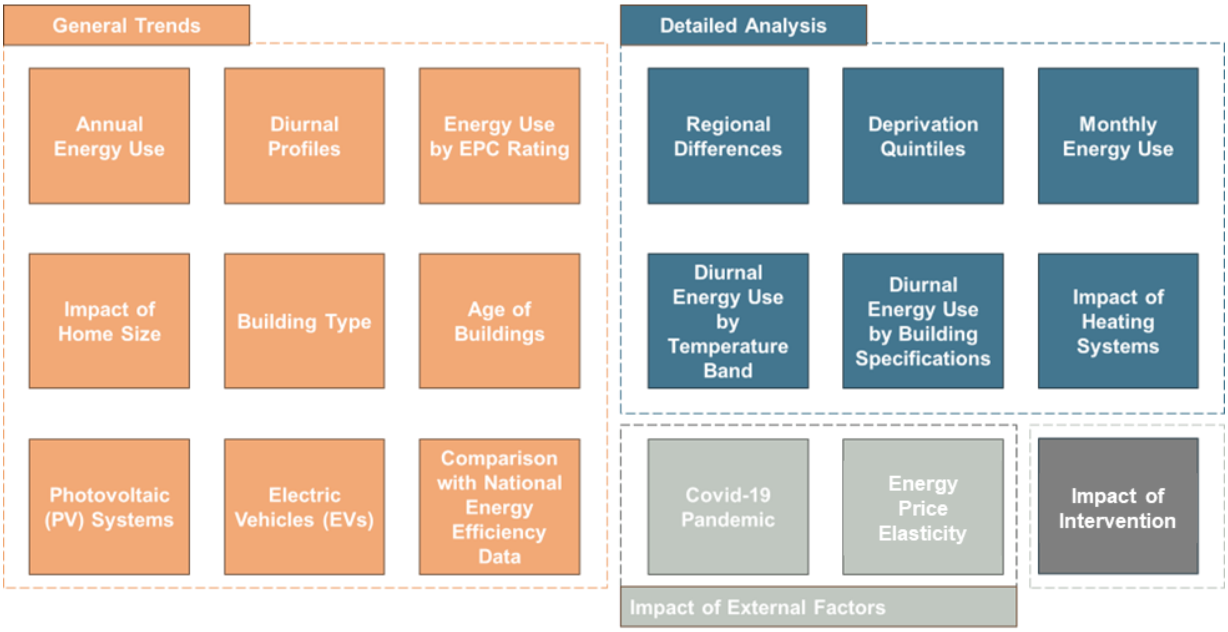


Figure 5: Overview of key obtainable insights from the SERL Observatory dataset. (source: own interpretation from (Few et al. 2024; Few et al. 2022))

The contextual data collected alongside the smart meter data can facilitate a deeper level of analysis. For instance, there could be insights into how energy use is changing over time due to increased patterns of working from home, changes in fuel price and changes in weather.

Since the SERL observatory dataset is representative of the building stock, it is possible for FIs to use similar data to obtain insights about customers and their dwellings. There could be inferences drawn about expected consumer behavior of current and prospective customers.

This could then contribute to forward-looking development of financial products that can be offered to various types of customers in order to solve specific problems, such as EV charging requirements, energy efficiency requirements and so on. Key opportunities include the following:

- **Risk Assessment and Loan Underwriting**: By understanding annual energy use and the efficiency ratings of properties, FIs can better assess the risk associated with lending for property purchases or renovations.

