Technical Manual of the Joint Solution

EM4Energy

Solution Title:	**EM4Energy**
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1. Introduction

The ECO Adapt system is an integrated Condition and Energy Monitoring solution for industrial applications. It combines electrical energy metering (Power-Adapt) with machine condition monitoring (Predict-Adapt) and a cloud-based analytics platform (Power-Cloud). The system is designed for the structured acquisition, transmission, visualization, and evaluation of operational and energy-related data from electrical drive systems and associated production equipment.

ECO Adapt enables continuous monitoring of electrical parameters such as current, voltage, active and reactive power, energy consumption, and power factor, as well as condition-related parameters including vibration and temperature. By combining these data streams, the system supports both predictive maintenance and energy efficiency optimization within a unified architecture.

The solution follows a retrofit-oriented approach. It can be integrated into existing low-voltage switchboards and production environments with minimal mechanical modification. Data transmission is performed via wireless communication interfaces, depending on site requirements, and is aggregated centrally within the Power-Cloud platform. The platform organizes monitored assets hierarchically into organizations, sites, and areas, thereby replicating the physical structure of industrial installations and enabling multi-site management.

Through structured dashboards and analytical views, ECO Adapt supports operational transparency, fault detection, efficiency analysis, and data-driven decision-making. The system is suitable for discrete manufacturing, process industries, and infrastructure applications where electrical drive systems represent critical assets.

1.1 Background of Solution Development

The development of ECO Adapt was driven by increasing industrial requirements for predictive maintenance, improved energy efficiency, and digital transparency in production environments. Industrial operators require systems that provide reliable operational data while remaining economically viable and technically compatible with existing infrastructure.

Traditional maintenance strategies are often reactive or interval based. This results in either unplanned downtime or unnecessary maintenance interventions. At the same time, rising energy costs and regulatory frameworks demand systematic energy monitoring and documentation. In many cases, condition data and energy data are collected separately, limiting the ability to correlate machine health with energy performance.

ECO Adapt addresses this gap by integrating Condition Monitoring and Energy Monitoring within a single hardware and software ecosystem. The development objectives included:

- Reliable acquisition of vibration, temperature, and electrical power data from rotating machinery and electrical drives.
- Standardized data transmission using industrial communication protocols and wireless technologies.
- Centralized cloud-based visualization and analysis.
- Structured user and rights management for industrial organizations.
- Scalability across multiple locations and applications.

The Power-Cloud platform was developed as the central data management and analytics layer. It provides configuration tools for system hierarchy, device assignment, equipment grouping, and user management. It also enables the visualization of load curves, energy histograms, operational indicators, and machine health trends within a unified environment.

The integrated approach supports correlation analyses between electrical load behavior and mechanical condition parameters. For example, deviations in current consumption can be evaluated alongside vibration trends to improve diagnostic accuracy and support predictive maintenance strategies.

The system architecture is based on sensor-based data acquisition at machine level, secure transmission via wireless or wired networks, and centralized processing in the cloud.

1.2 Aim of the Solution Development

The primary aim of ECO Adapt is to provide a technically robust, cost-efficient, and scalable monitoring solution that combines machine condition assessment and energy performance evaluation within one structured system.

The specific objectives of the solution are:

- Enable seamless integration of monitoring functionality into existing industrial environments.
- Provide real-time transparency regarding machine condition and energy consumption.
- Support predictive maintenance strategies by detecting deviations from defined reference states.
- Improve energy efficiency through systematic analysis of load profiles, operating states, and performance indicators.
- Facilitate structured organizational management through hierarchical system configuration (Organization – Site – Area – Equipment).
- Offer user-specific dashboards and analytics views tailored to different stakeholder needs.

The system supports condition-based and predictive maintenance concepts. Relevant physical parameters are continuously measured and compared against defined baseline values or trends. Analytical methods such as time-domain and frequency-domain evaluation enable early detection of anomalies, for example in rotating components.

In parallel, energy monitoring functions enable the identification of inefficiencies such as load peaks, idle operation, or unfavorable operating points. Key performance indicators (e.g., specific energy consumption per production output) can be derived and tracked over time.

By structuring data within defined system hierarchies and configurable dashboards, users can analyze performance at different aggregation levels, ranging from individual assets to entire facilities. This supports operational decision-making, maintenance planning, and energy optimization initiatives.

The system is designed to be adaptable to different industrial use cases and scalable across organizational levels.

1.3 Beneficiaries

ECO Adapt is intended for industrial and commercial organizations that operate electrically driven machinery and require structured monitoring of machine health and energy performance.

The primary beneficiaries include:

- **Industrial organizations operating multiple production sites**
  These users benefit from centralized monitoring, standardized data structures, and cross-site performance comparison. The hierarchical configuration enables consolidated reporting and benchmarking.

- **Technical implementers and commissioning engineers**
  Responsible for installation, configuration, and system integration. They require clear hardware interfaces, defined communication protocols, structured commissioning procedures, and reliable data transmission.

- **Maintenance engineers and reliability specialists**
  They use condition data (vibration, temperature, current signatures) to assess machine health, detect anomalies, and plan maintenance activities based on actual equipment condition rather than fixed intervals.

- **Energy managers and sustainability officers**
  They analyze electrical consumption, load profiles, and energy performance indicators to identify efficiency potentials, reduce operational costs, and support compliance with internal or external energy management requirements.

- **Operational management and project stakeholders**
  They require aggregated dashboards, structured reports, and KPIs to evaluate asset performance, operational reliability, and energy cost development.

By combining condition and energy data in one unified system, ECO Adapt supports both technical reliability and economic efficiency objectives. The integration of monitoring disciplines reduces information silos and enhances decision support across engineering, maintenance, and energy management functions.

2. Technical Specification of the Solution

This chapter provides a structured technical description of the ECO Adapt system, covering functional capabilities, system architecture, communication interfaces, and deployment models. The objective is to define the technical boundaries of the solution and clarify how hardware, communication infrastructure, and cloud analytics interact within an integrated Condition and Energy Monitoring framework.

2.1 Solution Description (Key Features and Benefits)

ECO Adapt is an integrated monitoring solution that combines electrical energy measurement with machine condition assessment within unified hardware and software architecture. The system consists of field devices (Power-Adapt for electrical measurements and Predict-Adapt for condition monitoring) and a centralized cloud platform (Power-Cloud), forming a coherent data acquisition, transmission, and analytics environment.

At the core of the solution is the synchronized acquisition and evaluation of heterogeneous data sources. Electrical parameters such as current, voltage, power, and energy consumption are continuously recorded alongside mechanical indicators such as vibration and temperature. This enables correlation between energy behavior and machine condition, which significantly improves diagnostic reliability compared to isolated monitoring approaches.

For example, an increase in current consumption combined with elevated vibration levels can indicate mechanical degradation (e.g., bearing wear), while stable electrical load with abnormal vibration may suggest localized mechanical issues. This integrated analysis forms the basis for both predictive maintenance and energy efficiency optimization.

The system is structured hierarchically within the Power-Cloud platform using Organizations, Sites, Areas, and Equipment. This digital representation mirrors real industrial installations and enables scalable deployment across multiple facilities. Measurement channels are mapped to physical assets, ensuring consistent aggregation, comparison, and interpretation of data.

From a technical perspective, the solution provides the following key capabilities:

- ✓ Multi-channel electrical measurement (up to six three-phase circuits per device)
- ✓ Acquisition of mechanical condition indicators for rotating equipment
- ✓ Standardized communication via industrial protocols and LoRaWAN
- ✓ Time-synchronized data processing and cloud-based analytics
- ✓ Configurable dashboards and KPI-based evaluation

The primary benefit of ECO Adapt lies in its ability to bridge the gap between energy monitoring and condition monitoring, enabling users to move from reactive analysis to proactive, data-driven decision-making.

2.2 System Architecture, Communication, and Deployment

The ECO Adapt system follows a layered architecture consisting of a field layer, communication layer, and platform layer, each responsible for a specific stage in the data lifecycle.

At the field layer, measurement devices acquire raw data directly from electrical and mechanical systems. Power-Adapt units measure electrical quantities such as current, voltage, and power, while Predict-Adapt modules capture vibration and temperature signals from rotating machinery. Initial preprocessing, including signal validation and threshold checks, may be performed locally to reduce unnecessary data transmission.

The communication layer ensures reliable and standardized data transfer. Depending on the application, this includes industrial protocols such as Modbus TCP/IP, BACnet/IP, and Modbus RTU, as well as wireless communication via LoRaWAN. This hybrid communication approach enables both retrofit installations and integration into existing automation environments.

The platform layer (Power-Cloud) acts as the central intelligence of the system. It aggregates incoming data streams, performs time synchronization, and enables advanced analytics, including trend analysis, KPI calculation, and correlation of condition and energy data.

A key architectural feature is the time-aligned fusion of data streams, which allows users to analyze cause-effect relationships between machine condition and energy consumption. This enables detection of inefficiencies that would not be visible in isolated systems.

The system supports flexible deployment models:

- Cloud-based for centralized multi-site monitoring
- On-premises for integration with existing IT infrastructure
- Hybrid for combined local control and cloud analytics

This modular architecture ensures scalability, interoperability, and adaptability across different industrial environments.

3. Installation & Setup

3.1 Prerequisites

Before installation, confirm that the intended measurement point (feeder, motor supply line, or cabinet section) is electrically accessible, offers sufficient DIN-rail space, and allows safe routing of voltage leads and **current sensors (also known as current clamps, clamp-on sensors or non-invasive current sensors)**.

Currents up to 400A can be measured using current sensors (current clamps). For higher currents, Rogowski coils are used, enabling measurements of up to 1000A. The different clamps also vary in their design and maximum conductor diameter (see Table 1). According to the manufacturer, no valid measurements are possible below 5% of the nominal current.

Reference	Max RMS Current	Max. Diameter
3TC-10-1A	1A	10mm
3TC-10-5A	5 A	10mm
3TC-10-32A	30 A	10mm
3TC-10-70A	70 A	10mm
3TC-16-100A	100 A	16 mm
3TC-24-200A	200 A	24 mm
3TC-32-400A	400 A	36 mm
3TS-105 + INT-ROGO	1000 A	105 mm

Table 1: Classification of current sensors (Schaeffler open source)

ECO Adapt is intended for retrofit installation in low-voltage switchboards and must be installed by qualified personnel following local electrical safety rules and the site's lockout/tagout procedures.

Hardware prerequisites include the relevant ECO Adapt measurement units (Predict-Adapt for condition data and Power-Adapt for energy data), the appropriate current sensors, and the necessary communication components. Current sensors are connected to the measurement unit via RJ45. For meaningful power measurement, the monitored load must be above the minimum measurement threshold stated for the sensor system; below a low fraction of nominal current, measurements are not considered valid and commissioning tests should therefore use a sufficiently large motor/load or appropriately sized clamps.

Power supply prerequisites differ between modules. Predict-Adapt requires a 12–24 V DC supply, while Power-Adapt must be supplied with AC voltage depending on the application (230 V or 400 V). The wiring concept must match the selected supply variant and the cabinet's phase system.

The connection to the internet and cloud differs between the two systems. In the predict adapt system, a preconfigured cellular modem is directly attached to the measuring unit, which automatically establishes a Wi-Fi connection. Only a SIM card needs to be inserted and configured to enable internet access. The modem is powered via a USB port on the measuring unit.

For Power-Adapt connectivity, a separate gateway is required to provide a LoRaWAN link between the measurement unit and the gateway. The gateway then forwards data to the cloud via the site's internet connection. This separation is important for planning cabinet space and network connectivity: Power-Adapt requires both LoRaWAN coverage between device and gateway and reliable internet access at the gateway location.

For installation access and safety planning, the following practical prerequisites must be met before arriving on site: cabinet access authorization, isolation capability (upstream protective device and safe working clearance), and confirmation that current sensors can be mounted without violating creepage/clearance distances or cable bend radii.

Split-core clamps are shown as installable without disconnecting conductors when safety rules are observed, which is a key retrofit advantage in production environments.

Network prerequisites depend on the chosen integration path. For cloud operation, ensure outbound internet connectivity for the cellular modem (Predict-Adapt) and for the gateway (Power-Adapt). For local integration, confirm availability of the required wired interfaces and addressing rules if the device is to be read via Ethernet-based protocols or RS485. During initial commissioning and troubleshooting, ensure availability of a laptop/tablet for local configuration access and verification of live measurements.

