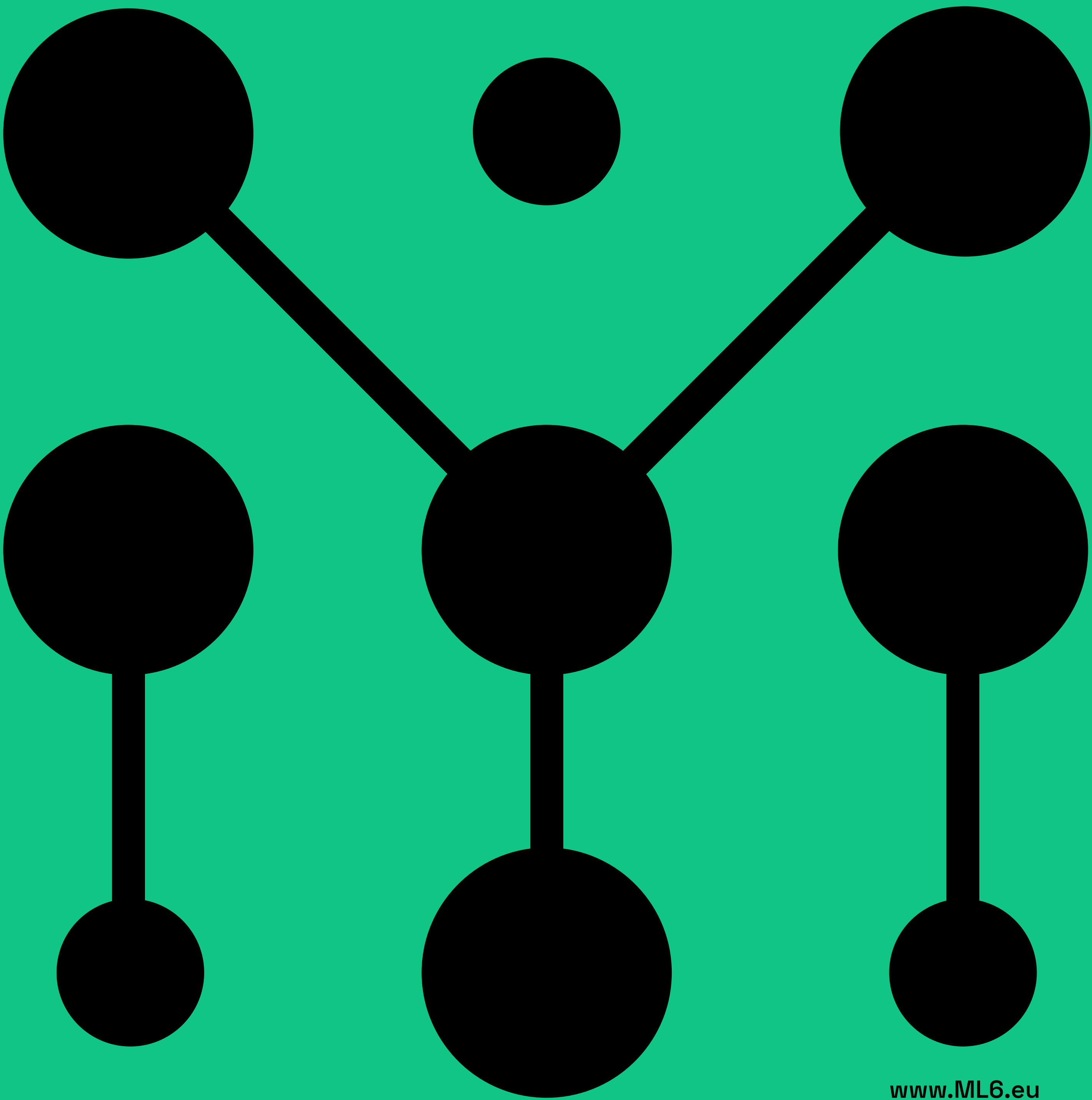
ENERGY & UTILITIES

ML6

HOW AI DRIVES VALUE IN THE SMART METER VALUE CHAIN.