- **Green Financing Products**: Information on PV systems and EVs can help develop green financing products, such as loans for solar panel installations or electric vehicle purchases, encouraging environmentally friendly investments.
- **Customized Mortgages**: Offering lower interest rates or better terms for energy-efficient homes, which are likely to have lower operating costs and thus lower default risks.
- **Investment Decisions**: Insight into building types and age can inform investment strategies, highlighting sectors or regions with older buildings that might be ripe for energy-efficient upgrades, potentially increasing property values and investment returns.
- **Targeted Marketing and Product Development**: Regional differences and deprivation quintiles can guide targeted marketing campaigns and product development. For example, areas with higher deprivation levels might benefit from tailored financial products like low-interest loans for energy-efficient home improvements.
- **Portfolio Diversification**: Detailed energy use analysis can help in diversifying investment portfolios by identifying regions or building types that offer better returns due to lower energy costs or higher efficiency.
- **Insurance Products**: Monthly energy use and the impact of heating systems can influence the design of insurance products. Properties with more stable and predictable energy usage might be offered lower premiums.
- **Sustainability Goals**: Aligning financial products with sustainability goals by promoting energy-efficient upgrades and supporting clients in reducing their carbon footprint.
- **Risk Management**: Understanding the impact of external factors such as the Covid-19 pandemic and energy price rises helps in assessing economic risks and adjusting financial products accordingly. For instance, during times of economic stress, offering more flexible loan repayment options could be crucial.
- **Stress Testing and Scenario Analysis**: Using data on energy price rises to perform stress testing on loan portfolios, ensuring they are resilient under different economic scenarios.
- **Policy and Advocacy**: Data-driven insights can support policy advocacy for financial incentives or government programs promoting energy efficiency, benefiting both the institution and its clients.
- **Customer Education and Engagement**: Educating customers on the benefits of energy efficiency and offering financial solutions that support their goals, enhancing customer loyalty and satisfaction.

3.2 REPLICATION REQUIREMENTS AND COLLABORATION MODELS

The work done by SERL came as a result of collaboration between an academic consortium and the public sector, funded by the Engineering and Physical Sciences Research Council (EPSRC)[5].

For an FI, such collaborations could result in the development of two types of datasets:

- Dataset for the public good: As is the case with the SERL observatory dataset, since its results and findings are open to the public.
- Commercial dataset that is private, anonymized, and contextualized at asset level and geographical areas suitable for the FI's context and portfolio.

Collaboration with academic institutions can take various forms to either support research and innovation in energy efficiency or to gain specific access to data. This includes:

- **Financial Support:** Funding academic research projects focused on energy efficiency, carbon accounting, and sustainable building practices that aim to leverage smart meter data and provide actual emissions measurements.
- **Infrastructure and Personnel Support:** Providing access to research facilities, advanced technology, surveying tools and channels, and/or working premises for researchers.
- **Access to Consumers/Clients:** Facilitating access to real-world data through bridging the gap and introducing their clients to the implementing academic partner / research facility to enable data sharing for research purposes and the establishment of contextualized datasets.
- **Administrative Needs and Considerations:** Establishing formal agreements, ensuring ethical approval, defining project management structures, and managing intellectual property rights.

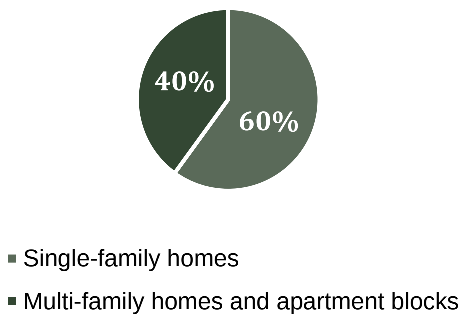
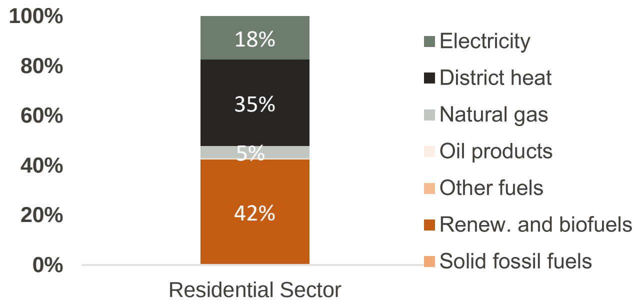
[5] A British Research Council that allocates government funds for grants to support research projects and postgraduate studies in engineering and the physical sciences, primarily targeting universities across the United Kingdom

4. Country specific replication potential

The potential for collaboration between academic institutions and researchers with FIs may vary in different European countries due to their smart meter roll out rate, data infrastructure and other boundary conditions as highlighted under the 7 key pillars in Chapter 1. Therefore, in the following section, three different European countries are assessed to gain a better understanding on how these boundaries conditions may impact the scaling of such collaborations. The countries were chosen to showcase a range of different European geographies as well as local boundary conditions from more challenging conditions, as is currently the case in Germany, to higher favoring conditions as is currently in Estonia or the Netherlands.

