Smart meters replacement benchmark study

January 2025

International comparators for failure information and replacement drivers & strategies for the first wave of smart meters

blunomy®

Citipower operates electricity distribution networks supplying electricity across Victoria covering most of the Melbourne CBD and inner suburbs, connecting 332,000 customers.

Powercor operates electricity distribution networks supplying electricity across Victoria spanning from the Western suburbs of Melbourne through Central and Western Victoria to the South Australia and New South Wales borders, connecting 844,000 customers.

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Blunomy is an international strategy consulting firm focused on accelerating the energy transition. Blunomy partners with clients over the long term, helping design robust business models, build coalitions, and attract capital to reach scale. Blunomy works with distribution system operators to find new ways to operate and manage networks, helping to maximise the opportunities relating to energy systems' decarbonisation, decentralisation and digitalisation.

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1. Introduction

In 2009, the Victorian Government mandated the rollout of smart meters for residential and small business customers. CitiPower, Powercor and United Energy completed the initial rollout of smart meters between 2009 and 2014. By the end of the 2026-2031 regulatory period, meters from this initial rollout will be between 17 and 21 years old; this is more than their 15-year design life[1].

CitiPower, Powercor and United Energy are seeking to invest collectively $920M over the 2026-2031 regulatory period into a meter replacement program. This represents a material step-up compared to the total metering investment of $170M over the current 2021-2026 regulatory period.

To inform and support that replacement strategy, CitiPower, Powercor and United Energy want to gather learnings from other jurisdictions and understand how these learnings might apply in a Victorian context. This report outlines the findings of this '*smart meter replacement benchmark study'* conducted by Blunomy on behalf of Citipower, Powercor and United Energy (CPPAL/UE).

As a part of this study, Blunomy engaged with multiple smart meter owners with fleets near or over the end of their design life, supplemented by interviews with leading smart meter OEMs. Blunomy conducted this study based entirely on publicly available information or data shared by third parties during interviews, without accessing CPPAL/UE data.

1.1 Objectives of this report

The objective of this report is to gather evidence from different smart meter owners and OEMs and summarise the findings to answer three key questions from CPPAL/UE.

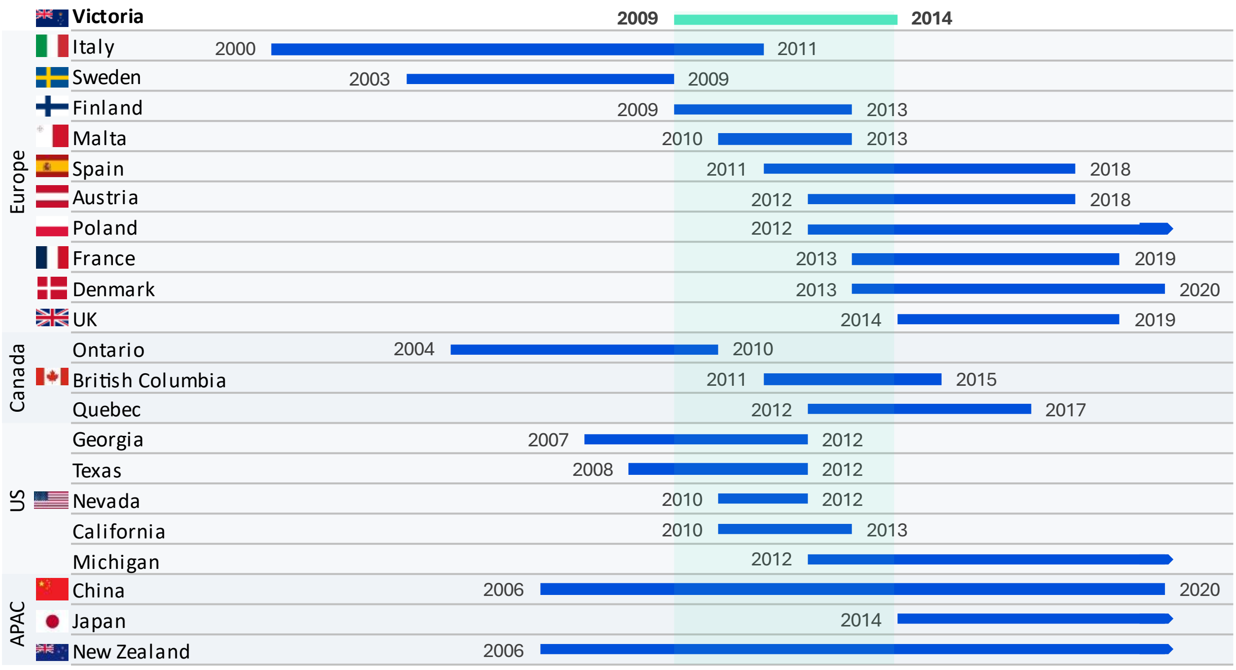
1. What do the ageing and failure rates[2] trends amongst similar aged smart meters look like and what are the most prevalent failure modes (i.e. communication, display, storage hardware, etc.)?
2. What are the drivers for smart meter replacement and what replacement strategies have been implemented or conceived by smart meter owners in other jurisdictions?
3. How were smart meter replacement programs justified to the regulators in other jurisdictions?

1.2 Methodology

To gather valuable findings, the analysis focused on jurisdictions with early rollouts of smart meters. Indeed, only jurisdictions with rollouts that happened at similar times, or earlier than in Victoria, can provide learnings about what lies ahead for Victoria. Shortlisted jurisdictions are shown in

[1] The design life of a smart meter refers to its expected operational lifespan, typically 10 to 20 years, during which it is expected to perform reliably and accurately under standard conditions