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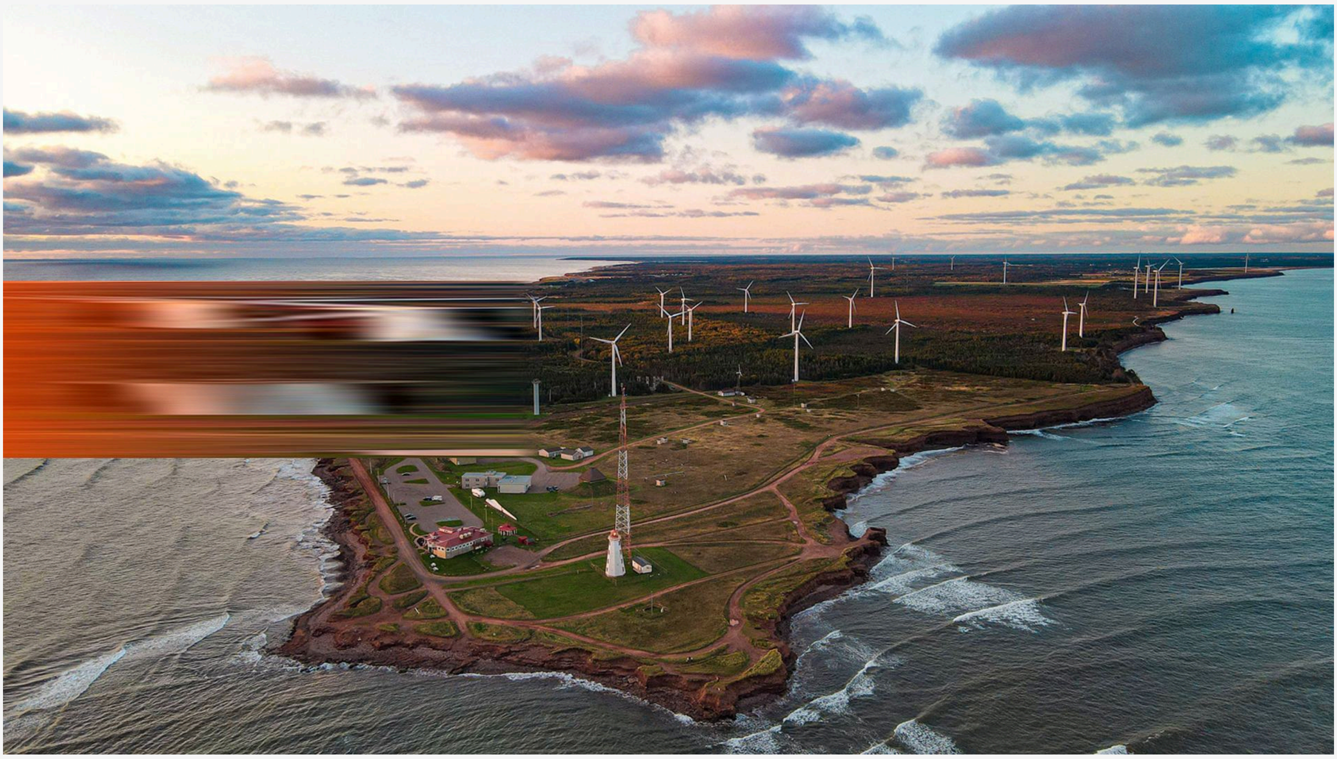


EXECUTIVE SUMMARY.

The energy sector faces a "perfect storm" of challenges, including managing grid volatility from distributed energy resources (DERs) and electric vehicles (EVs), handling an explosion of high-granularity meter data, and meeting stricter regulatory requirements for security and data privacy.

To address this, utilities must treat smart metering as an end-to-end value chain, with AI serving as a multiplier that transforms raw data into actionable intelligence.

This viewpoint explores how utilities can leverage the smart meter value chain and Artificial Intelligence (AI) to transform raw data into actionable intelligence for grid planning & operations and optimize customer service.

01 INTRODUCTION.

The energy sector is undergoing a major shift, driven by decarbonization, decentralization, and digitalization. As Europe moves toward Net Zero, the grid is transitioning from a traditional, unidirectional, supply-driven model to a volatile, demand-driven ecosystem consisting of millions of controllable loads.