4.1 ESTONIA

4.1.1 COUNTRY FACTSHEET

<table>
<tr><td colspan="2"> Estonia</td></tr>
<tr><td>Share of households with smart electricity meters installed, %
(TriPica 2023)
>98%</td><td>Near-term target
Replacement of all electricity meters with smart meters by January 2017. (Riigi Taetaja 2017)</td></tr>
<tr><td>Share of households with smart gas meters installed, %
No data</td><td>Near-term target
No target for smart gas meters</td></tr>
<tr><td>
Figure 6: Residential buildings distribution in Estonia, source: (Gevorgian et al. 2022)</td><td>
Figure 7: Share of fuels in final energy consumption of residential sector in Estonia, source: Eurostat (2024)</td></tr>
<tr><td>Smart meter rollout</td><td>Estonia has been proactive in the deployment of smart meters, as a result of the Electricity Market Act that mandated the replacement of all electricity meters with smart meters by January 2017 (Riigi Taetaja 2017).</td></tr>
<tr><td>Data Protection</td><td>Estonia has incorporated the GDPR into its national legislation through the Personal Data Protection Act (PDPA), which entered into force on January 15, 2019. The PDPA provides additional requirements and derogations to the GDPR, ensuring that data protection is tailored to the specific needs of Estonia. The Estonian Data Protection Inspectorate (DPI)</td></tr>
</table>

	is the authority responsible for monitoring and enforcing data protection rules in Estonia (DLA Piper 2024). The DPI along with other regulatory bodies, has implemented several privacy safeguards to ensure exceptionally high data protection and security standards throughout the development, manufacturing, distribution, and operation of smart meter gateways. These safeguards include: 1. The data collected by smart meters is restricted to the minimum necessary for the energy system to function effectively. 2. All data leaving the smart meter gateway is encrypted, and calculations necessary to determine the household's electricity usage are conducted on the consumer's premises. 3. The smart meter gateway transmits data in encrypted or pseudonymized form, ensuring that unauthorized third parties cannot view or manipulate the data. 4. All smart metering systems must be certified to prove compliance with all data protection and security requirements. Consumers have the ability to monitor and verify all communications and processing steps.
EPC	EPCs in Estonia were introduced by the Energy Performance of Buildings Directive (EPBD) in 2002 and are mandatory for: • Existing buildings and apartments that are purchased or sold after January 1, 2009. • New buildings, the design of which begins in 2009 where the builder is required to hand over the EPC to the owner of the building (CA EPBD 2019). Estonian national EPC database contains around 22,000 residential EPCs (~89% of total EPCs). Despite the growing demand for residential buildings EPCs, the overall number of EPCs is still low when compared to the overall number of buildings of 745,000 buildings in Estonia.
Data collection	A data exchange infrastructure with a unique access point for all market participants. Hourly metering data, available one day after the physical flow, can be accessed for free by Estonian customers and eligible third parties, both national and international companies, without the necessity of registering in Estonia (Dominguez et al. 2021).
Data management system	Estfeed platform which serves as a central platform for managing electricity and gas meter data access, facilitating access and ensuring efficient information management to increase the energy system's efficiency and reliability. It allows third parties, such as suppliers, app developers, and consumers, to access consumer smart meter data, provided users have granted access rights to the specific service provider.
Funding programmes and grants	Due to the country's focus on digital innovation and energy efficiency there are several funding bodies and grants in the country. **National funding programmes** - *Estonian Research Council (ETAg)* programmes (e.g. Personal Research Funding, Applied Research in Smart Specialization Growth Areas (RITA)). - *Ministry of Economic Affairs and Communications* (Provides funding for projects focusing on energy efficiency and development of smart grid technologies). - *Environmental Investment Centre (KIK)*. **European Funding Programs** - *Horizon Europe* (Cluster 5: Climate, Energy and Mobility, European Innovation Council (EIC)). - *European Regional Development Fund (ERDF)*.