[2] Unless otherwise specified, 'failure rate' refers to the number of meter failures expressed as a percentage of the number of meters in the entire fleet in that year, irrespective of their age.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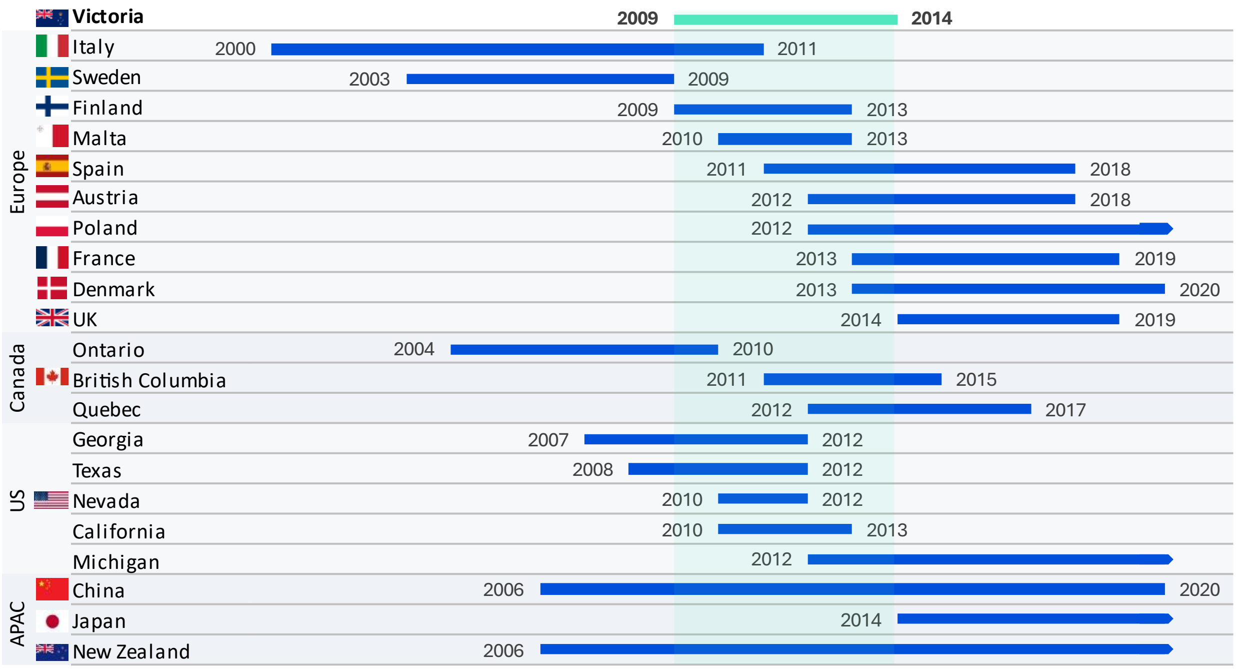

Figure 1: Shortlist of international comparators[3]

A literature review was conducted about these jurisdictions. Documents analysed include news publications, company reports, regulatory publications. Publicly available information proved scarce, and this literature review was complemented with interviews.

Eight smart meter owners were interviewed:

1. Europe:
   - Vattenfall (Sweden)
   - Ellevio (Sweden)
   - Enel (Italy)
2. North America
   - Pacific Gas and Electric (California)
   - Southern California Edison (California)
   - BC Hydro (British Columbia)
   - Hydro One (Ontario)
3. Asia Pacific
   - Bluecurrent (New Zealand)

As a complement, smart meter OEMs were also interviewed. They can share their experience and that of their customers, across a large sample of meters overall. Three OEMs were interviewed: EDMI, Landis and Gyr and Gridspertise (a subsidiary of Enel), which are amongst the market leaders (by market share, as seen in *Figure 2*).

[3] The start of New Zealand's rollout timeline refers to Meridian Energy's 2006 announcement to deploy 112,000 smart meters to Christchurch households over two years (Murray & Black, 2008). The deployment of smart meters has progressed steadily and has continued since 2008 and is still not complete in New Zealand.

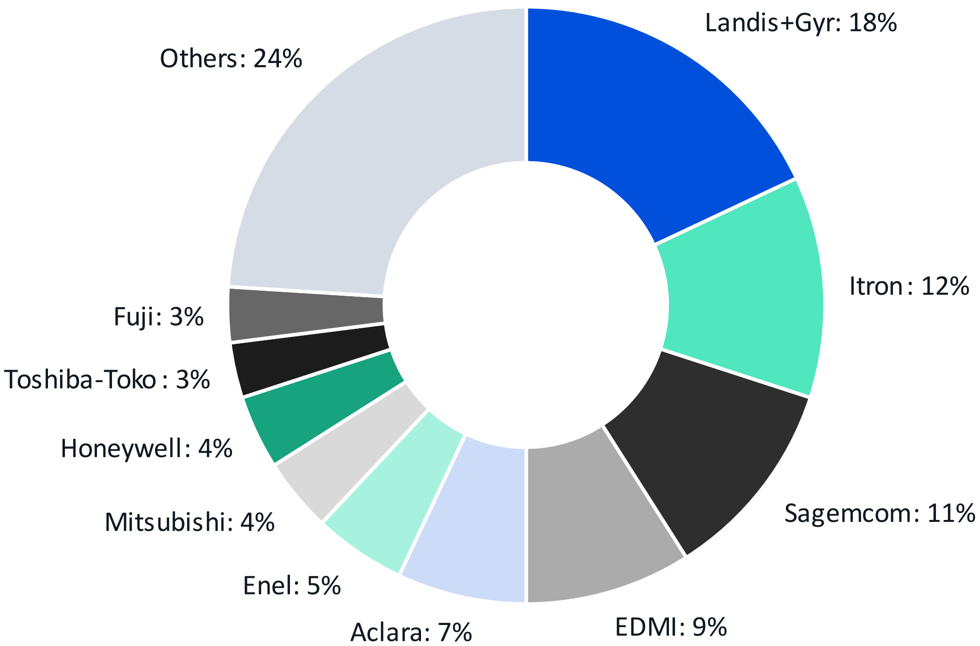

Figure 2: Smart meter OEMs by market share

2. Key findings from comparative analysis

This section presents the key findings from the data-gathering process. The collected evidence is segmented into three key areas, providing a structured framework for the report:

1. **Ageing trends of smart meter fleets:** this section provides information on the fleet of smart meters deployed[4], including the deployment timeline and the features of these meters. It also examines observed failure rates and highlights the most common failure modes.
2. **Replacement drivers and strategies:** this section explores replacement strategies, either already implemented or under development, in other jurisdictions. It seeks to address the primary reasons for replacement as well as other key considerations influencing replacement decisions.
3. **Justifications of replacement:** this section examines past or proposed justifications presented to regulators for the replacement strategies planned in relevant jurisdictions.

The information gathered is often anecdotal, as interviewees did not share supporting data or evidence. Hydro One is the exception and provided granular information regarding its failure rates.

2.1 Ageing trends of smart meter fleets

Amongst the smart meter owners interviewed with fleets that are approaching or have exceeded their design life, five out of eight have reported a noticeable increase in failure rates[5].

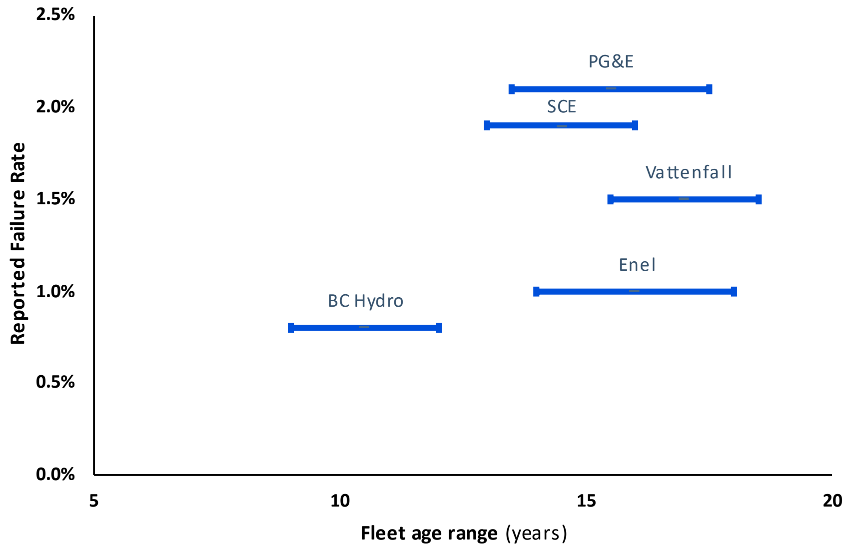

Figure 3: Reported Failure Rate vs Average Fleet Age from interviewees[6]

[4] The report focuses on utilities' initial rollout and fleet, rather than any recent replacement roll-out.