In this new landscape, the smart meter is no longer merely a digital "cash register" for billing; it has evolved into a critical edge sensor essential for grid stability, market facilitation, and customer engagement.

Utilities today face a dual pressure: (1) they must manage an increasingly complex grid loaded with intermittent renewables and electric vehicles (EVs), while simultaneously (2) meeting rising customer expectations for real-time insights and personalized services.

According to the International Energy Agency in its Electricity 2024 report, global electricity demand is expected to grow by around 3–4% annually through 2026, driven by electrification trends such as electric vehicles, heat pumps, and digital infrastructure—placing increasing pressure on grid systems that were not originally designed for this level of volatility and decentralization.

This evolution positions smart metering as a critical enabler of Demand Side Management (DSM) and distributed intelligence, where millions of connected endpoints continuously feed time series data into centralized and edge-based systems. As a result, utilities can transition toward a smart energy future, powered by AI tools, automated control systems, and data communication networks that operate across increasingly decentralized infrastructures.

The data generated by Advanced Metering Infrastructure (AMI) holds the key to unlocking these capabilities. However, realizing this potential requires moving beyond simple data collection to advanced value extraction.

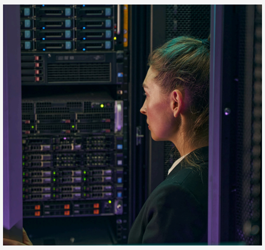
02 THE OPPORTUNITY: ENABLING GRID VOLATILITY AND CUSTOMER EXPECTATIONS THROUGH THE SMART METER VALUE CHAIN.

Utilities are navigating a ”perfect storm” of operational and strategic challenges.

→ **Grid volatility & complexity**
Integrating distributed energy resources (DERs) such as solar PV and wind, coupled with the electrification of heat and transport, creates unpredictable load patterns that stress existing infrastructure.

→ **Data explosion & accessibility**
There is a growing need for diversified meter data (voltage, power quality, ”last gasp” signals) at higher granularity and frequency. New market players, such as aggregators and energy communities, demand standardized and seamless access to this data to offer flexibility services.

→ **Regulatory & security**
Stricter regulations regarding data privacy (GDPR), the ”right to data” for consumers, and security-by-design to protect the critical infrastructure require robust, controllable architectures.



→ **Operational efficiency**
Aging assets and workforce constraints drive the need for remote operations and predictive maintenance to reduce OPEX.

These challenges are further amplified by the increasing complexity of the electric grid, where **intermittent renewable energy sources** create nonlinear load patterns often illustrated by phenomena such as the **duck curve.**

Mitigating this requires not only infrastructure upgrades but also advanced **energy management systems** capable of processing **massive consumption data streams** in near real time.

To address these challenges, utilities must view the smart meter value chain (see figure 1) as a key-enabler in their operations.