4.1.2 ASSESSMENT AND CONCLUSION

The analysis of Estonia's landscape under the 7 key pillars mentioned in **Chapter 1** suggest that the overall readiness and replication potential of the assessed approach in this report in the near term is **high** due to the following reasons:

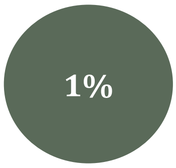
- **High smart electricity meter penetration rates and technology readiness**: With a near-total coverage of electricity smart meters, Estonia has successfully implemented a comprehensive smart meter rollout. This high penetration rate provides a robust foundation for collecting detailed energy consumption data across the entire nation. However, smart gas meters are not at full penetration due to the higher share of district heating and the lower reliance on natural gas as primary heating source. This in principle would not provide accurate insights on the overall emissions of a building due to the lack of real time heating measurements as would be the case with smart gas meters.
- **Advanced centralized data management infrastructure:** Estonia boasts a well-developed data management system, exemplified by platforms like Estfeed. Estfeed serves as a central platform for managing electricity and gas meter data access, facilitating seamless data sharing between consumers, third parties, and national and international companies. This infrastructure supports efficient information management, enhancing the reliability and usefulness of energy data.
- **Consumer-friendly energy market:** Estonia's fully liberalized energy market allows consumers to choose from multiple energy providers, fostering competition and innovation. This competitive market environment encourages energy companies to leverage detailed consumption data to offer personalized and efficient energy solutions. Consumers' ability to access their energy data and share it with third parties supports the development of tailored financial products and services.
- **Strong government support and funding opportunities**: The Estonian government's support for digital innovation and energy efficiency projects translates into various funding opportunities. These funds can be utilized to establish partnerships between financial institutions, technology providers, and academia, driving forward the use of contextualized datasets for enhanced strategic planning and financial product development.
- **Central repositories of EPCs**: The availability of a central repository eases the data collection and establishment of a contextualized data. This could also play a pivotal role in easing the recruitment process of consumers and their consent.

4.2 GERMANY

4.2.1 COUNTRY FACTSHEET

Germany

Share of households with smart electricity meters installed, % (FfE 2023)



Near-term target

95% smart meter coverage by 2030 for consumers of above 6,000 kWh per year and systems operators with an installed capacity above 7kW (FfE 2023).

Share of households with smart gas meters installed, %

No data

Near-term target

No targets for the use of gas smart meters. However, consumers are encouraged to install smart gas meters by the Federal Office for Information Security (BSI).

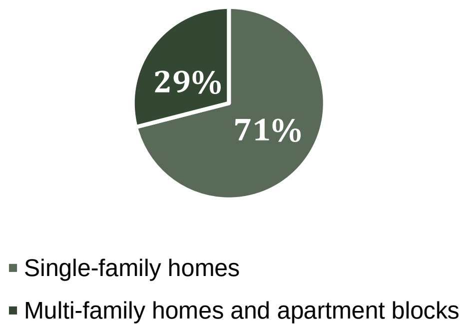


Figure 8: Residential buildings distribution in Germany, source: (Gevorgian et al. 2022)

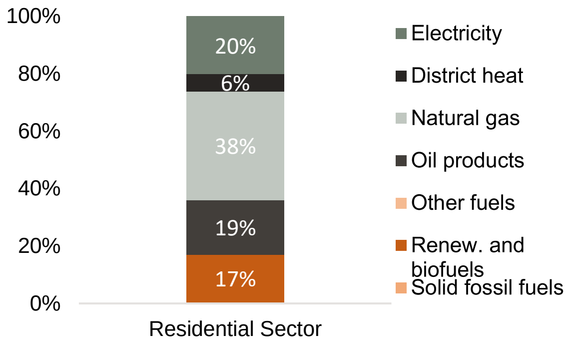


Figure 9: Share of fuels in final energy consumption of residential sector in Germany, source: Eurostat (2024)