[5] Although Bluecurrent was interviewed for this study (see Appendix 3.8), it was excluded from this comparative analysis. The failure rate they reported was significantly lower compared to figures from all other smart meter owners, indicating a different scope and/or definition of a failure. Requests for clarification were unfortunately not answered.

[6] Reported failure rates are approximate. When a range was provided by interviewees, the midpoint of the range was used. Ellevio is excluded from this chart as they did not provide any quantitative information on failure rates. Hydro One's detailed rates evolution is detailed in *Figure 4*.

Among the smart meter owners interviewed, Hydro One experienced the highest rate of failures. In 2020, the utility reported an average failure rate of ~2% across its entire fleet, which has since risen to ~5% in 2024.

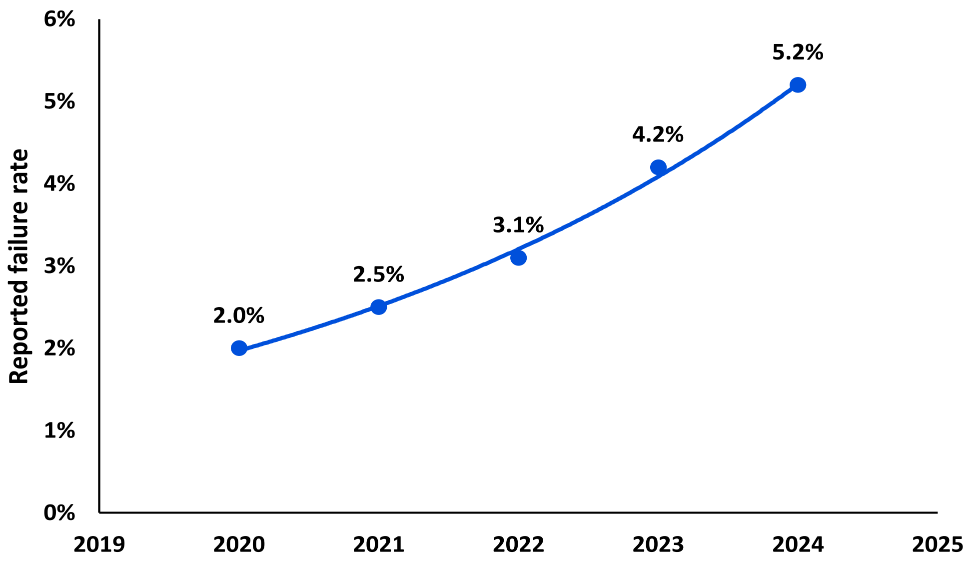

Figure 4: Hydro One annual failure rate evolution (2020-2024)

A closer analysis of failure rates by age reveals a close correlation between increasing failure rates and the ageing of the fleet. In 2020, meters between 5 and 10 years of age had failure rate of ~0.5%-1%, whereas meters greater than 10 years old saw this number exceed ~2%. Notably, meters over 12 years of age showed a consistent rise in failure rate, reaching ~4% for meters aged 13 years and ~6% for those aged 14 years. Hydro One's fleet average failure rate has now increased to ~ 5% in 2024 (YTD data). Although Blunomy did not have access to failure rate data by age for 2024, the current overall rate of ~5% suggests that the oldest meters (15+ years old) have experienced an increase in failures, likely in a range of 6.5%[7].

Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and Vattenfall, with meters installed between 2007-2010, 2008-2011 and 2003-2008, all experienced increasing meter failure rates as they approached the end of their design life (15 years):

- PG&E and SCE both reported a recent increase in average failure rates, rising to approximately 2% for fleets aged 14-17 and 13-16 years, respectively. Previously, SCE's failure rates were below 0.5%.
- Vattenfall reported an increase in the average failure rate before its mass replacement program which started in 2021. During the plateau period[8] of its initial fleet (between 5 to 10 years old), Vattenfall reported a failure rate of ~0.3%. As the meters went beyond 10 years of age and approached the end of their 15-year design life, failure rates increased by three to four times to approximately 1%-2%.

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[7] This figure was estimated by shifting Hydro One's 2020 meters age distribution to 2024 (e.g. a 10 year old meter in 2024 is now 14 years old). The same failure rates by age (up to 14 years) were applied to this new population. Therefore, with an overall failure rate of around ~5% for the entire meter fleet in 2024, meters older than 15 years are expected to have a higher failure rate of approximately 6.5% annually.

[8] The plateau period of the bathtub curve refers to the period of the product lifecycle when the product performs reliably. During this phase, the failure rate is low and remains steady. It represents the product's optimal, failure-free lifespan before failures begin to increase with age.

Ellevio also reported an increasing trend of failures before its mass replacement program, which occurred approximately 15 years after the initial deployment[9].

Apart from EDMI, the OEMs did not provide specific information regarding the ageing profile and current failure rates of their customers' fleets. OEMs mentioned that their fleets were performing according to design life (typically 15 years) and did not exhibit any signs of increased failure rates towards the end of life. This contrasts with the observations of smart meter owners.

Amongst the smart meter owners interviewed, failures of smart meters are predominantly in functional components, with minimal issues reported in the metrology components.

Metrology components refer to the parts of the meter that handle measurements, such as voltage, current, and other readings that ensure the meter records data correctly. Functional components refer to the broader set of features of the meter, such as communication modules, storage or displays that support the meter operation but are not directly involved in the core measurement process.

The failures reported by meter owners are predominantly in functional components. SCE, BC Hydro, and Hydro One identified clock battery, capacitors and digital display failures as the most common failures. Notably, SCE reported that over 50% of its meter failures were related to clock batteries.

None of the eight interviewees reported any issues with the metrology components, suggesting that the accuracy of measurements remains stable even as other features of the smart meters experience failures.

This is in line with the observations by the OEMs, where two out of three OEMs (EDMI and L&G) identified the failure of functional components as the most common cause of malfunction.

Amongst interviewees with smart meters using a radio frequency (RF) mesh network, six out of six reported the failure of the communication module was not the primary failure mode.

Six of the interviewees (Ellevio, BC Hydro, SCE, Hydro One and Vattenfall) utilised an RF mesh network as their primary or one of their main communication technologies. Most of the interviewees confirmed that the communication system has not been a cause of major failures for smart meters:

- SCE, Vattenfall, and Ellevio did not report the failure of the communication module as a primary failure mode. Similarly, PG&E, using the same communication technology (Silver Springs mesh) as CPPAL/UE, did not observe higher failures in the mesh technology compared to other components.
- BC Hydro reported encountering challenges regarding the communication module during the installation phase, but these issues were resolvable through firmware updates.
- Hydro One (using a combination of Trilliant mesh and Honeywell mesh) highlighted the cracking of solder joints connecting the metrology module to the communication module as a key failure point, not the communication module itself. This observation is in line with the response from L&G, who was the only OEM that cited that the communication module is more likely to fail, primarily due to meters often having a communication device from a different provider to the manufacturer of the meter itself.