In addition to the above, verify environmental suitability for cabinet installation (temperature, humidity, protection against conductive dust) and ensure that surge protection and upstream protection are consistent with the cabinet's installation category. Where the monitored circuits are subject to higher transient stress, protective measures should be planned to maintain measurement reliability and device safety.

3.2 Installation Steps

Installation of ECO Adapt is carried out in three consecutive blocks:

(1) mechanical installation and electrical wiring in the cabinet,
(2) connectivity and initial device commissioning,
(3) assignment and validation in the cloud environment.

The sequence below is written for retrofit installation in an operating industrial environment, but all electrical work must follow site isolation procedures and applicable safety rules.

Step 1 — Prepare the installation point and ensure safe isolation

Confirm that the measurement unit will be installed in a mechanically and electrically suitable, fire-resistant enclosure (typically a low-voltage switchboard). Ensure sufficient space on the DIN rail and adequate separation between hazardous voltage conductors and communication connectors (e.g., USB, antenna connectors, Ethernet where applicable). Install an upstream protective device (circuit breaker) for the measurement unit supply and voltage measurement leads. The protective device must remain accessible for isolation during commissioning and maintenance.

Step 2 — Mount the measurement unit

Mount the Power-Adapt measurement unit on the DIN rail and route cables in a way that avoids sharp bends, mechanical stress, and proximity to high-interference conductors where possible.

Figure 1: Installation of the measuring unit in a control cabinet (Schaeffler open source)

Step 3 — Install current sensors (CTs / clamps) on the monitored feeder

Install current transformers on the phases of the monitored supply. For retrofit, split-core clamps can be installed without disconnecting the conductor provided the site's safety rules permit this and safe working clearances are maintained. Ensure each clamp is fully closed, mechanically secure, and oriented correctly (polarity/orientation must match the system's expected direction). Incorrect orientation is a common cause of negative power readings or inconsistent phase power.

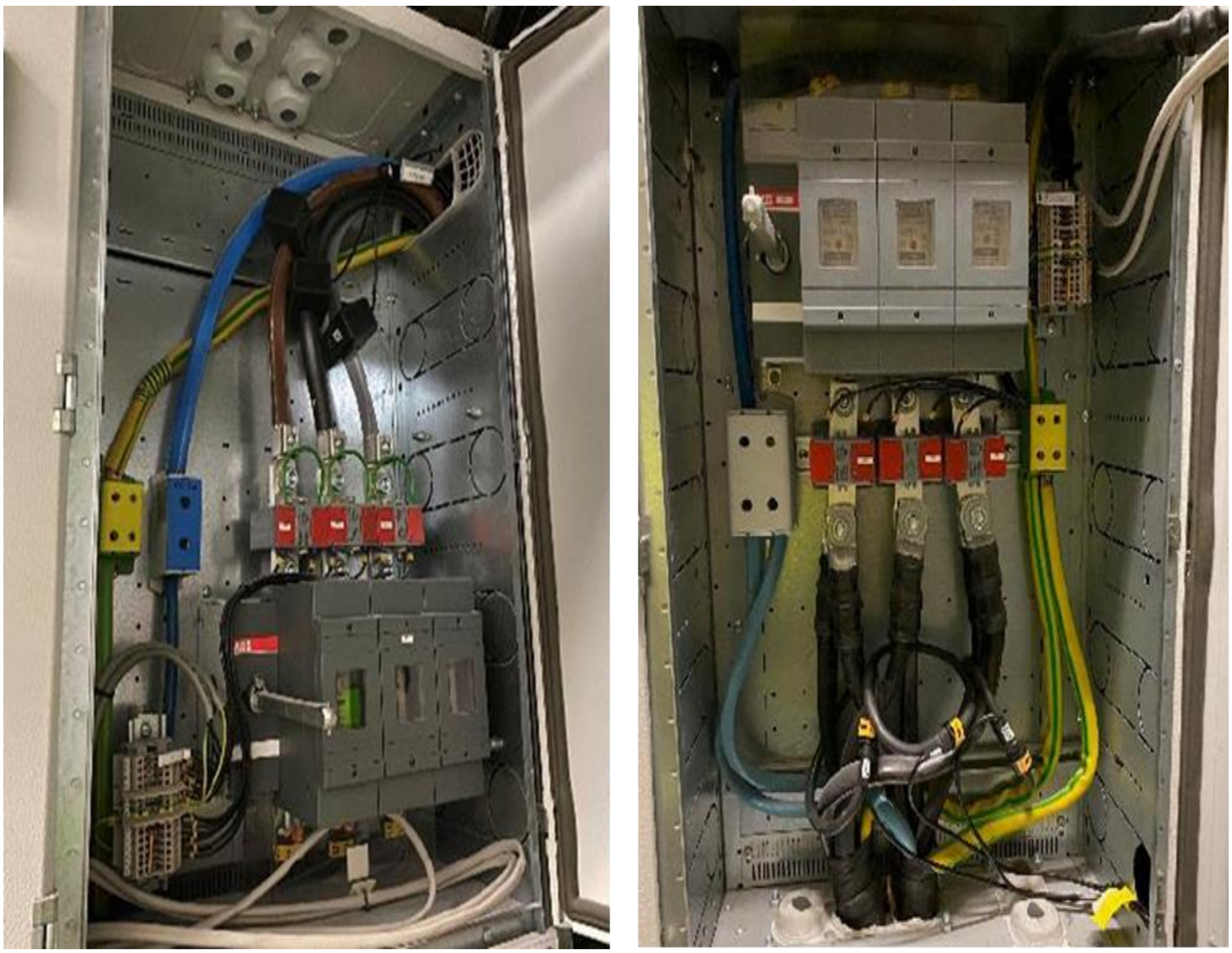

Figure 2: Installation of the current sensors (Schaeffler open source)

Where the system is used with the condition monitoring module on a motor application, clamps should be installed according to the recommended measuring point, for example between frequency inverter and motor supply where relevant.

Figure 3: Installation of the current sensors (Schaeffler open source)

Connect the current sensors to the measurement unit via the RJ45 sensor ports. Verify correct channel-to-phase assignment before energizing.

Step 4 — Connect voltage supply and voltage measurement

Wire the voltage supply and voltage measurement lead according to the cabinet voltage system (230 V or 400 V).

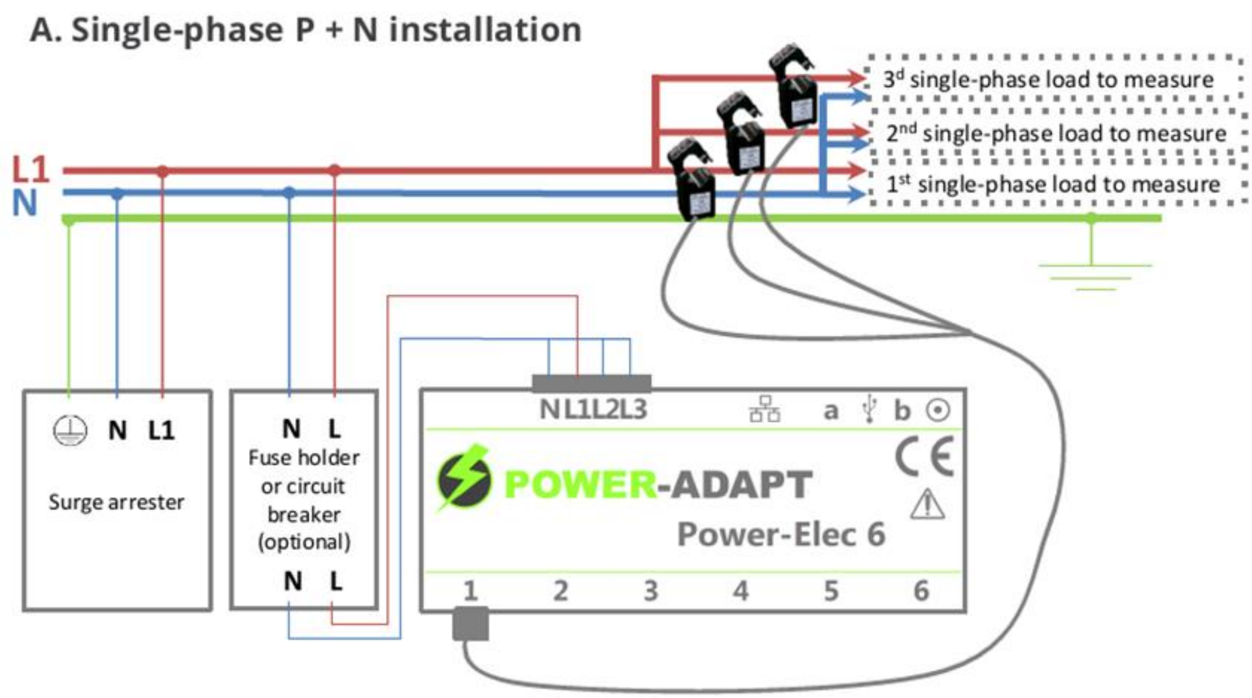

Figure 4: Wiring Power-Adapt 230V (Schaeffler open source)

The wiring schematic must be followed exactly to ensure correct reference for power calculation.

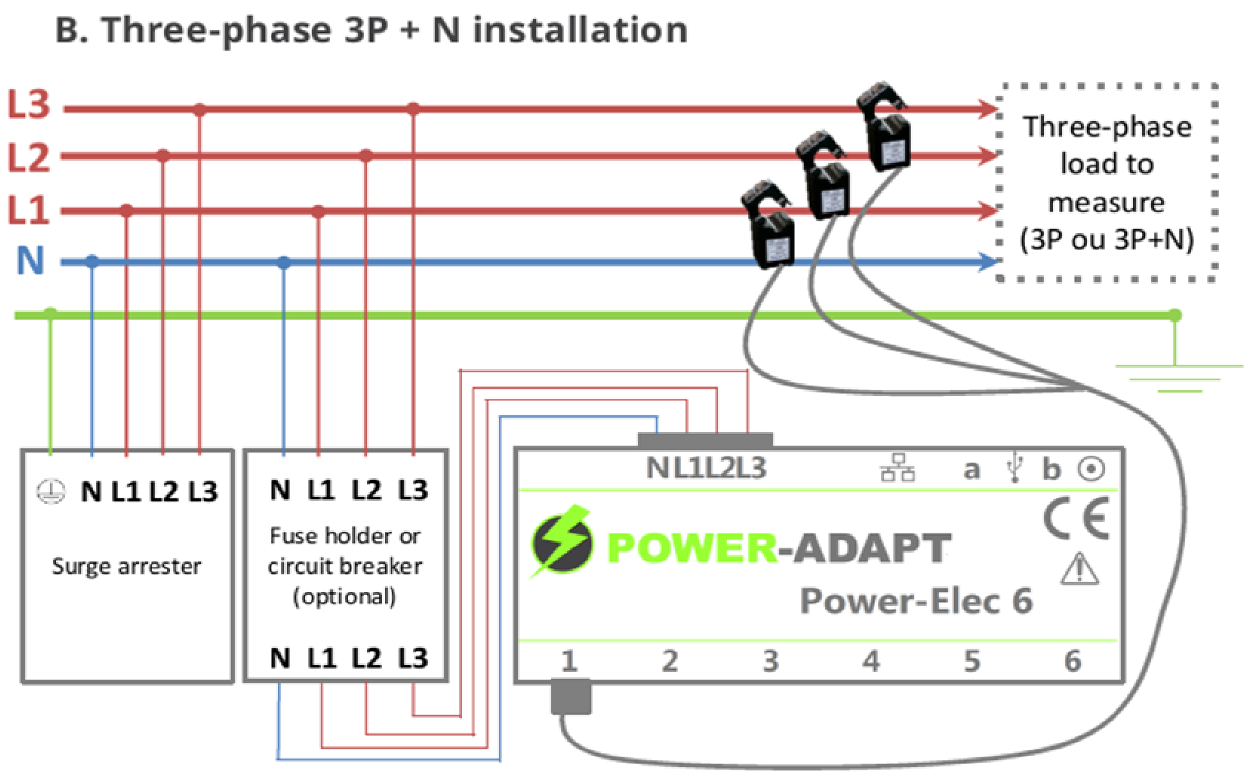

Figure 5: Wiring Power-Adapt 400V (Schaeffler open source)

After verifying wiring, connect the voltage plug/connector to complete voltage acquisition.