Smart meter rollout	The Act on the Digitization of the Energy Transition (GDEW) stipulates installation of smart metering systems by 2032, if technically feasible and economically viable. Through this law, the Metering Point Operation Act was introduced. The Metering Point Operation Act has been in force since 2016 and governs the installation and operation of smart meters. It creates a binding framework for the secure and data-protection compliant use of smart metering system in different areas of application while also creating rules on financing of smart meters (BMWK 2024). Germany has been a laggard in smart meter adoption. However, in 2023, the German Government revised the GDEW to accelerate the rollout of smart meters. Consumers of above 6,000 kWh per year and systems operators with an installed capacity above 7kW will be affected by this mandatory rollout (FfE 2023). A 95% uptake within the identified categories is targeted by 2030. Metering fees will be limited to 20 euros per year for consumers and small plant operators equipped with smart metering systems. Network operators will receive a greater share of the costs of metering point operation (FfE 2023). The main driver is the modernization of the measurement systems for nationwide smart-grid development. There are no mandatory or voluntary targets for the use of gas smart meters in Germany, which are a major energy source.
Data Protection	The Federal Office for Information Security (BSI) created 10 privacy safeguards to ensure exceptionally high data protection and security standards apply throughout the development, manufacturing, distribution, and operation of smart meter gateways,

	including provisions such as: explicit approval by the consumer for data gathering; intervals of meter readings need to be long enough, to prevent user habit insights; transmitted data needs to be anonymized, pseudonymized, or aggregated; data is processed at consumer's premises and deleted in specified time period. Ultimately, smart metering data is subject to stringent data protection and security rules across Germany (BMWK 2015).
EPC	EPCs are mandatory in Germany when selling or renting out real estate, pursuant to the German Buildings Energy Act (Dena 2024). A registration of energy certificates is not yet mandatory, resulting in no official database containing all issued EPCs. This makes it challenging to determine the exact share of buildings with EPCs across the country.
Data collection	Metering data must be stored directly at the smart meter device. Up to 24 months of data can be downloaded at any time by the end user and shared with third parties. After the use of data, the supplier is obliged to delete all person-related metering data. There are currently no options to transfer metering data out of the meter electronically. (Dominguez et al. 2021).
Data management system	**Grid hub** approach that emphasizes the collection, validation and exchange of data between network users (consumers and producers) and network operators, to ensure smoother network operation. In other words, the approach is geared towards leveraging smart meter data to enhance grid operation, including more accurate projections for balancing and contract flexibility (Buchmann 2017).
Funding programmes and grants	Given Germany's commitment to the energy transition and efficiency, there are several potential funding opportunities. **German Federal Funding Programs** - Federal Ministry for Economic Affairs and Climate Action (BMWK) (e.g. Energieforschung (Energy Research Program), Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG)). **European Funding Programs** - Horizon Europe (Cluster 5: Climate, Energy and Mobility, European Innovation Council (EIC)). - European Regional Development Fund (ERDF). There are also several potential funding and collaboration opportunities via research foundations, state-level funding and/or industry partnerships and private foundations.

4.2.2 ASSESSMENT AND CONCLUSION

The analysis of Germany's suggests that the overall readiness and replication potential of the assessed approach in the near term is low due to the following reasons:

- **Low smart meter penetration rates**: Germany has not yet achieved widespread deployment of smart meters. The low penetration rate limits the availability of real-time energy consumption data, which is crucial for creating detailed and accurate datasets. The slow rollout is a significant barrier to leveraging smart meter data for immediate policy and strategy development. Furthermore, there are no plans for making the rollout mandatory for consumers with consumption levels up to 6,000 kWh which excludes the largest share of energy consumption from residential applications. Similarly, there are no mandatory or voluntary targets for the use of smart gas meters in Germany.
- **Grid hub data management system and data sharing infrastructure**: The current grid hub data management system in Germany is not fully optimized for widespread

data sharing and integration with various stakeholders. The infrastructure needed to support seamless data exchange between smart meters, utilities, and external market participants is underdeveloped, posing a challenge to the implementation of sophisticated data-driven projects.