2.2 Replacement drivers and strategies

Two smart meter owners explicitly mentioned that the increase in failure rates across their meter fleets was a primary reason for mass replacement. The rising failure rates, coupled with uncertainty about the future trajectory of these failures, led them to adopt a 'calendar-based' approach for future replacements.

[9] No quantitative information was shared by Ellevio.

The two smart meter owners that specifically cited the increase in failure rates as a key driver for replacement are Hydro One and SCE, both of which are at different stages of their second rollout:

- Hydro One, whose meters are currently 14-17 years old, will begin a mass replacement in 2025, with its failure rates increasing from approximately 2% in 2020 to around 5% in 2024.
- SCE, whose meters are between 13-16 years old, are planning to approach the regulators in early 2025 about a mass replacement in the next regulatory cycle, starting in 2027. SCE also mentioned new features being a key consideration for future replacement (further detailed in the next paragraph).

Enel has been deploying its second generation of smart meters since 2017. The primary drivers for replacement were the meters reaching the end of design life, as well as the introduction of new features. However, it is important to note that in Italy, replacements are driven by compliance with regulation as it is mandatory for smart meters to be replaced at the end of their 15-year design life, which differs from the other four smart meter owners above.

Bluecurrent reported that it does not plan a mass replacement of meters at the end of their design life. Instead, Bluecurrent is opting for using regular sample testing to monitor fleet conditions and guide replacements. This can be explained by a spread-out rollout over many years, that began in 2009 and is still ongoing; this is in contrast to other smart meter owners, whose rollouts were completed over just a few years.

The introduction of new features was unanimously stated as a key consideration for future meter replacement, driven by national directives (e.g. in the EU) or based on economic analysis to support future network utilisation and defer network investments.

In the European Union (EU), EU directives drove member states to develop their own cost-benefit analysis (CBA) to identify the smart meter requirements for their own country. The introduction of new features was the primary driver for Ellevio and Vattenfall and a key consideration for Enel in its second-generation rollout.

As an example in Sweden, a report was prepared by the Swedish Energy Markets Inspectorate (Ei) in 2017 which was later adopted by the Swedish parliament to define the minimum functional requirements for its next generation of smart meters.

This study defined seven functionalities: power quality information (voltage, current, active and reactive power for each phase), provision of a customer interface to provide live energy usage, remote data collection by the network, energy reading every 15 minutes, outage information[10], remote software update and remote breakers[11] (Ei, 2018). Ellevio specifically reported that the 15-minute energy reading was not supported by its first fleet, which necessitated the mass replacement.

In contrast, several North American utilities, such as SCE, PG&E and Hydro One are voluntarily considering new additional features for their second generation of meters as a key factor to help with future grid utilisation.

- Both Californian utilities, SCE and PG&E, highlighted high electricity tariffs in California and the resistance from the California Energy Commission (CEC) to increasing these tariffs. They are exploring new technologies such as edge computing to enable new use cases, like load disaggregation, or near real-time power quality data (at the second level) to improve grid visibility. These new-generation meters are expected to optimise network utilisation and defer future infrastructure investments, helping to control distribution costs.

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[10] The meter should be able to register data about the beginning and end of a power outage in one or more phases, that are three minutes long or more to facilitate the DSOs to pay compensation to the customer for interruptions and to report data to Ei.

[11] Remote breakers, typically used for the remote connect and disconnect of supply.

- Hydro One is currently in the field-testing stage of its second rollout, demonstrating end-use cases of Distributed Intelligence (i.e. active transformer monitoring, load disaggregation, theft detection, EV awareness, etc.).
- Despite being only in the middle of the initial design life (20 years), BC Hydro has already started to investigate the features that will be needed in the future to support the network. Currently, the use cases and benefits are not well defined, and BC Hydro expects to engage experts to support the definition of these.

Among the five meter owners with replacement plans, four have scheduled a mass replacement within three to five years, in contrast to a more gradual replacement, driven by factors such as high failure rates, legislative deadlines or costs optimisation.

As previously mentioned, new smart meter requirements drove mass replacements in Sweden. However, both Ellevio and Vattenfall also cited minimising deployment costs as a reason for a mass replacement, benefitting from the economies of scale.

- Ellevio completed its second-generation rollout between 2020 and 2023, replacing its entire fleet of approximately 1 million meters.
- Vattenfall is currently completing its second-generation rollout, which began in 2021 and is expected to finish by the end of 2024.

Hydro One will begin its second-generation rollout in early 2025, aiming to replace all 1.5 million meters within five years. The primary reason for this timeline is to address high failure rates and prevent them from increasing further.

SCE reported planning to begin its second-generation rollout in 2028, with the goal of replacing all 5.3 million meters within five years.

The only exception is Enel, whose more gradual replacement began in 2017 and is currently still ongoing, with approximately 75% of replacements completed. One potential reason for the slower rollout can be attributed to its larger fleet size, comprised of approximately 32 million meters.

The OEMs interviewed highlighted increasing failure rates across fleets, particularly as meters exceed their design life, as a key reason for smart meter replacement. They also emphasised that the introduction of new features, including real-time data, fault & outage detection, and edge computing, are secondary factors that can accelerate the replacement process.

EDMI reported that among its customers, increasing failure rates as meters exceed their design life was one of the key reasons observed for smart meter replacement.

However, EDMI also observed that customers who are meter service providers (such as Bluecurrent), as opposed to Utilities and DNSPs, have an incentive to extend the life of their meters beyond the design limits. For them, the key factor is closely monitoring both the failure rate and the overall condition of the fleet to proactively identify actions that can prevent future mass replacements. This strategy is made possible by regular sampling of the fleet and data analysis to determine the overall health of the meters.

Gridspertise, whose clients are primarily European, have replacements that are primarily driven by compliance with regulatory change. The following replacements are usually en masse to meet their respective legislative requirements, sometimes forcing change at the end of design life (E.g. Italy) but also mandating new features for smart meters, observed in both Italy and Sweden.

Although L&G confirmed EDMI's observation of increased failure rates, they noted that some customers in North America and Japan replaced meters before the end of their design life to introduce new features. The significant technological advances since the meters were first installed were seen as a compelling reason for this change.

Finally, one aspect that was only mentioned by L&G throughout the entire interview process was a cybersecurity concern, with the introduction of more advanced security features seen by some of its customers as a reason for replacement.

2.3 Justifications

In Europe, with directives setting new smart meter requirements, few justifications were needed for meter replacements, as long as the new meters complied with these updated standards.