Step 5 — Establish connectivity (Predict-Adapt vs. Power-Adapt)

Connectivity differs by module and must be planned during installation:

For Predict-Adapt, a cellular modem is mounted on the measurement unit. Insert and configure a SIM card capable of establishing an internet connection. The modem power supply is provided via a USB port on the measurement unit (see Fig. 6).

Cellular modem

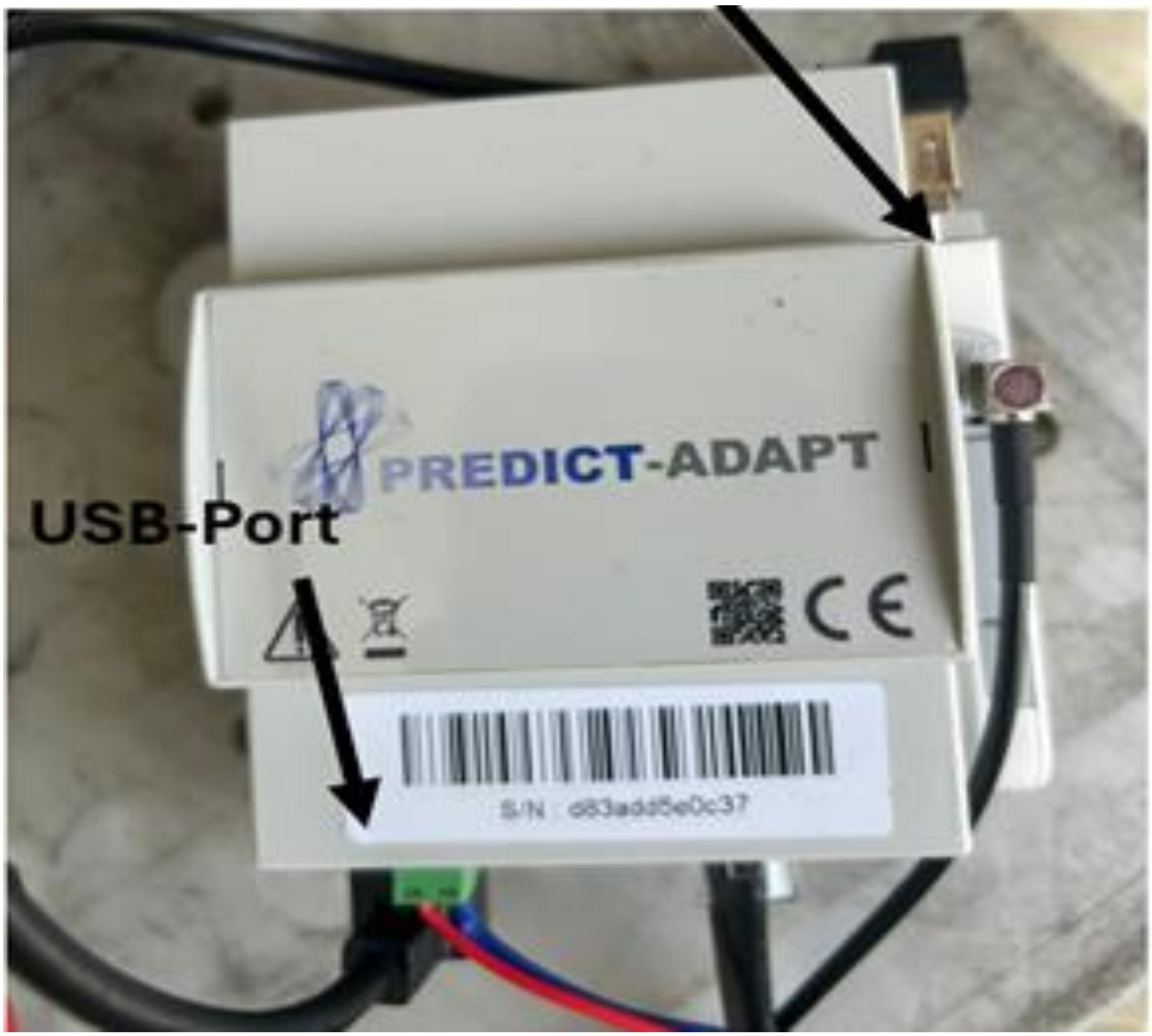

Figure 6: Predict adapt - position of mobile modem and USB port (own illustration)

For Power-Adapt, a separate gateway is required to create the LoRaWAN link between the measurement unit and the gateway. The gateway then provides an internet connection for transmission to the cloud.

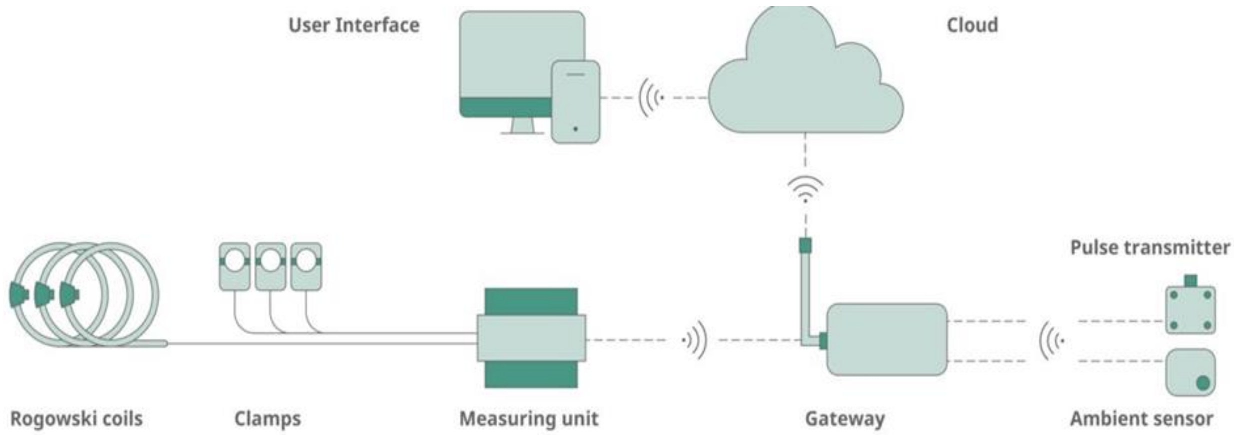

Figure 7: Schematic functional representation (Schaeffler open source)

A high-level functional overview of both subsystems (Predict-Adapt and Power-Adapt) supports planning the required hardware and network path. Note that additional components shown there (e.g., pulse transmitters or ambient sensors, see Figure 7) may exist as options but are not required for the basic ECO Adapt commissioning workflow.

Step 6 — Perform initial electrical verification before first measurements

Before enabling continuous monitoring, perform installation controls, that prevent systematic measurement errors. In field commissioning, the following checks proved essential: correct phase relation between current and voltage signals, firm seating and correct orientation of current transformers, cabinet wiring verification under safety rules, validation of measured voltage using a reference instrument, and a basic data transmission test.

A practical commissioning constraint must be considered for functional tests: below a small fraction of nominal current, no valid measurement is possible. Therefore, commissioning tests should use a sufficiently large motor/load or appropriately sized clamps to bring phase current into a valid measurement range.

Step 7 — Initialize the device via the gateway/configuration interface and verify live data

After electrical installation, initialize the Power-Adapt component using the gateway configuration interface. Typical commissioning actions include automatic detection of current and voltage modules, integrity checks during the first measurement cycles, setting measurement resolution and intervals, and assigning the measurement channel to the specific asset in the cloud. Once activated, live data should appear shortly and reflect plausible operating behavior (e.g., expected load cycles for compressors).

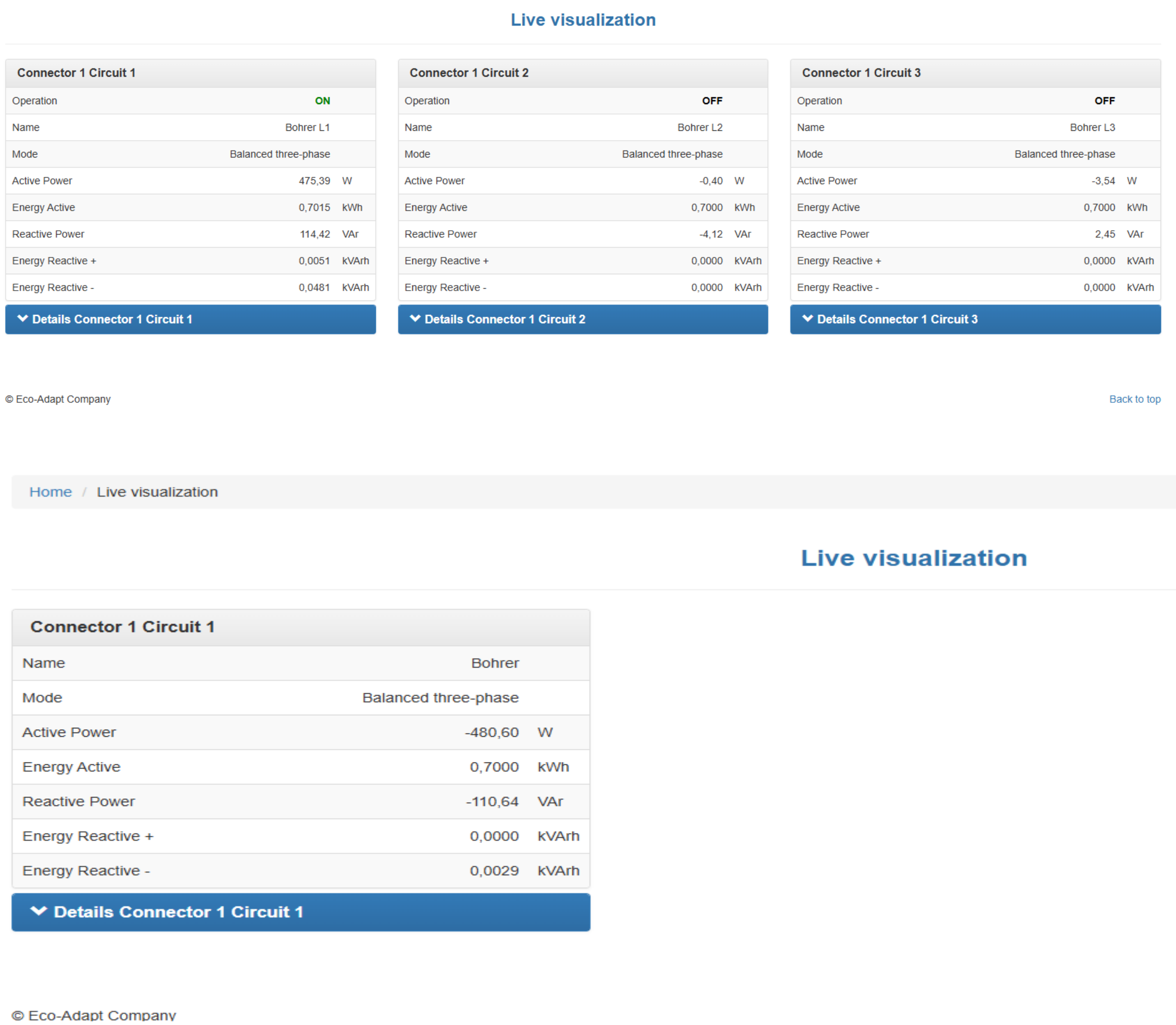

Figure 8: First measurement power adapt (own illustration)

Step 8 — Configure the cloud environment and map channels to the organization structure

In Power-Cloud, create or confirm the Organization hierarchy (Sites and Areas) so that the physical installation is mirrored digitally. Create users and assign rights as required. Then create or update the Equipment entries and link each device channel/measurement to the correct equipment and Area. This mapping is critical for meaningful dashboards, aggregation, and later cross-correlation of condition and energy data.

Optional reference figures for device identification during installation

If the installation team requires a visual reference for the Power-Adapt unit and its connectors (useful during multi-channel commissioning or when linking multiple units), the following figures can be inserted at the end of this section:

Figure 9: Power Adapt (schaeffler open source)

Figure 9 shows the measuring unit of power adapt and Figure 10 describes the connections in more detail.