- **High data protection provisions:** Germany has stringent data protection laws, including the GDPR and the Federal Data Protection Act (BDSG-new). These regulations impose strict controls on data collection, storage, and sharing. While these measures protect consumer privacy, they also challenge the ability to collect large-scale, non-intrusive insights from smart meter data, making certain use cases, such as comprehensive energy consumption analysis, infeasible at this point.
- **Lack of centralized register for EPCs:** currently there is no centralized repository for EPC data in Germany making it slightly more difficult to obtain several parts of the contextualized dataset and hindering a full comparison with actual consumption obtained from smart meters.

Despite these challenges, there are several factors that could make the implementation of a contextualized dataset and associated strategies viable in the future, once smart meter penetration rates increase:

- **Availability of funding opportunities:** As Germany's commitment to energy transition is high, associated funding opportunities will ease the establishment of such a project and on-ground partnerships.
- **Strong regulatory and policy framework**: Germany has a robust regulatory framework that supports the energy transition. This includes policies aimed at reducing carbon emissions, improving energy efficiency, and promoting renewable energy. As smart meter adoption increases, these policies will likely evolve to support greater data integration and utilization, making it easier to implement advanced energy management solutions. A shift from grid hub approach to a retail hub approach may develop with the increasing uptake of smart meters.

4.3 THE NETHERLANDS

4.3.1 COUNTRY FACTSHEET

The Netherlands

Share of households with smart electricity meters installed, % (ACER and CEER 2022) — 88%	**Near-term target** 100% by 2020
Share of households with smart gas meters installed, % (ACER and CEER 2022) — 87%	**Near-term target** No specific target for smart gas meters, but they follow the general mandate for smart electricity meters.

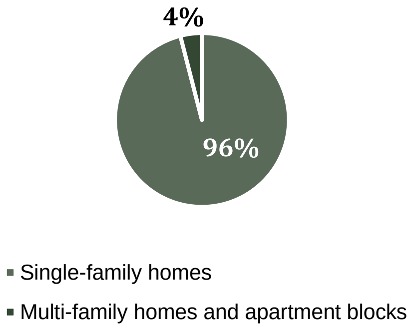


Figure 10: Residential buildings distribution in the Netherlands, source: (Gevorgian et al. 2022)

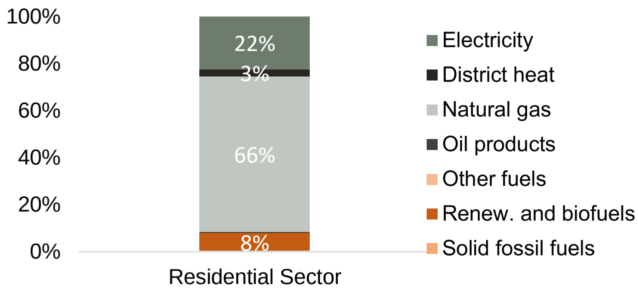


Figure 11: Share of fuels in final energy consumption of residential sector in the Netherlands, source: Eurostat (2024)

Smart meter rollout	The Dutch government mandated the rollout of smart meters with the aim of achieving 100% coverage by 2020. This initiative was part of a broader effort to embrace the Internet of Things (IoT) and create a smart grid that ensures consumers are paying the correct amount for utilities (Essential Install 2018). The rollout was conducted in two phases: a small-scale phase from 2012 to 2014 and a large-scale phase from 2015 to 2020 (Huizing 2014). The Dutch Smart Meter Requirements (DSMR) and its companion standards lay down the specifications of smart meters (Netbeheer 2019). The rollout has been generally well-received, with a high acceptance rate of 98% among consumers owing to voluntary participation, readiness of technological infrastructure and a strong cultural focus on sustainability.
Data Protection	The Netherlands also adheres to the GDPR, which is complemented by the Dutch GDPR Implementation Act. This act incorporates the GDPR into Dutch law and provides specific national provisions. The Dutch Data Protection Authority (DPA) (Autoriteit Persoonsgegevens) is the independent administrative body responsible for enforcing the GDPR in the Netherlands and protecting personal data (van Dam and van der Eijk 2024). Some of the safeguards emphasized by the Dutch DPA are as follows: 1. Consumer consent and control ensuring that consumers have control over their data. 2. Data minimization and purpose limitation where the Dutch DPA states the importance of collecting only the data necessary for the specified purposes. The Dutch DPA requires technical and organizational measures to be implemented to ensure the security of smart meter data. This includes encryption of data in transit and at