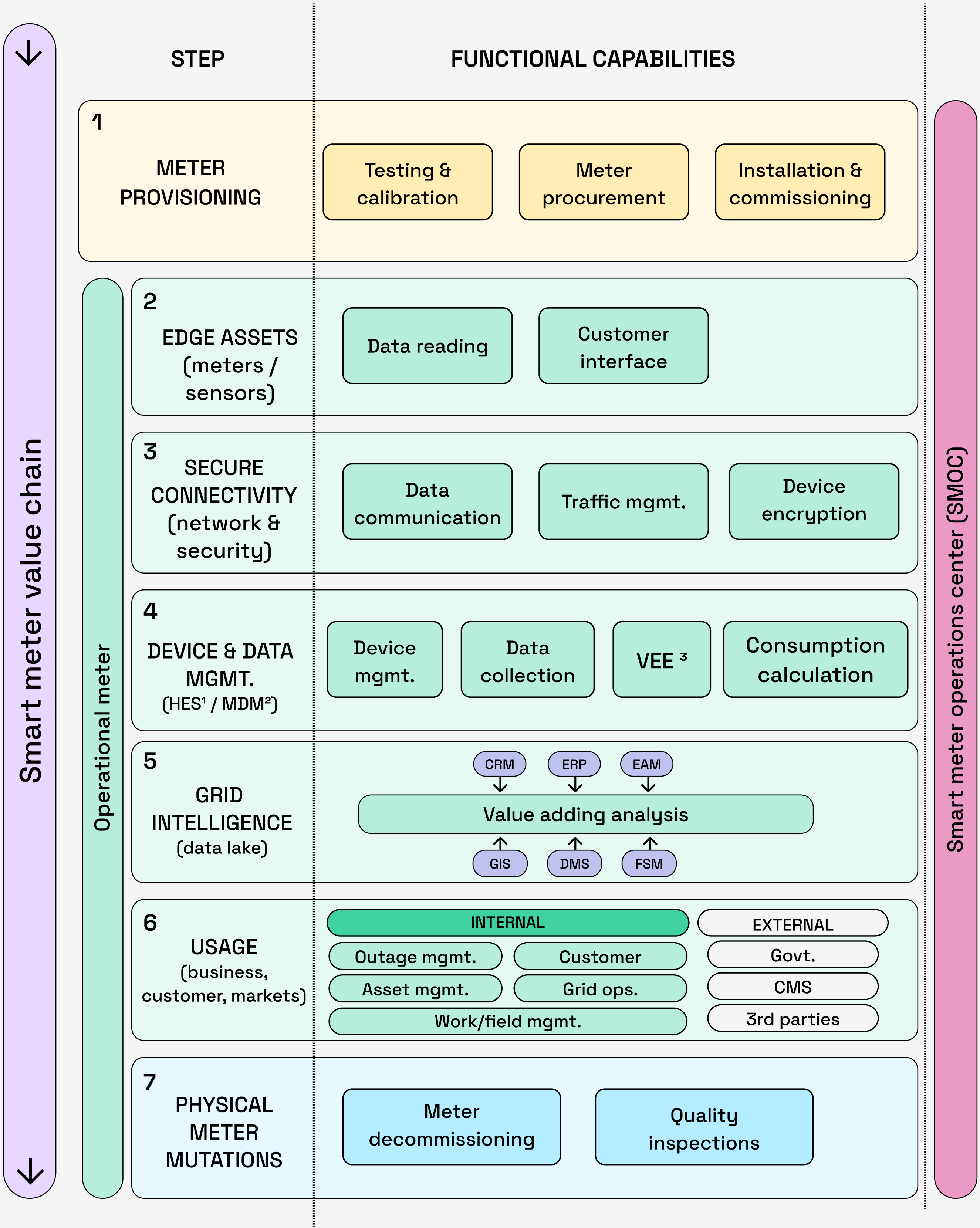


Figure 1: smart meter value chain and related functional capabilities.

1 | Head-end system
2 | Meter data mgmt.
3 | Validation, estimation, editing

01 Meter provisioning

This initial phase covers supplier selection, rigorous testing, and calibration of meter shipments before they are installed and commissioned in the field.

02 Edge assets and connectivity

This layer covers the smart meter itself and local IoT gateways. Modern architectures are moving towards modular hardware with edge computing capabilities, allowing for local data processing and real-time decision-making without overloading the central network. Connectivity technologies (PLC, RF Mesh, 4G/5G) ensure the reliable transport of this data.

03 The Data Core (HES & MDM)

The Head-End System (HES) and Meter Data Management (MDM) systems form the central nervous system. They handle the massive ingestion of raw data, manage bidirectional device communication, and perform critical Validation, Estimation, and Editing (VEE) transactions to ensure data quality for downstream billing and analytics.

04 Grid Intelligence (DSO operations)

Here, data is transformed into operational value. This involves integrating meter data with Asset Management and Outage Management Systems (OMS) to visualize grid health, predict congestion, and manage outages proactively rather than reactively.

05 Business, Market & Customer Value (User layer)

The final layer translates data into user-facing services. It enables accurate billing, flexibility markets, dynamic tariffs, and personalized energy insights, placing the consumer in control of their energy footprint.

06 Physical mutations

This involves the physical management of meters at the end of their life, during upgrades (e.g., phase shifts), or due to technical issues, including decommissioning, visual, and technical quality inspections for root-cause analysis.

07 Smart meter operations center (SMOC)

Serves as the digital twin of the physical meter fleet, ensuring operational continuity through continuous meter health monitoring and the rollout of firmware, security, and meter configuration updates.