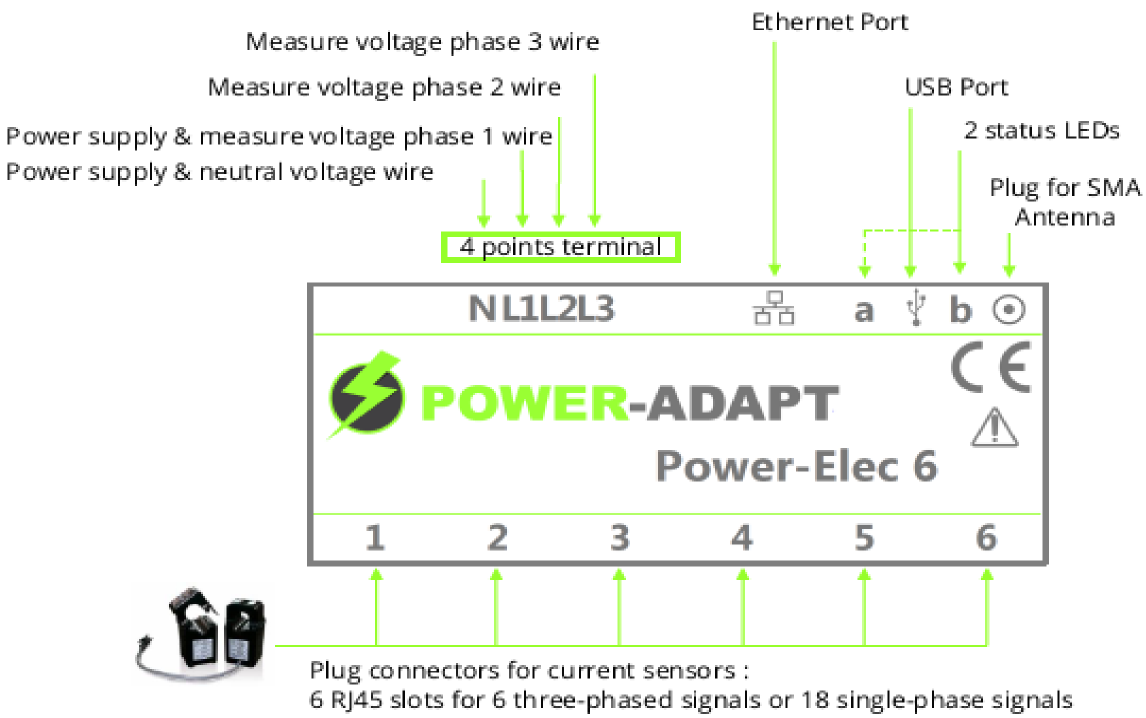

Figure 10: Connection diagram for Power Adapt (Schaeffler manual)

Furthermore, power adapt offers the possibility to link multiple measuring units together, as shown in Figure 11.

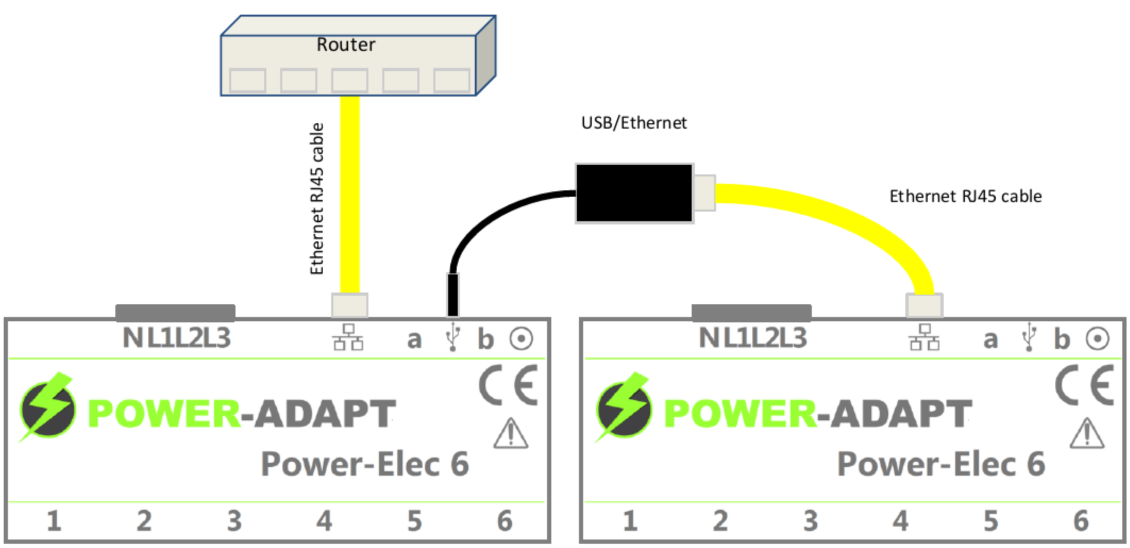

Figure 11: Linking of Power Adapt (Schaeffler manual)

3.3 Configuration and Setup Guidelines

Configuration of ECO Adapt is performed in two layers. The first layer is the local device setup, where the measurement unit is powered, checked for plausibility, and prepared for data transmission. The second layer is the platform setup in Power-Cloud, where the organizational structure, user rights, locations, sensors, and equipment are configured so that incoming measurements are assigned correctly and can be visualized consistently.

3.3.1 Local device access, basic settings, and licensing

After wiring and power-up, confirm that the device boots normally and that the measurement channels deliver plausible raw values (e.g., expected voltage level and current behavior underload). ECO Adapt devices are then configured for communication and feature activation. Standard and Expert functionality is enabled by uploading the corresponding license file via the system menu, after which additional indicators and extended analytics become available (where licensed).

Configure the electrical acquisition mode according to the installation topology. For single-phase applications, multiple electrical inputs can be configured to cover several single-phase feeders. For three-phase applications, the device is configured for the corresponding three-phase topology so that phase relationships are evaluated correctly and power calculation is consistent.

Where condition monitoring is used (Predict-Adapt), verify that the sensor is linked to the intended asset and that transmission is active. Where energy monitoring is used (Power-Adapt), verify that the LoRaWAN link to the gateway is established and that the first live measurements are visible shortly after configuration. In commissioning practice, data transmission begins immediately after activation and first live values become visible within the first minutes, which is a key indicator that device-to-cloud connectivity is functioning.

3.3.2 Power-Cloud access and basic navigation

Access to the Power-Cloud environment is performed via the Power-Adapt landing page (Figure 12).

Figure 12: Landing page poweradapt.com (own illustration)

Once logged in, the platform provides a modular user interface that supports both an overview of all devices and detailed views of individual assets (Figure 13).

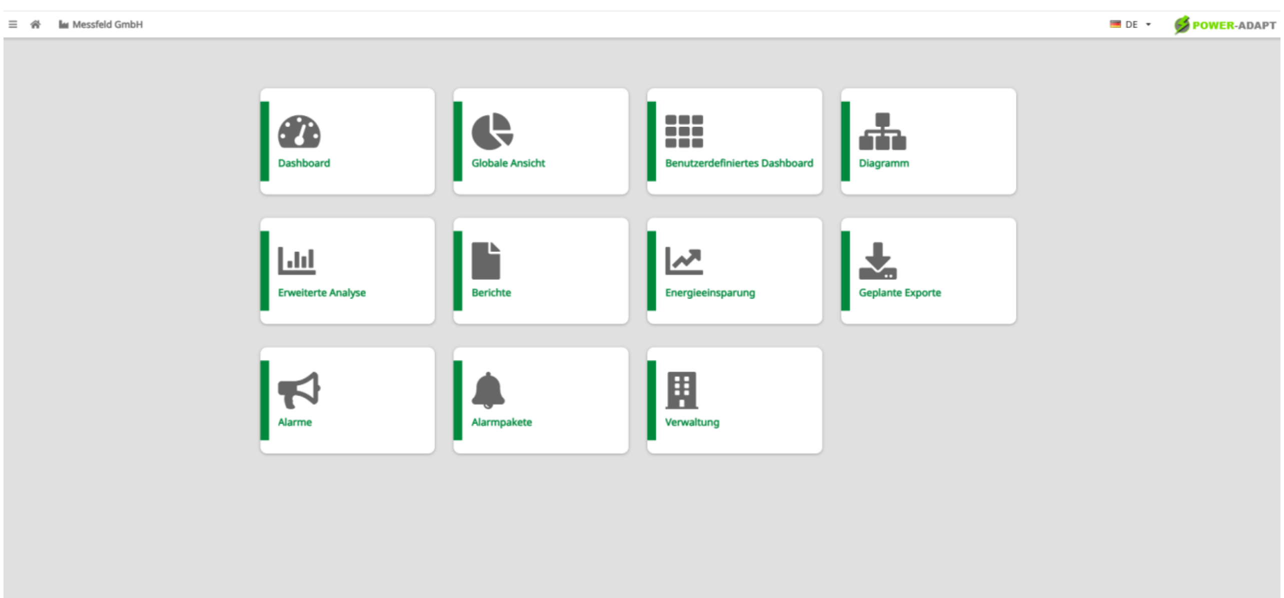

Figure 13: Power Cloud homepage (own illustration)

Trend visualizations and dashboards are used for systematic evaluation of time behavior and operating patterns.

3.3.3 User setup, roles, and access rights

User management is performed via the administration area of the platform.

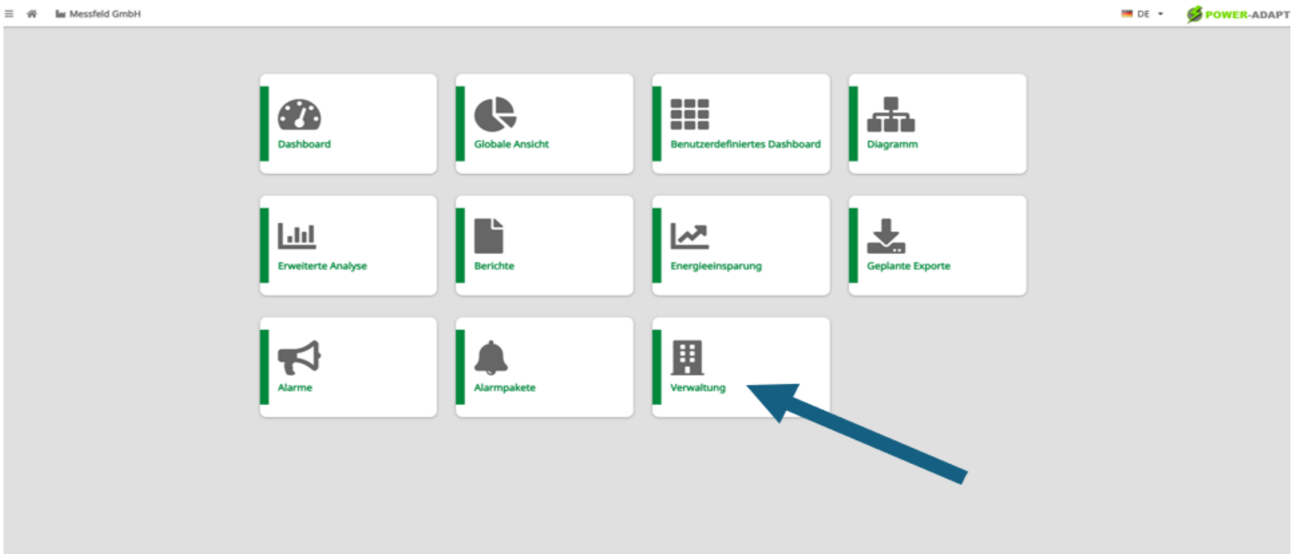

Figure 14: Power Cloud homepage (own illustration)

The user overview provides visibility of whether users are active, whether they have administrator rights, and whether two-factor authentication is enabled.