As previously stated, in the EU, high-level directives were set by the European Parliament which were then interpreted by each member nation's legislature to derive the future requirements for smart meters. As a result, Enel, Ellevio, and Vattenfall reported that they required minimal economic justification for smart meters mass replacement, as long as the new meters complied with the regulatory requirements in their respective countries.

In the other jurisdictions investigated, economic analyses of smart meter mass replacements were or are expected to be required as justification to the regulators for future replacement programs.

Outside of the EU, where smart meter requirements are defined by prescriptive legislation, smart meter owners have stated that detailed economic justifications will be required for the replacement of future smart meters, such as a CBA.

- In California, both SCE and PG&E expect to present a detailed CBA to the CEC as justification for their new smart meter fleet, relying on the development of new meter features, such as load disaggregation or real-time data, to support the economic analysis.
- Similarly, BC Hydro, whose meters are currently only midway through their lifespan, are proactively exploring new features that will be a part of its next rollout. It also expects to present a CBA to the British Columbia Energy Regulator in the future when it begins its replacement program.
- In Ontario, Hydro One presented evidence of its increasing failure rates as justification to its regulator, including both past data as well as projections of future failures performed by a third party. Furthermore, Hydro One presented fact-based analyses such as a cost benchmark between both the expected labour and meters of a one-by-one reactive replacement program compared to a mass rollout as justification for its mass replacement program.

3. Appendix – Deep dive into smart meter owners

This section summarises the evidence gathered from meter owners. The information is divided into three parts: first, details on the initial rollout, key features, and data on ageing and failure rates; second, an overview of the replacement drivers, strategies, and considerations for future smart meters; and third, the justifications made or planned for regulators in each jurisdiction.

3.1 Ellevio (Sweden)

3.1.1 Current fleet information

Fleet information

Ellevio's initial rollout spanned 2006-2009, when approximately 1 million smart meters were installed. During this initial deployment, the communication technology employed by the meters involved the 2G network ~80% of meters), mesh technology (~10%) and powerline communication (~10%).

Key features

Key features that were a part of these meters included a remote breaker function, remote reading of measurements, outage detection and up to 180 days of onboard storage. The meters using the cellular network collected measurements hourly, while those with mesh and powerline communication technology recorded data daily.

Failure information

Ellevio reported higher failure rates as the meters neared the end of its 15-year design life but did not provide specific failure statistics or primary failure modes.

3.1.2 Replacement drivers and strategies

Replacement strategy

Ellevio conducted a mass replacement program in 4 years, from 2020-2023, in which the entire fleet was replaced. This replacement began when the initial fleet was between 11-14 years old and was completed with meters between 14-16 years old, whose initial design life was 15 years.

Primary drivers

The primary driver of this wave of replacement was compliance with updated requirements for smart meters from Sweden. *Figure 5* shows an extract from the report prepared by the Swedish Energy Markets Inspectorate (Ei, 2018) which outlined seven functional requirements for smart meters, which were later adopted into regulation, with a deadline set for the implementation of these requirements by January 2025.

Table describing the seven suggested functions/functionalities

No.	Functionality	Purpose
1	The meter should for every phase be able to measure voltage, current, active and reactive power for withdrawal and input of electricity. The meter should also be able to measure and register the total energy for withdrawal and input of electricity.	Promotes efficient network operation. Facilitates integration of micro production in the network.
2	The meter should be equipped with a customer interface, supported by an open standard, for the customer to be able to take part of the measured values (see functionality no. 1) in near real time. It should not be possible to send information to the meter through the interface. The interface needs to be activated by the DSO, on request by the customer, to provide information. The DSO should control the identity of the user and must deactivate the interface when the customer moves out.	Creates conditions for a developed energy services market. Promotes demand side flexibility and energy efficiency. Increases customer empowerment.
3	The DSO should be able to read the measured values (see functionality no. 1) remotely (with remote control).	Promotes efficient collection of meter data.
4	The meter should be able to measure the energy for every hour and be able to convert to measure the energy for every fifteen minutes.	Increases the customers possibility to be active (participate) in the market.
5	The meter should be able to register data about the beginning and end of a power outage in one or more phases, that is three minutes long or more.	Facilitates for the DSOs to pay compensation to the customer for interruptions longer than 12 hours and to report data to Ei. Empowers the customer.
6	The DSO should be able to update software and change settings of the meter with remote control.	Provides that new functionalities can be introduced in a cost-efficient way. Expensive field visits can be avoided.
7	The DSOs should be able to turn on and off the power through the meter with remote control. This requirement only applies for meters that are not transformer connected.	Facilitates for the DSOs to turn off the power if the customer moves out. Expensive field visits can be avoided.

Figure 5: Description of seven functional requirements for smart meters

Ellevio mentioned that its previous generation of meters did not measure at a quarter-hourly interval, which was mandated in the new requirements, a primary driver for replacement.

The decision to roll out the second wave in approximately four years was primarily driven by the need to comply with the deadline set by Swedish regulators to meet new requirements by 1 January 2025. Additionally, Ellevio designed this mass replacement to minimise deployment costs by leveraging economies of scale when possible. The replacement also synergized with the phasing out of 2G communication technology by the Swedish telecommunications companies, used by greater than 50% of its meters.

3.1.3 Justifications

The regulator did not require specific economic justification, provided the new meters complied with the new requirements set by legislation.

3.2 Vattenfall (Sweden)

3.2.1 Current fleet information

Fleet information

Vattenfall's initial rollout spanned 2003-2008, where approximately 1 million meters were deployed. There was a combination of communication technologies used, including a radio frequency mesh network and others using powerline communication technology.

Key features

Key features within this fleet included remote reading, remote breakers and onboard data storage. There was also limited ability for some of its meters to provide power quality information.

Failure information

Regarding failure information, Vattenfall reported that during the plateau period[12], the failure rate observed was approximately 0.3%. As the meters came towards the end of design life, this number increased by 3 to 4 times, to approximately 1%-2%. The primary failure modes were related to electronic components such as diodes and issues with the digital display. Furthermore, natural weather phenomena such as lightning were cited by Vattenfall as the cause for part of its meter failures, without mentioning the specific percentage of failures associated with this.

3.2.2 Replacement drivers and strategies

Replacement Strategy

Vattenfall is currently conducting a mass replacement program, having started in 2021 and is expected to finish by the end of 2024, in which the entire fleet will be replaced. This replacement began when the initial fleet was between 13-18 years old and will be completed between 16-21 years after the initial rollout began in 2003.

Primary drivers

The primary driver is similar to Ellevio, in Section 3.1.2.

Before the rollout of the second generation, Vattenfall conducted an internal analysis to identify additional features beyond the minimum functional requirements set by the Swedish regulators, ultimately defining the benefits and end-use cases for its network. For example, this resulted in the decision to have the meters read every minute (as opposed to every 15 minutes as mandated) and collecting power quality data around undervoltage, overvoltage and harmonics.

3.2.3 Justifications

The regulator did not require specific economic justification, provided the new meters complied with the new requirements set by legislation.