03 MAXIMIZING THE SMART METER ROI THROUGH ARTIFICIAL INTELLIGENCE.

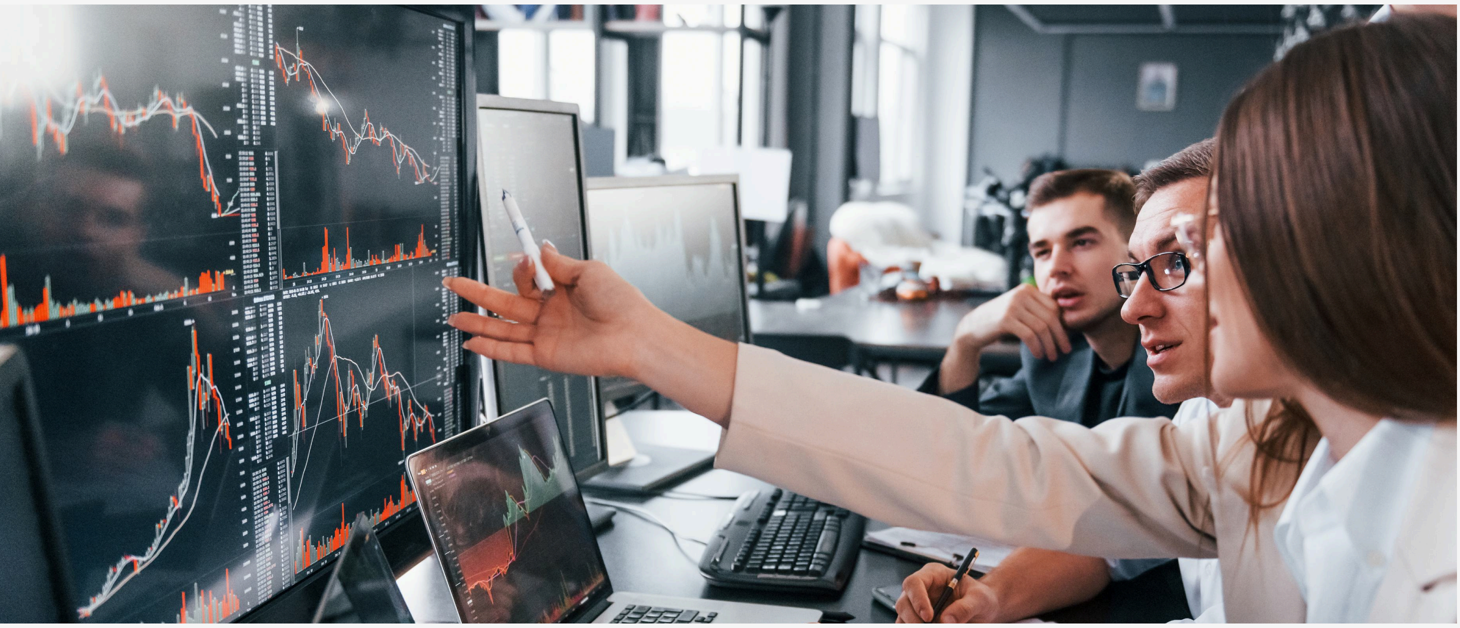
Artificial Intelligence (AI) is a key enabler that unlocks value at every step of the smart metering value chain, benefiting both internal DSO operations and the broader utility ecosystem.

3 key AI technologies and underlying use cases are being considered as highly relevant in unlocking the value:

→ **01 Predictive & Analytical AI**
The application of algorithms to vast amounts of (meter) data to automatically identify patterns, make predictions, and automate/optimize critical utility operations

→ **02 Autonomous/Agentic AI**
Autonomous agents that sense, decide, and act within the smart meter network, moving from reactive to proactive self-healing grids, orchestrating edge devices (like managed EV charging and HEMS) and customer operations to improve network performance and customer value + satisfaction.

→ **03 Vision AI**
Interprets and analyzes images or videos to augment physical and logistical operations, such as verifying first-time-right wiring installations, automating commissioning, and inspecting returned assets for tampering or wear.



Each technology has its application in the value chain (see figure 2 for a non-exhaustive view of AI value pockets), with predictive and analytical AI the most predominant, followed by Vision AI for physical interventions, and agentic AI to automate customer/user actions across systems and market parties.