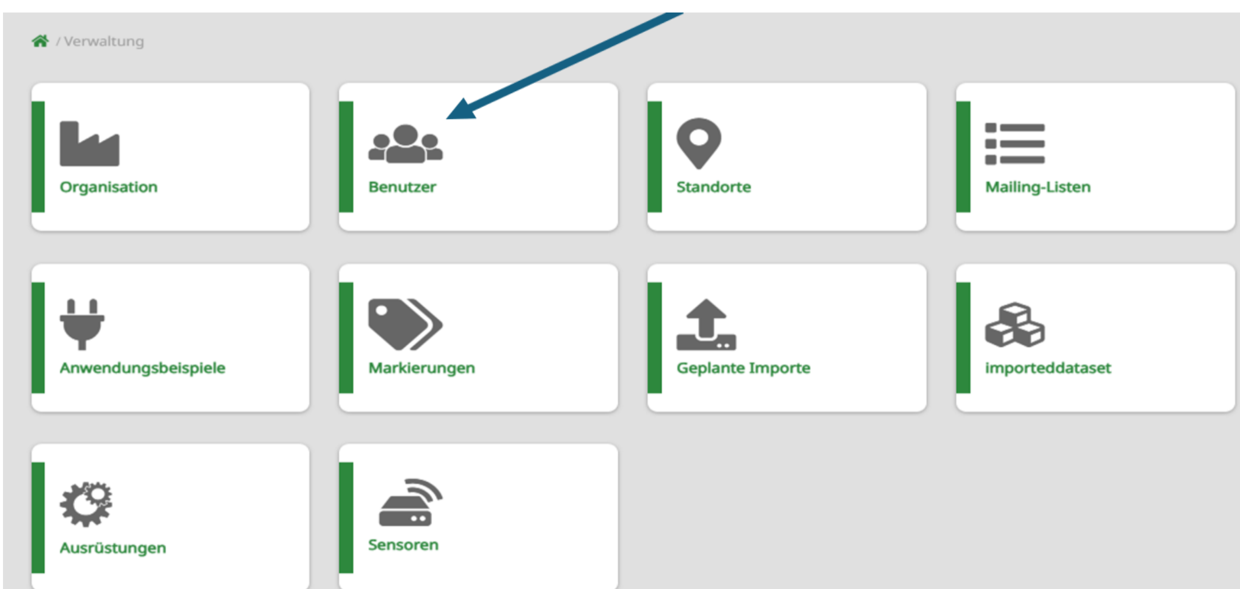

Figure 15: Power Cloud administration (own illustration)

Once a user has registered, it also appears in the list shown in Figure 16.

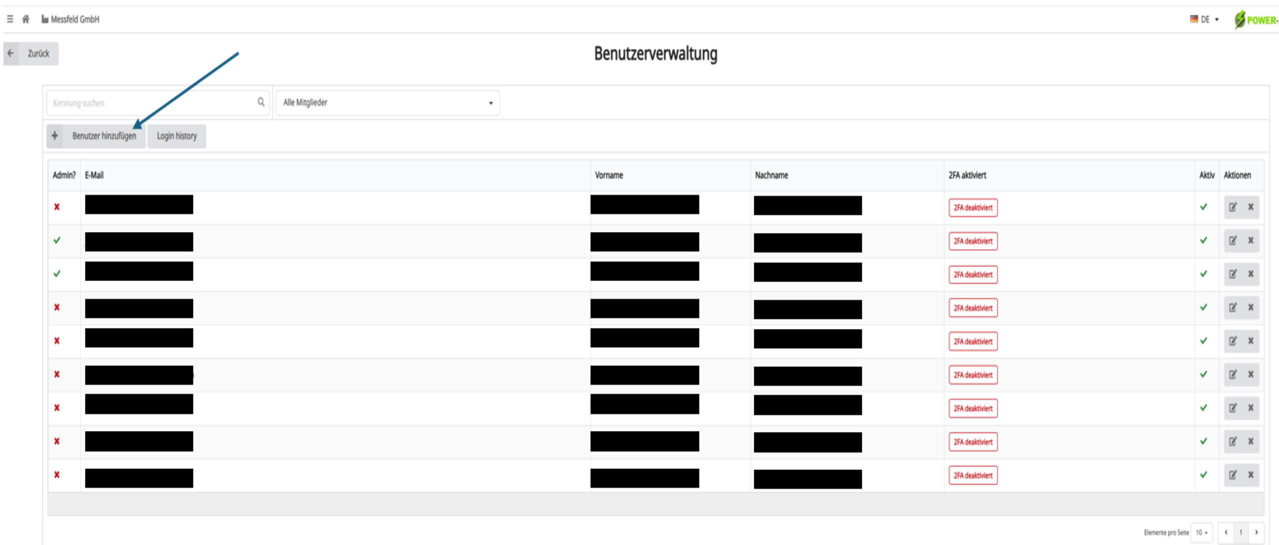

Figure 16: Overview of registered users (own illustration)

New users are invited using their email address (Figure 17); they receive a registration link and then appear on the user list once registration is complete.

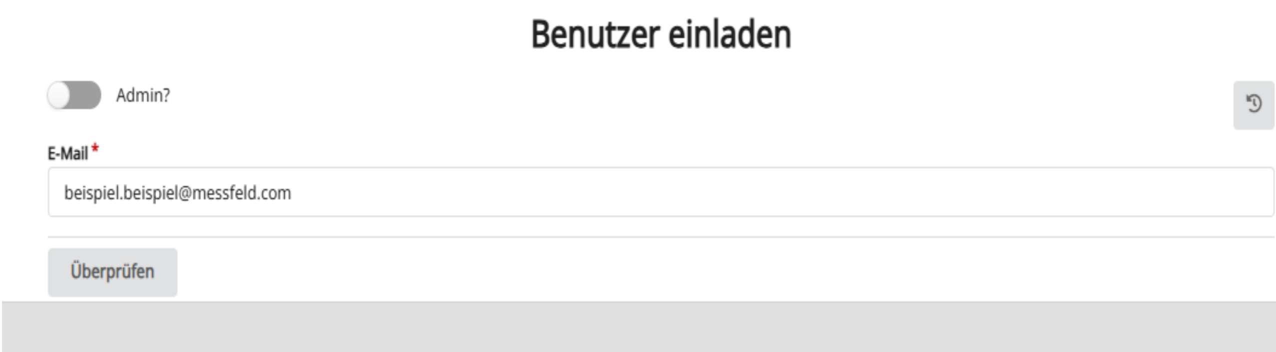

Figure 17: Invite new user (own illustration)

After a user is created, assign site-specific rights so that users only see the locations relevant to their responsibilities (see Figure 18).

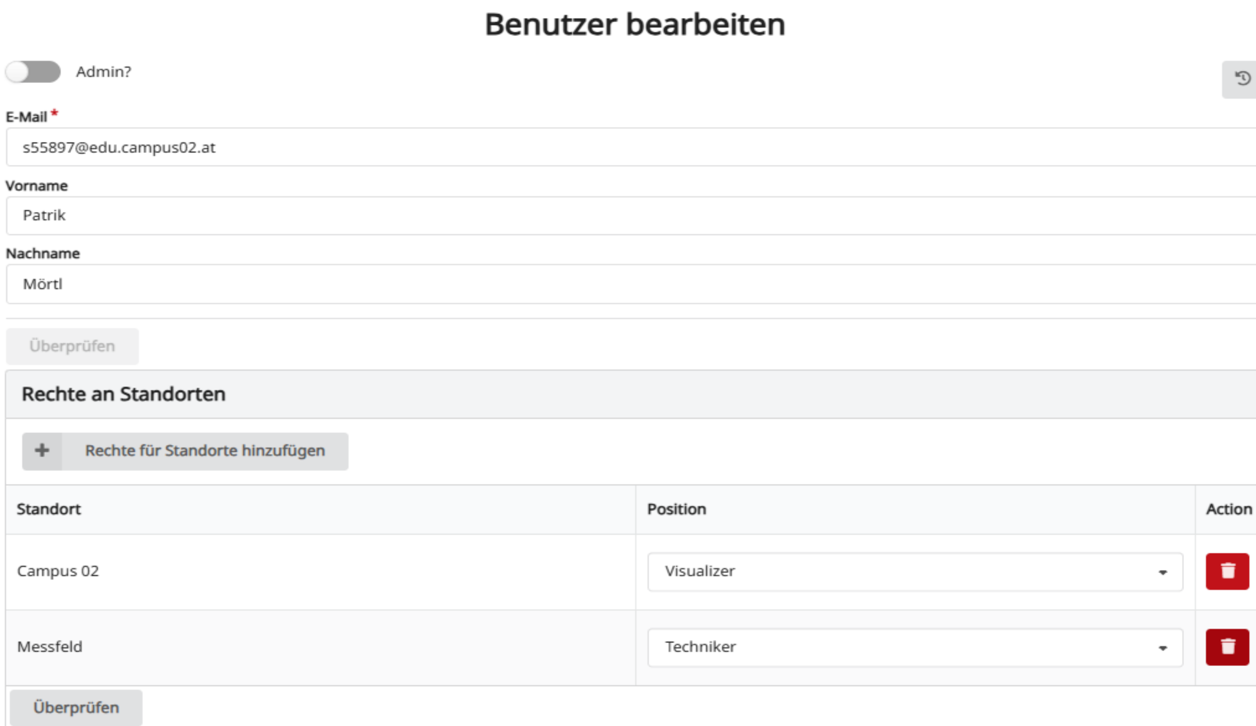

Figure 18: Allocation of site rights (own illustration)

Two practical role patterns are used: a “Techniker” can modify sensor-related data and configuration parameters, while a “Visualizer” is limited to viewing measurement values. Administrative changes to user data are restricted to users with admin rights.

3.3.4 Sites, Areas, and grouping logic

In Power-Cloud, sites represent physical locations (German: Standorte). Areas (or equivalent sub-structures, depending on the naming used in your organization) represent buildings, production lines, or zones within a site and are the basis for meaningful aggregation and comparison (for example, consumption per area, or grouping by line/zone).

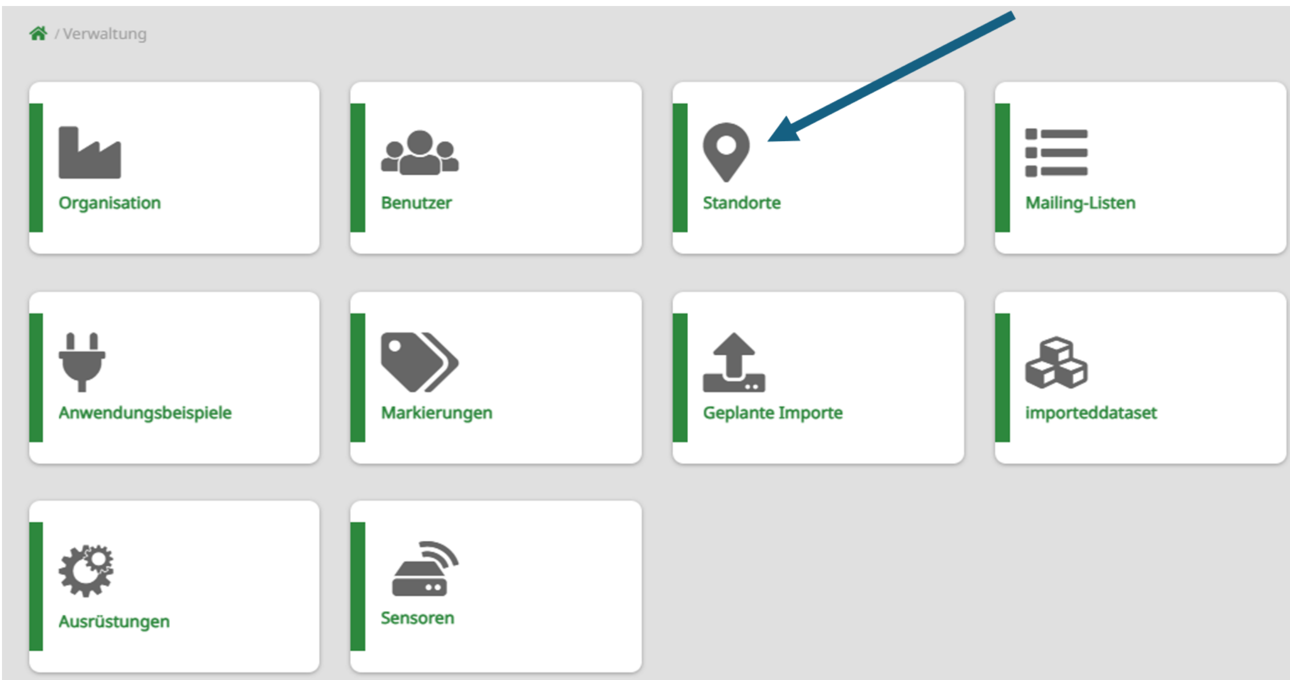

Figure 19: Open icon locations (own illustration)

When creating a site, define name, description, address, and assign contextual settings such as time zone, currency, and weather station where applicable.