[12] The plateau period of the bathtub curve refers to the period of the product lifecycle when the product performs reliably. During this phase, the failure rate is low and remains steady. It represents the product's optimal, failure-free lifespan before failures begin to increase with age.

3.3 Enel (Italy)

3.3.1 Current fleet information

Fleet information

Enel's initial rollout spanned 2001-2007, when approximately 32 million Enel smart meters were installed. During this initial deployment, the communication technology employed by the meters was powerline communication technology, mentioned as a cost-efficient solution due to sharing common power infrastructure. Enel has since started a second-generation rollout, beginning in 2017.

Key features

Key features of these meters include remote reading and remote breaker functions. There were no mentions of the collection of power quality information or outage detection. These meters were remotely read once per month.

Failure information

Regarding failure information, the failure rate observed was less than 1%, for both its fleet rolled out in the early 2000s as well as the second-generation rollout. Enel identified the primary failure mode as an issue with breakers, which hindered the remote connection and disconnection of smart meters. These failures primarily occurred during the installation phase and were regarded as "infant mortality period[13]" of the meter fleet.

3.3.2 Replacement drivers and strategies

Replacement Strategy

As previously mentioned, Enel began a second-generation rollout in 2017, which is still currently ongoing, with approximately 75% (24 million out of 32 million) of meters replaced. Enel did not provide information regarding the specific timeline of its rollout, which began nearly 7 years ago, contrasting the timeline provided by other meter owners with defined timelines but also the time frame taken during the initial rollout from 2001-2007.

Primary drivers

Enel outlined two key drivers behind its meter replacement program. The first was to comply with the regulatory requirement to replace the meters at the end of the 15-year design life. The second driver was the introduction by the legislation of new requirements for smart meters, which required upgrades to remain compliant with evolving standards.

As a part of the second rollout, new requirements were mandated such as an addition channel of communication, increasing reading frequency from hourly to quarter-hourly and a last-gasp function to provide outage information. All these features were not available in Enel's first generation of smart meters.

[13] Infant mortality period refers of the bathtub curve refers to the period of the product lifecycle at the very beginning of deployment, typically characterised by higher but decreasing failure rates, often associated with manufacturing defects, installation errors or design flaws.

3.3.3 Justifications

Similar to Ellevio and Vattenfall, there were no specific economic justification requirements from the regulators as the replacement was driven by compliance with new meter requirements. With a 15-year lifespan imposed by the regulators and new features required, Enel did not have to provide justification to conduct this replacement.

3.4 Pacific Gas and Electric (California)

3.4.1 Current fleet information

Fleet information

PG&E's initial rollout spanned 2007-2010, when approximately 5.6 million Itron meters were installed. Similar to CPPAL/UE, PG&E used the Silver Springs RF mesh radio communication technology for its smart meters during the initial deployment.

Key features

Key features of this initial fleet include remote reading, remote breakers, theft detection (preventing diversion of energy) and outage detection. The usage information was collected daily and relayed to customers via an online portal so that customers could see their daily energy usage.

PG&E noted that it conducted a pilot to investigate the needs for load disaggregation approximately 10 years ago, during its first rollout but didn't find it valuable. However, due to changing consumer behaviour and increasing cost awareness, the sentiment towards this feature has changed and will likely be implemented in the second-generation rollout.

Failure information

PG&E reported an increase in failures, with ~100-150k meter replacements per year in the last few years, equating to approximately 2% of its initial fleet, which is between 14-17 years old currently with an initial design life of 15 years. PG&E did not provide information regarding its primary failure modes, only mentioning that the communication technology was not a primary point of failure.

3.4.2 Replacement drivers and strategies

Replacement Strategy

PG&E did not comment on the specific timeline that it expects to complete its next rollout.

Primary drivers

One of the main drivers for replacement will be to implement new features in its next generation of meters. This will provide better visibility on its network (e.g. real-time, higher granularity, etc.) which will enhance decision-making to optimise network utilisation and support reducing future investments.

One of the key features PG&E has been testing is Distributed Intelligence (DI). According to PG&E, there are several potential use cases, including load disaggregation to improve customer's awareness of their real-time energy usage. Another important application is mapping the load distribution across the transformers within the low voltage network, which PG&E has identified as a critical issue due to the frequent overload of transformers, caused by the addition of loads such as electric vehicles. PG&E cited that the data provided by these meters will be valuable for its operations and planning teams, helping to inform of future upgrades.

3.4.3 Justifications

Due to California's high electricity tariffs, PG&E anticipates regulatory pressure against future rate increases. To address this, PG&E plans to demonstrate how the AMI 2.0 program can reduce future distribution costs for customers, supported by a clear, fact-based narrative and a cost-benefit analysis (CBA). A key part of this justification will be identifying meter features that improve network utilisation and ultimately help to defer investments for networks.

3.5 Southern California Edison (California)

3.5.1 Current fleet information

Fleet information

SCE's initial rollout spanned 2008-2011, where approximately 5.3 million Itron meters were installed. During the initial deployment, the Itron Openway mesh was selected as the communication technology that would be installed on its meters.

Key features

Key features of these meters include remote reading, onboard data storage for up to 25 days, and some power quality information provided for its C&I customers.

Failure information

SCE reported that starting last year, it began closely monitoring its failure rates and observed ~2% failure rate for meters aged 13 to 16 years. This is higher than the 0.5% failure rate observed during the warranty period (no information shared on the duration of warranty period). Amongst the failures, the most common failure mode was the clock battery, accounting for over 50% of failures. Other failures were primarily related to communication errors.

3.5.2 Replacement drivers and strategies

Replacement Strategy

SCE is in a similar position to its Californian competitor, PG&E, having not yet begun replacing its first generation of smart meters. SCE expects to employ a mass replacement strategy, replacing all 5.3 million of its meters in 5 years beginning in 2028. They will approach the regulators next year for its next regulatory case in 2025, with meters between 17-20 years old by 2027, the end of the current regulatory cycle.

Primary drivers

SCE, whose meters are between 13-16 years old is planning to approach the regulators in early 2025 about a mass replacement in the next regulatory cycle, starting in 2027, due to increasing failure rates as their fleet is approaching the end of life.

SCE highlighted the introduction of new features as a key factor in supporting its replacement strategy, mentioning edge computing & distributed intelligence, DER management, situational awareness, and enhanced customer engagement. SCE expected these features to support the ageing of the grid by improving future network utilisation and facilitating the integration of additional DER.

Lastly, SCE expects the replacement to involve both the communication system and the meters themselves, with the creation of a technology-agnostic system a central part of the strategy, increasing overall interoperability and reducing reliance on a single vendor's proprietary technology as it does now.

3.5.3 Justifications

In addition to the ageing infrastructure of the grid, which will require significant future investments, SCE highlighted California's ambitious goal of achieving carbon neutrality by 2045. To support this target, SCE anticipates an 80% increase in electrification and expects the deployment of the second generation of smart meters to play a crucial role in enhancing the integration, management, and orchestration of Distributed Energy Resources (DER) within the grid.