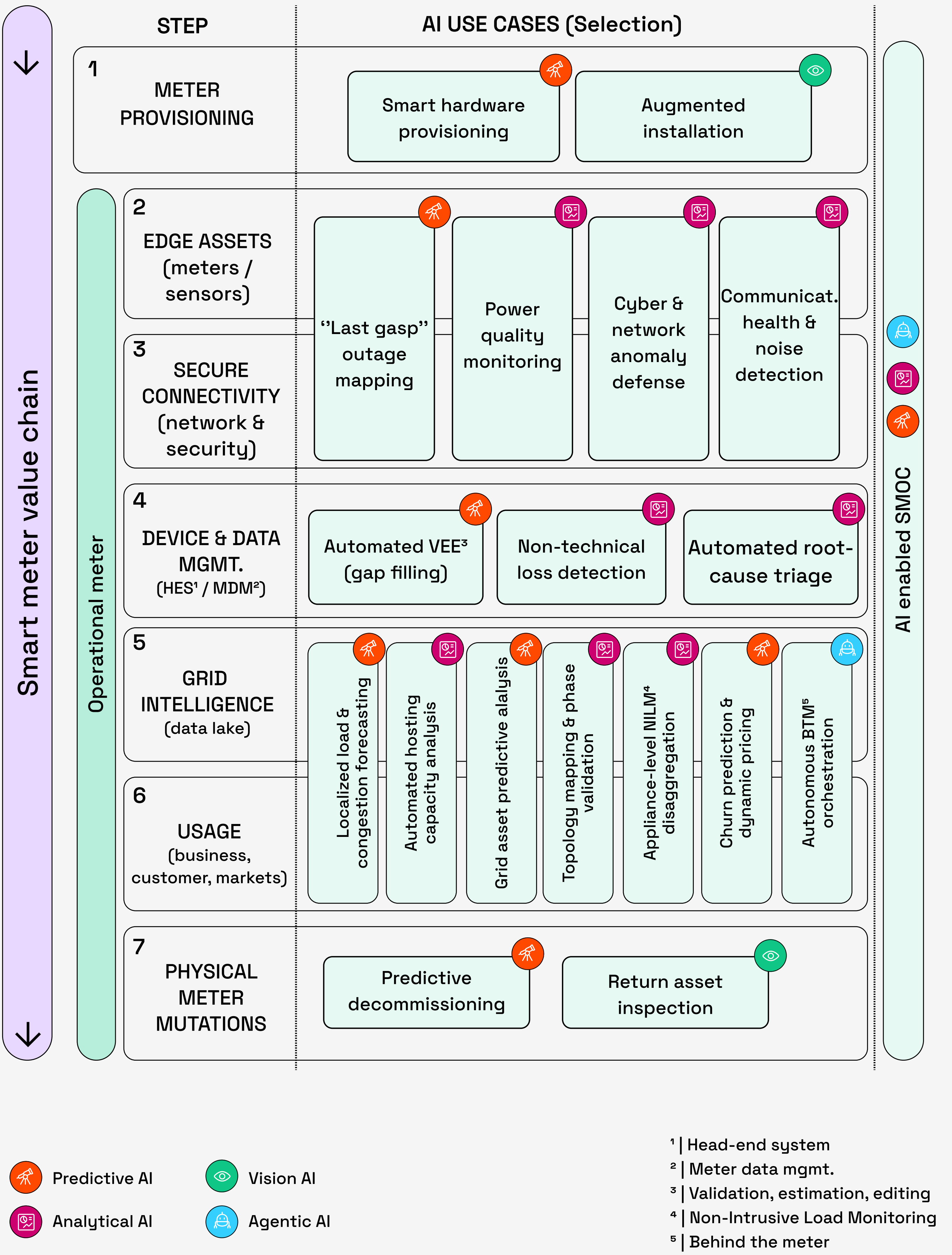


Figure 2: Selected AI value pockets across the value chain

03.1 Meter provisioning and physical mutations.

AI streamlines the physical asset lifecycle from deployment to disposal, ensuring logistical efficiency and data integrity at every stage.