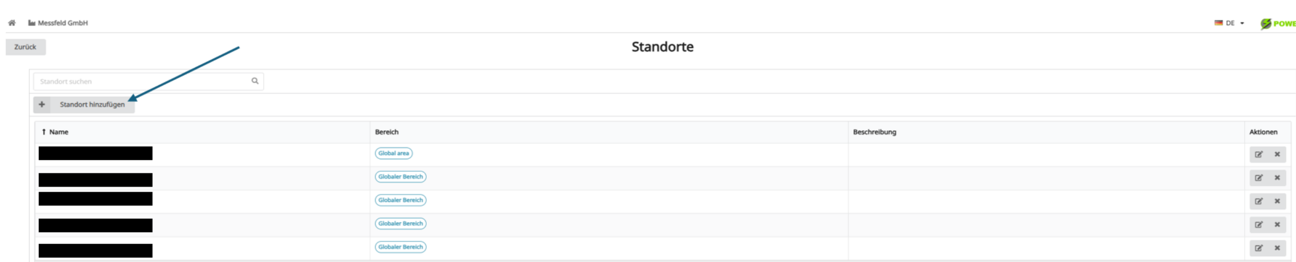

Figure 20: Create new location (own illustration)

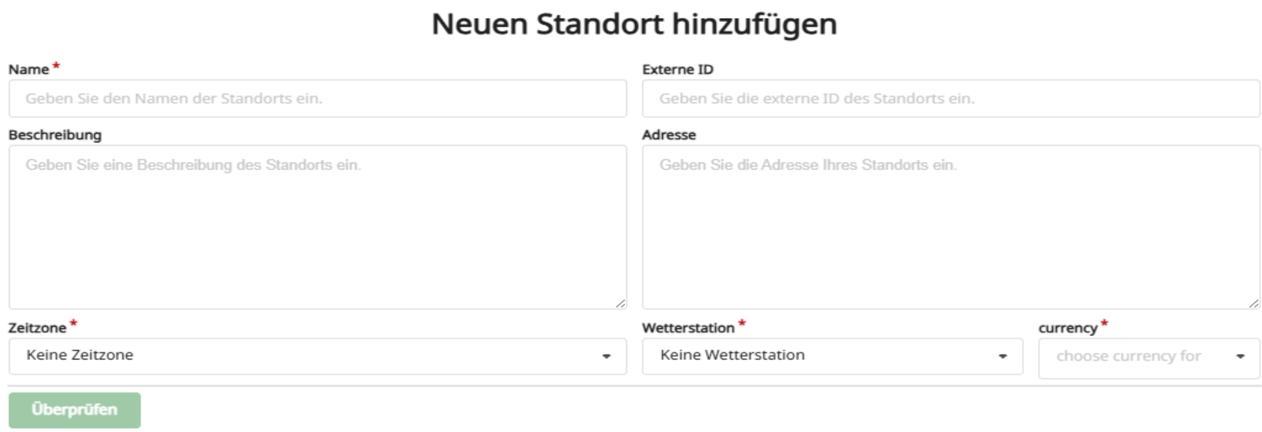

Figure 21: Add new location (own illustration)

The interface for adding a new location is shown in Figure 21.

These settings support consistent time-series analysis and simplify troubleshooting in multi-site environments.

3.3.5 Sensor assignment and equipment configuration

Sensors are typically added by the manufacturer prior to delivery. In the platform, the "Sensoren" view provides a list of available sensors including serial number, product type, assigned site, and last update timestamp.

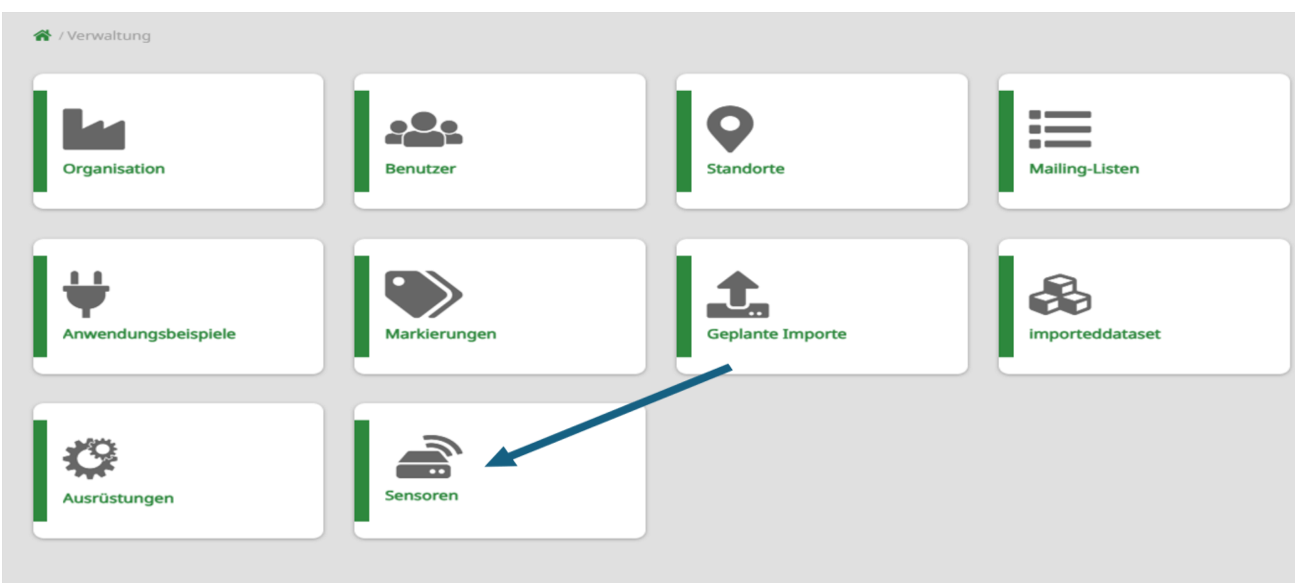

Figure 22: Overview of assigned sensors (own illustration)

Opening the Sensors icon (Figure 22) displays a list of all added sensors (Figure 23). This list shows the serial number, product type, assigned location, and last update date of each sensor. Changing the location of a sensor is possible here.

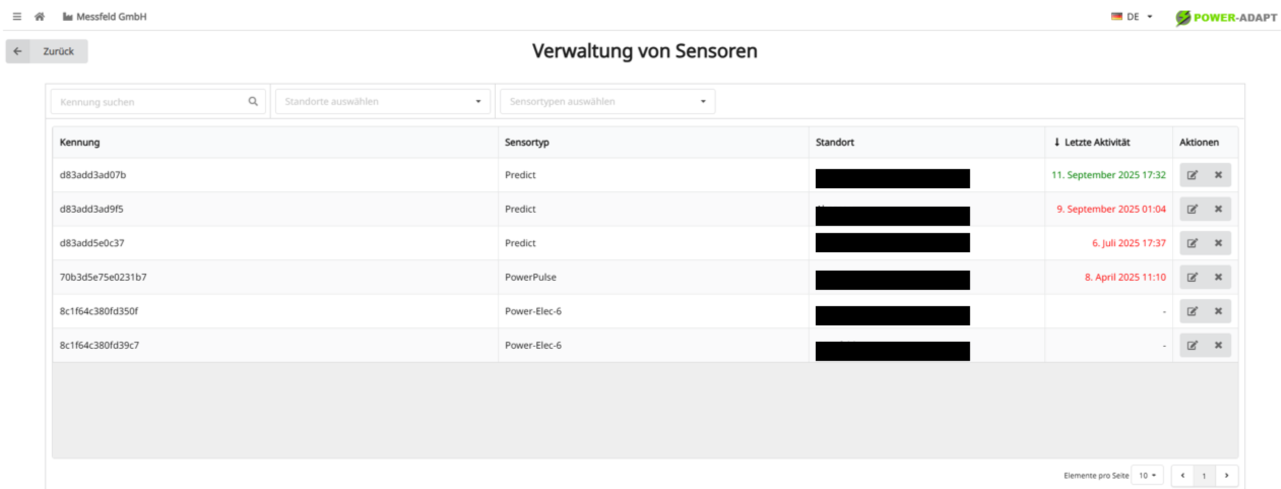

Figure 23: Overview of the management of assigned sensors (own illustration)

If required, the assigned site of a sensor can be changed to reflect the physical installation.
Equipment entries ("Ausrüstungen") represent the monitored assets that deliver data. Once a sensor has been commissioned locally and starts transmitting, it becomes visible as an equipment item that can be configured in detail. In this step, all relevant machine parameters are captured.

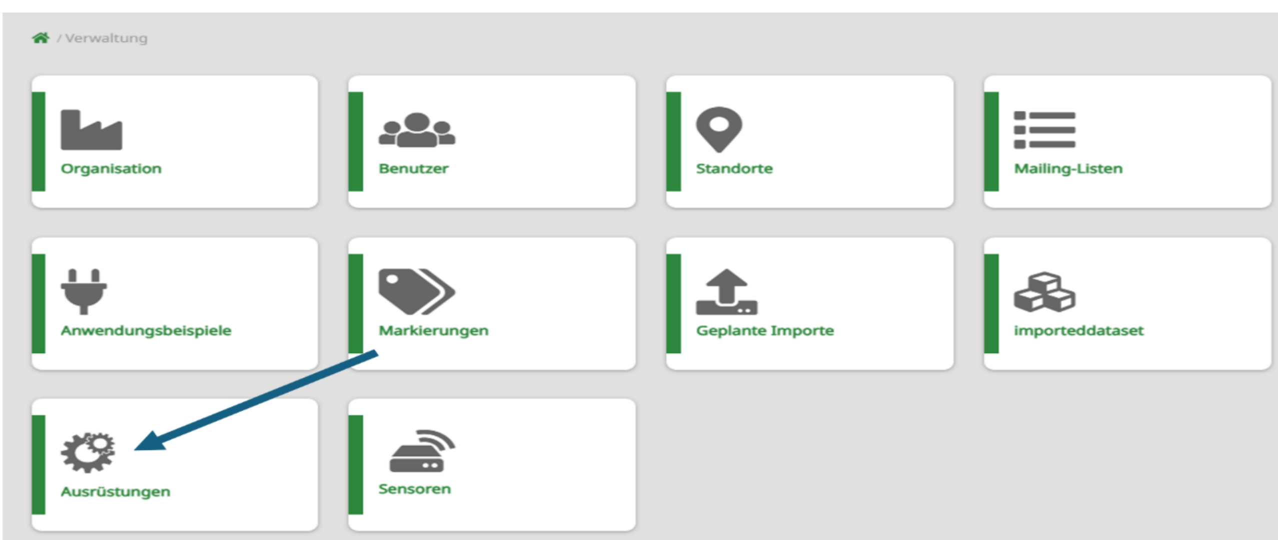

Figure 24: Equipment management (own illustration)

Figure 25: Device management (own illustration)

This includes electrical motor properties and, where applicable, information about installed bearings, gearboxes, or belt drives.

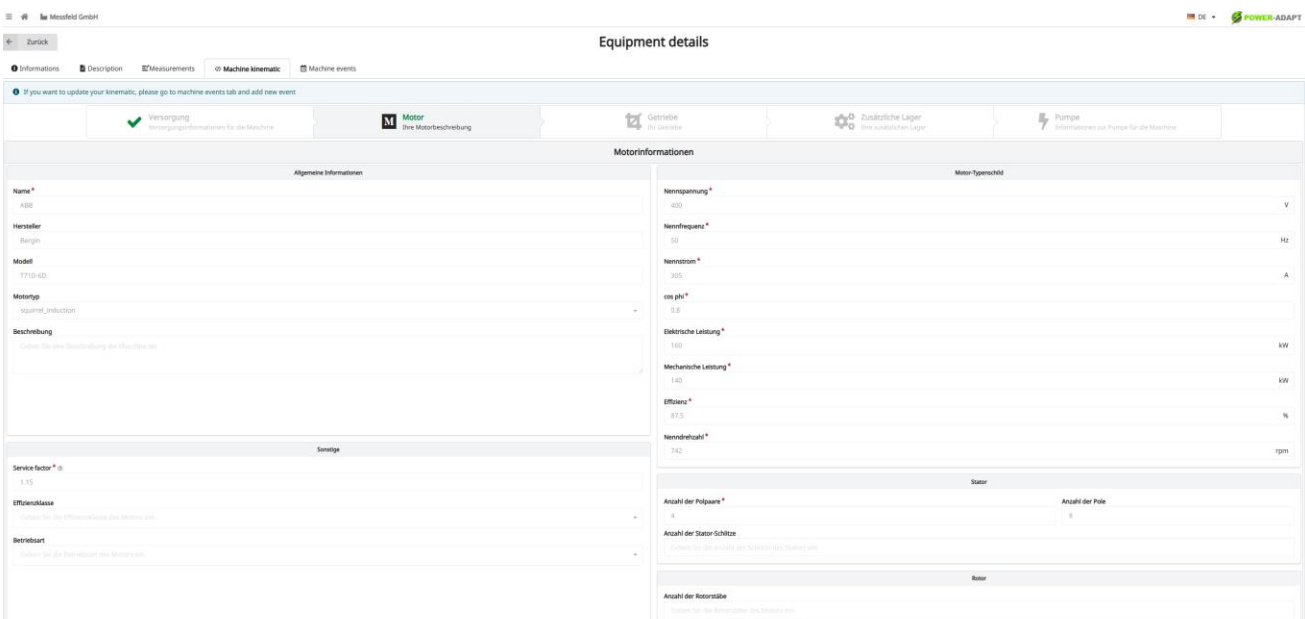

Figure 26: Equipment details (own illustration)

If the monitored motor drives a pump and this is configured accordingly, pump-related parameters must be recorded as well. These parameters are required to enable pump-specific functions and avoid incorrect calculations.