SCE outlined two key elements that would form the basis for justifying their approach to the regulator, as detailed in a comprehensive Cost-Benefit Analysis (CBA):

- The increasing uncertainty surrounding the future failure rates of its fleet, which could result in higher costs associated with reactive maintenance, compared to proactive replacement.
- The introduction of new features to optimise future network utilisation, defer capital investments, and facilitate the integration of Distributed Energy Resources (DER), in alignment with California's carbon neutrality goals.

3.6 BC Hydro (British Columbia)

3.6.1 Current fleet information

Current fleet

BC Hydro's initial rollout spanned 2012-2015, when approximately 2 million Itron meters were deployed. A combination of communication technology was used, with the majority of meters using a radio mesh network, primarily in urban areas and approximately 20-30 thousand meters using cellular technology where population density did now allow for a mesh system.

Key features

Key features of these meters included remote reading, theft detection, remote breakers and provision of outage information. Similar to CPPAL/UE, BC Hydro offered a gateway device using Zigbee technology that would provide an in-house display to customers about its energy usage. However, the uptake of this device was low.

Failure information

BC Hydro noted that during the early stages of the rollout, it had issues that were resolvable through firmware updates. Since achieving system stabilisation, BC Hydro reports having failure rates between 0.5%-1% on an annual basis. So far, no significant increases have been observed by BC Hydro, whose fleet is between 9-12 years old. The most common failures are related to functional components rather than metrology, with the failure of batteries and displays mentioned. Furthermore, BC Hydro reported encountering challenges regarding the communication module during the installation phase, but these issues were resolvable through firmware updates.

3.6.2 Replacement drivers and strategies

Replacement strategy

BC Hydro expects to treat the second-generation rollout of its smart meters similar to an asset replacement at the end of life.

Primary drivers

BC Hydro, with the youngest smart meter fleet within this group, between 9-12 years old, has begun to investigate the next generation of smart meters. Although only mid-way through its current lifespan (design life of 20 years), BC Hydro explicitly mentioned investigating new features that will support its future network utilisation. Currently, the use cases and benefits are not well defined, and BC Hydro expects to engage experts to support the definition of these.

One use case that was highlighted was the integration with an Advanced Distribution Management System (ADMS), which was considered during the first deployment but never realised. Some other features that are expected to be important are edge intelligence and having more near real-time data to support future integration of DER. Furthermore, BC Hydro expects to transition to a standards-based solution that should be backward compatible with its existing meters.

3.6.3 Justifications

In the first meter deployment, a CBA identified energy diversion reduction as a key benefit for smart meters rollout. For the next rollout, although not currently well defined, BC Hydro expects that increased failures with fleet ageing will form a key part of the justification, supported by a CBA of the new features that it eventually decides to implement.

Unlike its Californian counterparts, BC Hydro highlighted that its large portfolio hydro assets results in lower electricity tariffs and less pressure from an end-cost perspective. Nevertheless, BC Hydro anticipates the need to conduct an economic assessment to support its case to regulators.

3.7 Hydro One (Ontario)

3.7.1 Current fleet information

Fleet information

Hydro One's initial rollout spanned 2007-2010, when approximately 1.5 million meters were deployed. During the initial deployment, the meters used a combination of mesh and the cellular network as its communication technology. Due to Hydro One's use of three different meter OEMs during its initial deployment (Trilliant (~95%), Honeywell and Sensus (~5%), there were also different mesh networks being used (Trilliant mesh and Honeywell mesh).

Key features

Key features within these meters included remote reading, outage information and remote breakers for a portion of the meters.

Failure information

Hydro One reported an average failure rate of ~2% across its entire fleet in 2020, which has since risen to ~5% in 2024. A closer analysis of failure rates by age reveals a close correlation between increasing failure rates and the ageing of the fleet.

Specifically, *Figure 6* from Hydro One's 2021 regulatory filing (Hydro One, 2021), illustrates three distinct periods, which closely resemble the phases of the bathtub curve:

1. An infant mortality period during the initial years (from years 1-4) with a low and decreasing failure rate;
2. A plateau period during the middle years (from years 5-9) with a low and constant failure rate (~0.5%-1%); and
3. A wear-out period during the latter years (year 10 onwards) with increasing failures as the product reaches the end of design life.

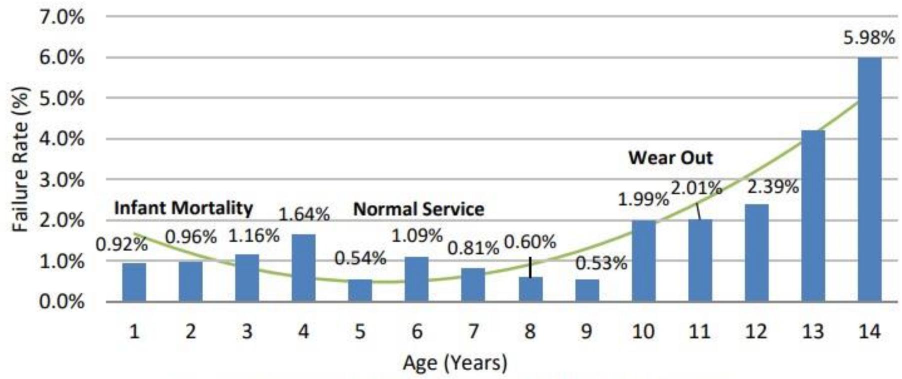

Figure 75: Meter Failure Rate by Age of Meter (as of 2020)

Figure 6: Hydro One Meter Failure Rate by Age as of 2020

As a result, in 2020, meters between 5 and 10 years of age had failure rate by age of ~0.5%-1%, whereas meters greater than 10 years old saw this number exceed ~2%. Notably, meters over 12 years of age showed a consistent rise failure rate by age, reaching ~4% for meters aged 13 years and ~6% for those aged 14 years. As the fleet aged between 2020 and 2024, and a growing portion of the fleet now surpassing 10 years of age, Hydro One's average failure rate has increased to ~ 5% in 2024 (YTD data). Although Blunomy did not have access to failure rate based by age for 2024, the current overall rate of ~5% suggests that the oldest meters (more than 15 years old) have experienced an increase in failures, being now in a range of 6.5% (calculation detailed in footnote of page 8).

The primary failure modes that were identified through Accelerated Life Testing, conducted by Hydro Quebec (Hydro One, 2021), included capacitor leakages leading to communication faults, LCD component failures and cracking solder joints between the metrology and communication components. Overall, failure modes were all identified on different functional components of the meter, with no metrology issues identified.

3.7.2 Replacement drivers and strategies

Replacement Strategy

Hydro One is about to begin its second-generation rollout in 2025, currently in the field-testing stage. They have secured funding to replace a portion of its meters in the next 3 years and expect to complete the entire replacement in 5 years.