- **Smart Provisioning & Deployment**
  Predictive analytics forecast precise hardware requirements to prevent stockouts, while AI-driven routing optimizes field-technician schedules to maximize daily installations.

- **Predictive Decommissioning & Replacement**
  AI and event telemetry can predict when specific meter batches are likely to fail, enabling targeted, risk-based replacement strategies rather than reactive or age-based neighborhood sweeps.

- **Returned Asset Inspection**
  Vision AI systems automate the physical inspection of meters returned from the field, using computer vision to detect tampering, grade condition, and digitize final display readings for rapid processing.

CASE STUDY

IMPROVING INSTALLATION DATA INTEGRITY THROUGH VISION AI.

The Flemish "Blue Deal" includes a digital water meter rollout to transform traditional infrastructure into a data-driven Smart Grid, integrating water telemetry for advanced behavioral analytics and proactive resource management.

A key challenge in this transition is ensuring precision-critical installation & synchronization, as physical misalignment during digital commissioning degrades telemetry quality and compromises the data integrity required for advanced use cases.

To address this, ML6 deployed a Vision AI solution to serve as an automated validation layer. By analyzing installation imagery, the solution verifies the digital commissioning and ensures each meter is accurately mapped to its physical location in the central database. This automated audit enables the swift correction of installation errors by identifying discrepancies at the source. Consequently, the compounding effects of incorrect data are eliminated, ultimately securing reliability for advanced use cases and insights.

03.2 Edge AI: Real-time "sensing" & anomaly detection.

By embedding AI algorithms directly on the meter, utilities can process high-frequency data locally.

This approach reflects a broader shift toward Edge AI, where intelligence is distributed closer to IoT devices to reduce latency, improve resilience, and enable real-time anomaly detection in critical grid operations.

- **Outage & anomaly detection**
  "Last Gasp" functionality allows meters to send a final distress signal upon power loss, enabling AI models to instantly map the outage scope and dispatch crews with precision.
- **Power quality monitoring**
  AI can analyze voltage sags and swells in real-time to detect local grid instability or hazardous conditions before they cause asset failure.
- **Cybersecurity & Network Anomaly Detection**
  Continuously monitoring network traffic to detect anomalous patterns indicative of False Data Injection Attacks (FDIAs) or distributed denial-of-service attempts.
- **Comms Network Health**
  AI algorithms detecting physical communication degradations, such as PLC noise pockets or cellular LTE-M/RF routing drops, to improve read and success rates.

03.3 Data intelligence: automated quality & security.

Within the HES and MDM, AI streamlines the massive data flows required for billing and settlements.

- **Automated Validation, Estimation, and Editing (VEE)**
  AI-driven "Gap Filling" predicts missing meter readings with high accuracy using historical usage patterns and trends, weather data, and other factors, ensuring billing continuity without manual intervention.
- **Non-Technical Loss (Theft) Detection**
  Machine learning algorithms analyze consumption patterns to identify irregularities indicative of meter tampering, bypasses, or energy theft, directly protecting revenue.
- **Automated Root-Cause Classification**
  Using AI to automatically triage MDM exceptions by distinguishing malicious anomalies (like vacant properties or temporary network drops) from true hardware failures. This drastically reduces manual review backlogs and prevents costly, unnecessary technician truck rolls.

03.4 Grid optimization: The "Digital Twin".

Smart meter data is the fuel for AI-driven grid simulation and planning, particularly in the context of modern time series foundation models that are increasingly being explored for energy forecasting tasks. This is particularly relevant with the rise of time series foundation models for energy forecasting. A deeper technical perspective can be found in our analysis of Chronos-2 in grid imbalance forecasting.

- **Congestion & load forecasting**
  AI models fuse smart meter data with weather and socio-economic data to predict transformer-level load peaks. This allows DSOs to forecast congestion from EV charging or heat pumps and defer costly grid reinforcement through targeted flexibility.

- **Automated hosting capacity analysis**
  Creating high-resolution, AI-generated replicas of the grid to assess real-time hosting capacity for new solar generation or EV charging without needing manual engineering studies.

- **Predictive maintenance**
  By correlating meter data (voltage fluctuations, load stress) with asset age, AI can predict the remaining useful life of transformers and cables, enabling "just-in-time" maintenance.