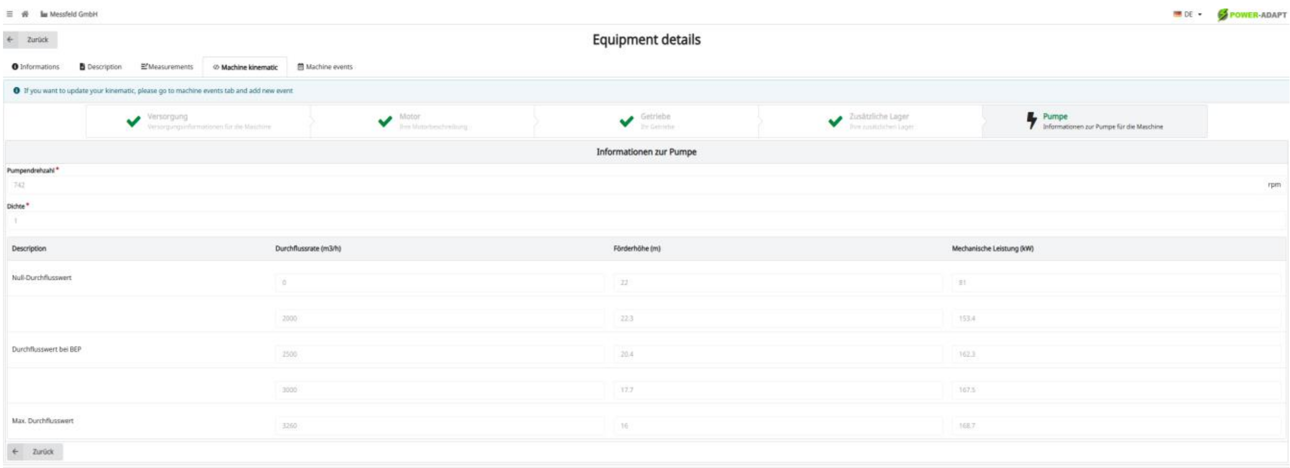

Figure 27: Equipment details (own illustration)

Within equipment settings, define general information and grouping attributes (e.g., type, usage, tags, and assignment to the correct site/area). Define measurement settings as required, including meter offset (for synchronization against reference meters), conversion factors (for engineering unit conversion), and display units. Where threshold-based views are used, define gauge bounds and standby thresholds so that dashboards distinguish between idle and operating periods consistently.

For rotating-machine monitoring, select the correct machine type to unlock dedicated functions such as pump monitoring. Be aware that changing machine kinematics or motor-related attributes can trigger recalculation of operating points and may reset health-related indicators; apply changes only after reviewing the platform's confirmation summary.

Accurate completion of these fields is necessary because these parameters influence derived indicators and health evaluations.

3.3.6 Dashboards, detail views, and custom dashboards

For day-to-day operation, the “home” icon returns to the start page. The dashboard provides an overview of configured equipment, typically showing key information such as asset name, health status, current power intake, last measurement transmission, and assigned site.

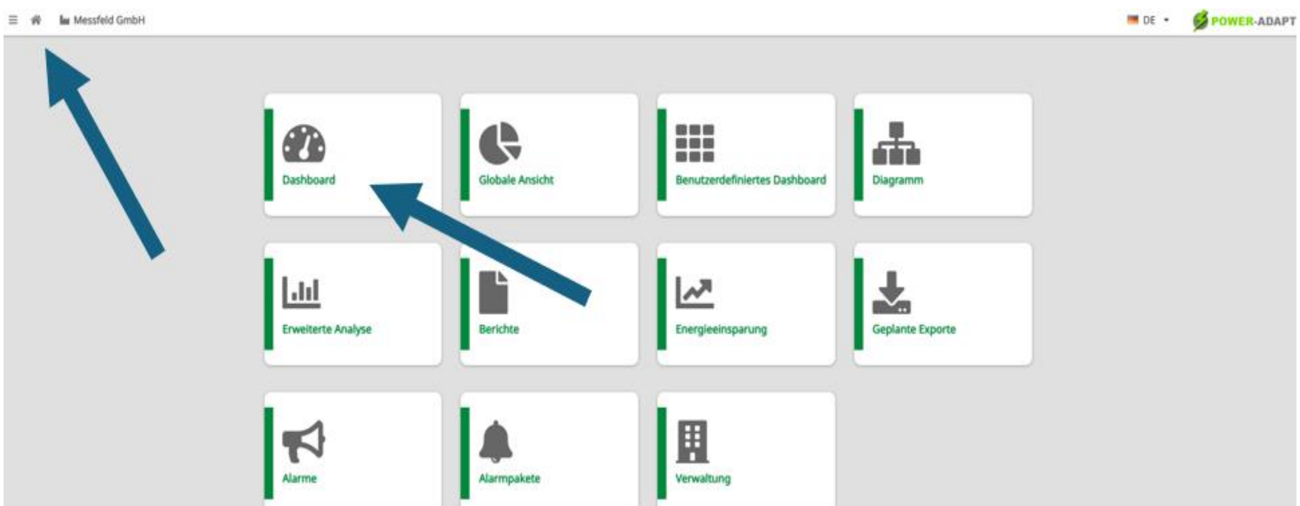

Figure 28: Equipment details (own illustration)

From the dashboard, each equipment entry can be opened into a detailed view that summarizes machine status and provides deeper component-level information via expandable sub-views.

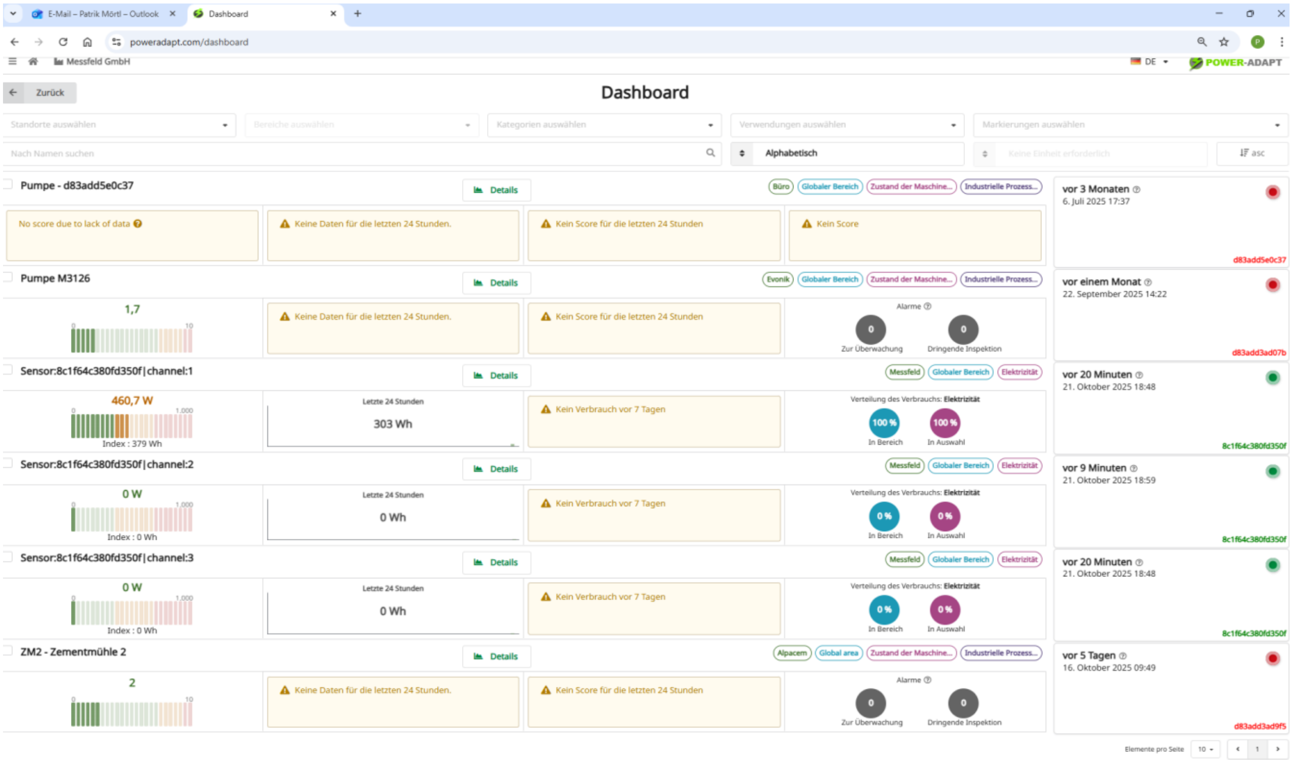

Figure 29: Standard dashboard (custom rendering)

For each visible piece of equipment there is a detailed view, which, as shown in Figure 30, contains an overview of the machine and the traffic light symbols directly indicate the condition of individual components.

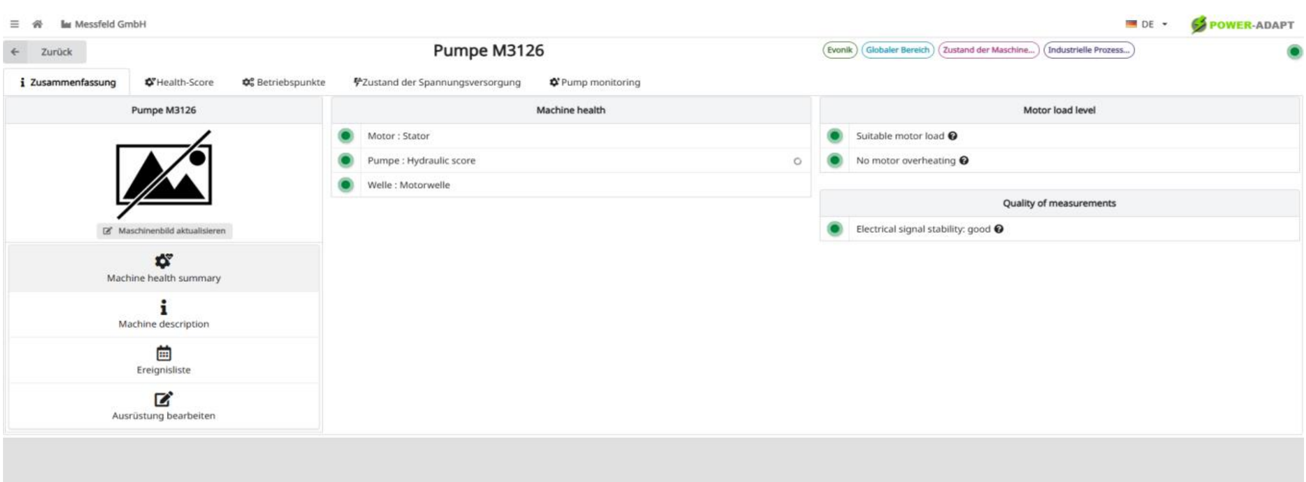

Figure 30: Detailed view (custom rendering)

All detailed information is available by opening the individual sub-items. Figure 31 shows the condition of the motor shaft, rotor, and stator.