Primary drivers

Hydro One reported that the main reason for replacement is the increasing failure rates in its ageing fleet, which reached about 2% of the total fleet in 2020, and now around 5% in 2024. Hydro One also reported that a forecast of future failures based on current trends was conducted in 2020 by a third party, showing a continuous increase after 2020 (higher compared to current failure rates observed in 2024). The combination of rising failure rates and uncertainty about future trends were key factors in the decision to proceed with mass replacement.

As part of the next generation, many new features will be added, including remote disconnect and reconnect capabilities, improved outage management, and the introduction of DI, with use cases still being defined. Hydro One is testing DI use cases such as active transformer monitoring, load disaggregation, theft detection, and EV awareness. They believe the new meters will act as sensors, providing enhanced visibility and control over the low-voltage network.

Furthermore, Hydro One will move from a 2.4GHz mesh solution to a 900MHz solution, which will reduce the number of collectors by half due to the increased range of the new solution. A key reason for selecting the new communication solution is to reduce the number of devices in the field, reduce field testing requirements overall and better compatibility with the sparse nature of Hydro One's service area.

3.7.3 Justifications

During the last regulation submission (Hydro One, 2021), Hydro One built a cohesive narrative regarding the need to replace its first generation of meters, with the primary justification being the clear evidence of ageing amongst its fleet as it approaches the end of the lifecycle. Furthermore, it demonstrated the risks to the quality of service (e.g. billing reliability, time to replace smart meters, etc.) and the increased costs of reactive replacement compared to proactive replacement.

A cost benchmark was completed to demonstrate the financial risks associated with the higher labour costs for individual replacements and higher per unit meter costs relative to bulk purchase. In addition, Hydro One cited the opportunity to use a newer metering solution to improve customer service in its submission to the regulators.

3.8 Bluecurrent (New Zealand)

3.8.1 Current fleet information

Fleet information

Bluecurrent's rollout started in 2009 and is still on-going with approximately 1.5 million EDMI meters installed. The legacy meters used the 2G cellular network as its communication technology. This since has been upgraded to 4G modems, with approximately 1 million meters having been upgraded in an ongoing deployment.

Key features

Key features of these meters included remote reading, onboard storage for up to three months and remote breakers.

Failure information

Although Bluecurrent was interviewed for this study, it was excluded from the comparative analysis. The failure rate they reported was significantly lower compared to figures from all other smart meter owners, indicating a different scope and/or definition of a failure. Requests for clarification were unfortunately not answered. During the initial phase of the rollout, Bluecurrent noted failures due to installation errors and customers overloading the equipment (customers exceeding the limited rating of their supply), rather than actual hardware issues with the meters.

Outside of the failures during the initial installation phase, some of the more common failure modes that were observed included issues with the onboard memory and computing issues, stemming from an overlap of the measurement cycle and computing cycle of the meter.

3.8.2 Replacement drivers and strategies

Replacement Strategy

Bluecurrent cited that it does not expect to complete a mass replacement, unlike most of the other interviewees. This can be explained by a historically spread-out rollout over many years, as it began in 2009 and is still ongoing in contrast to other smart meter owners, whose rollouts were completed over just a few years. Unlike other interviewees, its meters are not part of a regulated asset base, and it aims to maintain them as long as possible beyond their design life.

Primary drivers

Bluecurrent expects to pursue a proactive approach based on the overall condition of the fleet, determined through regular fleet sampling. Based on Bluecurrent's current observations, there is no indication that the fleet requires replacement due to increasing failures from aging assets.

In addition, new features were mentioned as a consideration in any future replacement, including edge computing, onboard computing and allowing for more complex load control schemes.

3.8.3 Justifications

Bluecurrent is not under a regulation framework, so it does not require justifications to the regulators for any future replacement. This is likely a conversation between Bluecurrent and the networks that it serves.

4. Appendix – Deep dive into smart meter manufacturers

This section outlines the evidence gathered from smart meter OEMs. The information collected across the three OEMS will be structured across two different sections. Firstly, information regarding the ageing and failures of existing meters from their customers. Secondly, information regarding the replacement strategy and justifications of their customers.

4.1 EDMI

4.1.1 Ageing trends of existing smart meter fleets

EDMI reported a significantly lower failure rate, with a calculation method different compared to other smart meter owners. Their failure rate only includes smart meters returned to EDMI for repair during the warranty period, excluding all other failures within the smart meter fleet. Blunomy considered EDMI's failure rate not relevant for direct comparison and excluded it from the study.

4.1.2 Observed replacement strategies and justifications

EDMI reported that among its customers, increasing failure rates as meters exceed their design life was one of the key reasons observed for smart meter replacement.

However, EDMI observed that for meter service providers like Bluecurrent, who are incentivised to extend the lifespan of meters beyond their design life, replacement strategies are often based on the condition of the existing fleet rather than 'calendar-based'. For them, the key factor is closely monitoring both the failure rate and the overall condition of the fleet to proactively identify actions that can prevent future mass replacements. This strategy is made possible by regular sampling of the fleet and data analysis to determine the overall health of the meters.

4.2 Gridspertise

4.2.1 Ageing trends of existing smart meter fleets

Regarding ageing and failure, Gridspertise cited a failure rate is below 1% across the past years. However, they did not provide the average fleet age that this statistic relates to so any comparison must be done with caution. In terms of primary failure modes, Gridspertise stated that during the initial deployment in Enel (started in 2001), there was an issue with the breakers within the meters, these issues were later resolved. Outside of this, there was no primary mode of failure available.

4.2.2 Observed replacement strategies and justifications

Due to the European nature of Gridspertise's clientele, the replacement strategies and justifications seen in their customers are very similar. In Europe, the European Union sets out directives to its member countries, and each member state define their own requirements for smar meters. Therefore, replacements tend to be en masse to comply with their respective legislative requirements.

4.3 Landis & Gyr

4.3.1 Ageing trends of existing smart meter fleets

Overall, L&G was unable to provide specific ageing and failure information, citing that the meters that it has deployed are performing as expected or better compared to its initial design life of 15 years. In general, they believe that the communication module does not last as long as the meters themselves as communication modules tend to be from a different solution provider to the meters themselves, as is the case with CPPAL/UE who use Secure and L&G meters but Silver Springs (later Itron) as its communication technology.

In terms of prominent failure modes, L&G highlighted capacitors, batteries and LCDs as being more prone to failure, although not observed amongst its products. This is generally in line with the observations from different meters, with those who have identified a primary failure mode often citing batteries and LCDs as a common issue.

4.3.2 Observed replacement strategies and justifications

L&G noted that in some of its overseas customers in North America and Japan, there are instances of replacement prior to the end of design life in order to introduce new features, with the step change in technology compared seen as a key reason for replacement. The features that its customers have mentioned as important include flexibility management, real-time data, power quality information and edge computing. This is widely in line with features that have been mentioned by the other meter owners.

Furthermore, an additional justification that was mentioned was the inclusion of new cybersecurity features. With cybersecurity an increasingly prominent issue in the digital world, the introduction of more advanced security features is seen as a key reason for some L&G customers in their replacement strategy.

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Majority of information gathered in this report are from interviews.

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