- **Topology mapping & phase validation**
  Analyzing voltage patterns across multiple premises to autonomously uncover topological errors in the Geographic Information System (GIS) and identify exactly which electrical phase a meter is connected to.

These capabilities are foundational to building **digital twins of the electricity grid,** enabling simulation-driven planning and enhancing **grid reliability, asset loading analysis,** and long-term infrastructure investment strategies.

CASE STUDY

EXTENDING TRANSFORMER LIFESPAN WITH MACHINE LEARNING.

ML6 showcased how a utility could replace rigid physical models with a dynamic Machine Learning approach, aiming to safely maximize the use of existing grid infrastructure and delay costly upgrades.

Leveraging historical time-series data - anchored load data from the smart meter value chain and temperature metrics - the solution accurately accounts for thermal inertia to continuously predict transformer hotspot temperatures, even during rapid load changes.

This predictive capability reduced the Mean Absolute Error (MAE) of temperature predictions by over 65%. Furthermore, it empowered operators to simulate strategic interventions, demonstrating that targeted battery support could prevent up to 80% of forecasted grid disconnections, effectively balancing grid resilience and extending asset lifespan.

03.5 Customer AI: Hyper-personalization & flexibility.

AI unlocks the "behind-the-meter" value for consumers and retailers.

This marks a shift toward more intelligent customer interaction layers, where utilities can deliver **dynamic pricing programs and personalized insights**, significantly improving both customer engagement and overall **customer experience (CX).**

- **NILM (Non-Intrusive Load Monitoring)**
  AI disaggregates total household consumption into appliance-level data (e.g., "Heating," "Cooking," "EV Charging") without extra sensors. This drives personalized energy-saving tips and alerts.
- **Churn Prediction & Dynamic Pricing**
  Analytics identify customer segments at risk of churning or those suitable for time-of-use (ToU) tariffs, enabling tailored product offerings that align consumption with renewable generation peaks.
- **Autonomous Behind-the-Meter Orchestration**
  Moving beyond analytics and incentives, AI-powered Home Energy Management Systems (HEMS) directly interface with EV chargers, heat pumps, and smart inverters, and take autonomous action based on price and system signals.

CASE STUDY

ENOVOS - CUSTOMER SEGMENTATION BASED ON LOAD PROFILES.

ML6 partnered with a major European Energy Supplier to build a modern cloud data platform and enable advanced customer pattern detection to accelerate sales insights.

The smart meter value chain forms the foundation of the solution, leveraging approximately 1 TB of historical meter usage data for behavioral analysis. This enabled efficient classification of consumption patterns, allowing the energy supplier to detect behavior changes such as the acquisition of an Electric Vehicle.

This capability unlocks opportunities for personalized marketing, dynamic cross-selling, and improved demand forecasting.

03.6 Smart meter operations center (SMOC).

Considering the volume of deployed meters and their increasingly critical role in ensuring system stability, the Smart Meter Operations Center (SMOC) acts as a centralized intelligence layer enabling end-to-end monitoring, optimized utility operations, and coordinated actions across field teams, support teams, and digital systems.

AI can be leveraged to:

- Improve meter, communication and security diagnostics and actions
- Automate remote meter transactions (configurations, firmware upgrades...) with deep-integration in e.g. customer and market systems
- Prioritize and orchestrate field-technician operations

KEY TAKEAWAYS.

01 Strategic shift

Utilities must pivot from viewing smart meters solely as billing devices to recognizing them as the **primary sensor network** for the digitized grid. This shift is essential to manage the volatility of the energy transition.

02 Architecture matters

To capture the full value of AI, the underlying architecture must be **modular and scalable.** A flexible Head-End System (HES) and robust connectivity are prerequisites for handling the exponential growth in data volume and frequency.

03 AI is the multiplier

The deployment of hardware alone is insufficient. The real Return on Investment (ROI) comes from **AI applications**—from automated outage detection at the edge to predictive asset management and overall meter fleet up-time in the core.

04 Proactive vs. reactive

The integration of AI allows utilities to shift operations from reactive (waiting for customer calls) to proactive (predicting outages and maintenance needs), significantly improving reliability indices (SAIDI/SAIFI) and customer satisfaction.

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