	rest, regular security assessments, and updates to protect against unauthorized access and data breaches.
EPC	EPCs in the Netherlands were introduced by the Energy Performance of Buildings Directive (EPBD) in 2002. EPCs are mandatory for a wide range of buildings in the Netherlands: - All newly constructed residential buildings must have an EPC before they are occupied. - Any residential property being sold or rented must have an EPC. Currently there is no central or de-centralized EPC repository.
Data collection	The DSMR specifies that smart meters record and store measurements for the DSO where the retention time depends on the measurement interval, as follows: • Monthly: 13 months • Daily: 40 days • Hourly (natural gas): 10 days • 15 minutes (electricity): 10 days Live electricity and gas measurements, along with equipment status and tariff information, are directly available to consumers on a 10-second interval and are not retained in the smart meter. Data could be gathered from metering administrator companies, such as Ealyze. 15-min metering data, with an availability of one day after the physical flow, can be accessed for free by customers and eligible third parties, both national and international, without the necessity of registering the company in the Netherlands (Dominguez et al. 2021).
Data management system	The Netherlands runs a data exchange infrastructure where metering data is stored in decentralized locations with unique access points for all market participants (Dominguez et al. 2021). Meterbeheer acts as a data hub for energy consumption and metering data, providing access to data from all Dutch meter administrators. This hub retrieves meter readings as quarter-hourly values and processes various data sets into one standard set, making it available for use in websites, dashboards, or apps. The system is designed to be AVG (GDPR) compliant, ensuring privacy and data protection. Meterbeheer's approach facilitates the retrieval of metering data for large-scale connections and supports the development of applications that can leverage this data.
Funding programmes and grants	Given the Netherland's commitment to the energy transition and efficiency, there are several potential funding opportunities. **Dutch National Funding Programs** - Netherlands Organization for Scientific Research (NWO), e.g., NWO Domain Applied and Engineering Sciences (AES) - Netherlands Enterprise Agency (RVO), e.g., Mission-Driven Research, Development, and Innovation (MOOI) **European Funding Programs** - Horizon Europe (Cluster 5: Climate, Energy and Mobility, European Innovation Council (EIC)). - European Regional Development Fund (ERDF). There are also several potential funding and collaboration opportunities via research foundations, state-level funding and/or industry partnerships and private foundations.
Similar initiatives	The unique collaboration between the Dutch Central Bureau of Statistics (CBS) and PCAF on the provision of CO_2 emissions from households covered by mortgage portfolios of seven Dutch banks (PCAF 2020).

4.3.2 ASSESSMENT AND CONCLUSION

The analysis of the Netherlands' landscape suggests that the overall readiness and replication potential of the assessed approach in the near term is very high due to the following reasons:

- **High smart meter penetration rates (electricity and gas)**: The Netherlands has made substantial progress in the rollout of smart meters and has successfully implemented both small-scale and large-scale phases of the rollout, resulting in widespread adoption and a robust infrastructure for real-time energy data collection. The high penetration of both smart electricity and gas meters strengthens the ability to gain accurate insights to the overall emissions.
- **Advanced data management systems and technological infrastructure**: The Netherlands has developed sophisticated data management systems to handle smart meter data efficiently. Platforms like Meterbeheer act as decentralized data hubs, facilitating the collection, validation, and exchange of metering data between market participants. These systems ensure that energy data is accessible, accurate, and secure, supporting a wide range of applications and analysis.
- **Consumer-centric energy market**: The Dutch energy market is characterized by high consumer engagement and a strong focus on consumer-centric services. Consumers have the ability to access their energy data and share it with third parties, promoting transparency and empowerment. This consumer-friendly approach encourages the development of tailored financial products and services based on detailed energy consumption insights.
- **Government support and funding**: The Dutch government actively supports initiatives aimed at enhancing energy efficiency and sustainability. There are numerous funding opportunities available for projects that leverage smart meter data for strategic planning and policy development. This financial support can facilitate partnerships between financial institutions, technology providers, and academia, driving forward the use of contextualized datasets.
- **Former initiatives covering energy consumption data privacy and access:** an example is the Dutch Central Bureau of Statistics' (CBS) unique collaboration with PCAF Netherlands chapter on providing insights into CO_2 emissions from private mortgage portfolios. This collaboration resulted in the provision of accurate insights around CO_2 emissions of mortgages without exchanging or utilizing sensitive private information.

5. Conclusions and recommendations

Contextualized datasets like the SERL Observatory dataset offer comprehensive analyses of smart meter data, presenting significant opportunities for European FIs to enhance their strategies, improve financial products, and support the transition to net-zero buildings. Some of the conclusions and actionable recommendations from this study are as follows:

1. Leveraging contextualized datasets for strategic planning

- **Conclusion**: Contextualized datasets from smart meters provide detailed insights into energy consumption patterns, enabling more accurate and precise GHG emissions measurement.
- **Recommendation**: FIs should integrate these datasets into their strategic planning processes to enhance the accuracy of emissions reporting, improve risk assessments, and identify opportunities for green financing. By using real-time and historical energy data, FIs can better predict energy consumption trends and support investments in energy-efficient technologies.

2. Enhancing financial products and services

- **Conclusion**: Detailed energy consumption data enables the development of tailored financial products that promote energy efficiency and sustainability.
- **Recommendation**: With the help of such an approach, FIs could develop and market green financing products such as loans for energy-efficient home improvements, solar panel installations, and electric vehicle purchases. Additionally, customized mortgages for energy-efficient homes and insurance products with premiums based on stable energy usage patterns can be introduced.

3. Supporting policy and advocacy efforts

- **Conclusion**: Data-driven insights can support policy advocacy and the development of government programs that promote energy efficiency.
- **Recommendation**: FIs could collaborate with policymakers and regulatory bodies to advocate for incentives and regulations that support the deployment of smart meters and the use of energy data. These collaborations can help align financial products with national and regional sustainability goals, ensuring a supportive environment for energy-efficient investments.

4. Fostering collaborations with academia and technology providers

- **Conclusion**: Collaborations with academic institutions and technology providers are beneficial for accessing high-quality, contextualized energy data.
- **Recommendation**: FIs could establish partnerships with universities, research labs, and technology firms to leverage their expertise and infrastructure. Financial support for research projects, access to advanced analytical tools, and participation in data-sharing initiatives can enhance the quality and applicability of energy data for financial decision-making.

5. Building trust and consumer engagement

- **Conclusion**: Consumer trust and engagement are crucial for the successful collection and utilization of smart meter data.
- **Recommendation**: FIs should prioritize transparent communication with consumers about the benefits of smart meters and data sharing. Implementing robust data protection measures and obtaining informed consent will ensure compliance with data privacy regulations and foster consumer trust. Educational initiatives that highlight the advantages of energy-efficient practices and financial products can also enhance consumer participation and satisfaction.

6. Addressing data protection and privacy concerns

- **Conclusion**: Stringent data protection regulations can pose challenges to the large-scale collection and analysis of energy data.
- **Recommendation**: FIs must ensure compliance with GDPR and other relevant data protection laws by implementing secure data collection, storage, and processing protocols. Collaborating with legal experts and regulatory bodies to navigate data privacy concerns will be essential. Developing anonymized and aggregated data sets could help mitigate privacy issues while still providing valuable insights.

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