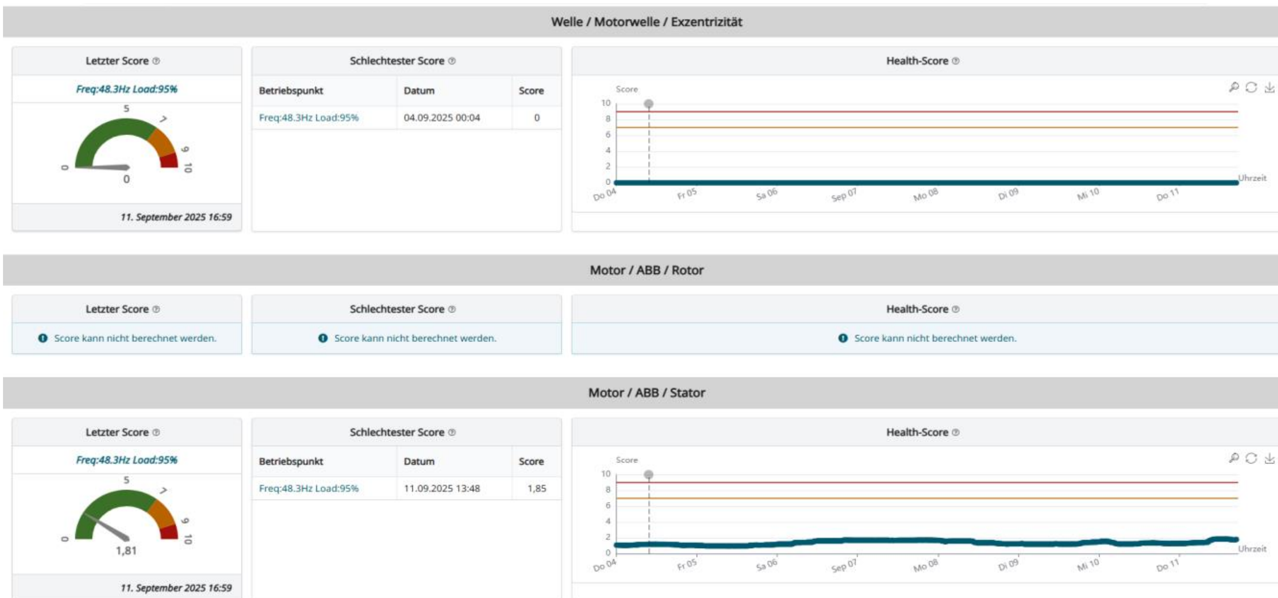

Figure 31: Engine condition (custom rendering)

If the equipment is configured as a pump, the platform provides additional pump-related indicators such as a hydraulic score and pump monitoring views (Figure 32).

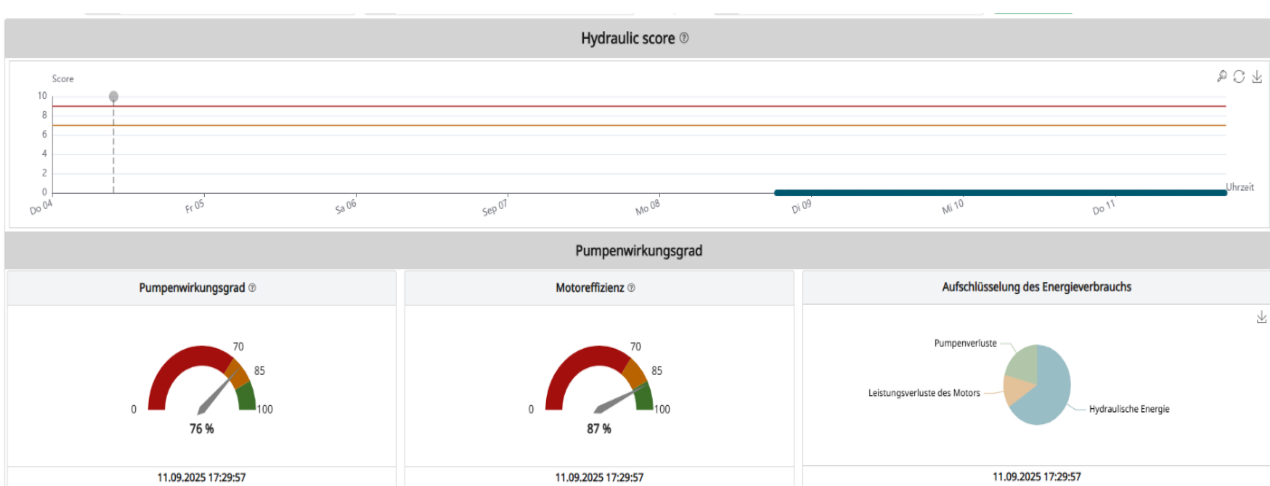

Figure 32: Engine condition (custom rendering)

These functions depend on correct machine-type selection and correct completion of pump parameters.

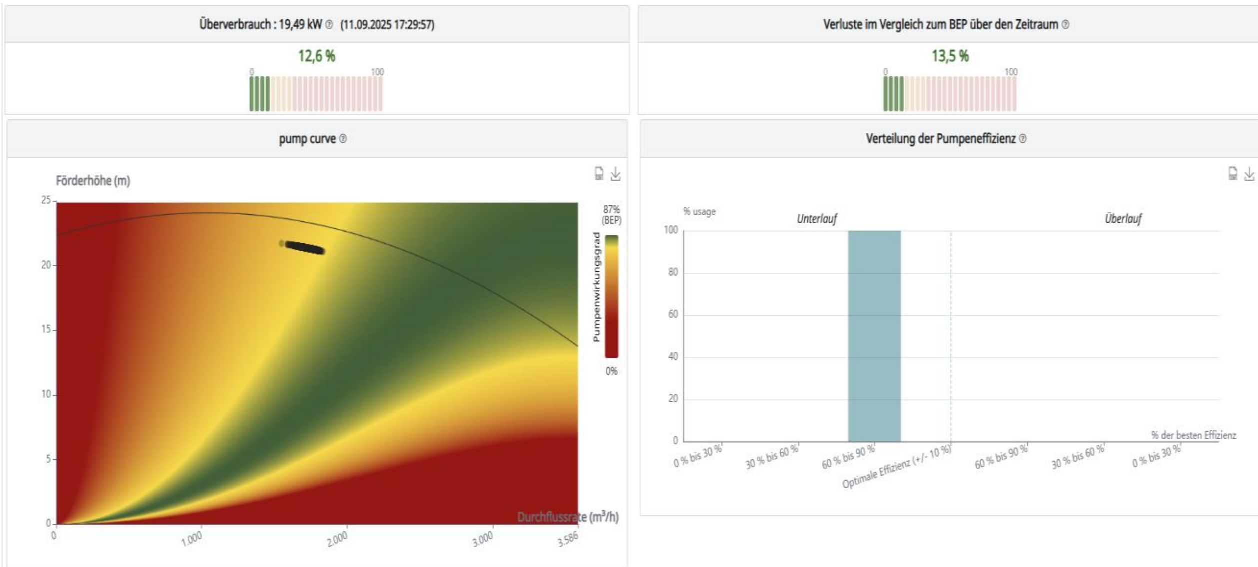

Figure 33: Pump monitoring (custom rendering)

For stakeholder-specific reporting, the platform supports user-defined dashboards (Figure 34). Custom dashboards are created via the dedicated dashboard icon and can be populated with widgets for selected measurements.

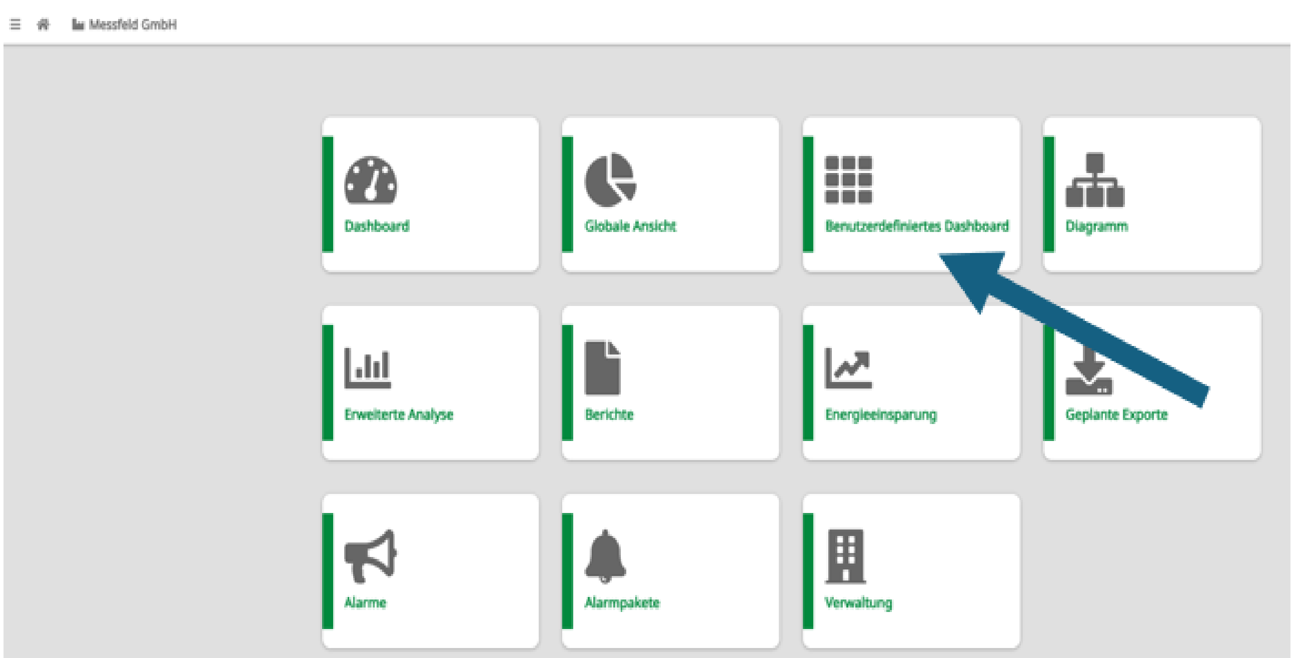

Figure 34: Create a custom dashboard (own layout)

Existing dashboards and the option to create new dashboards are accessed via the same drop-down interface.

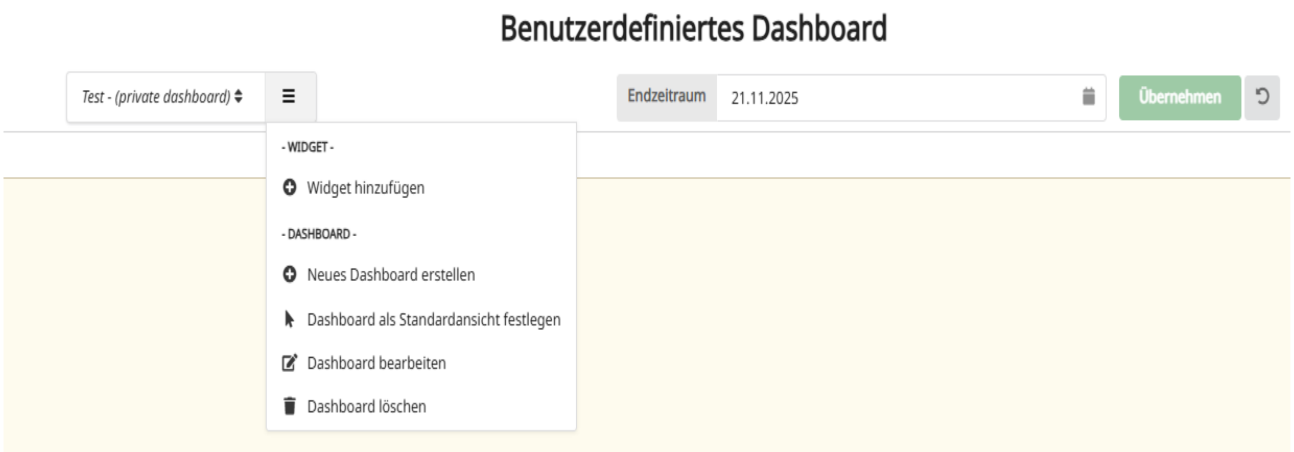

Figure 35: Options for custom dashboards (own representation)

Widgets are added and arranged via drag-and-drop.

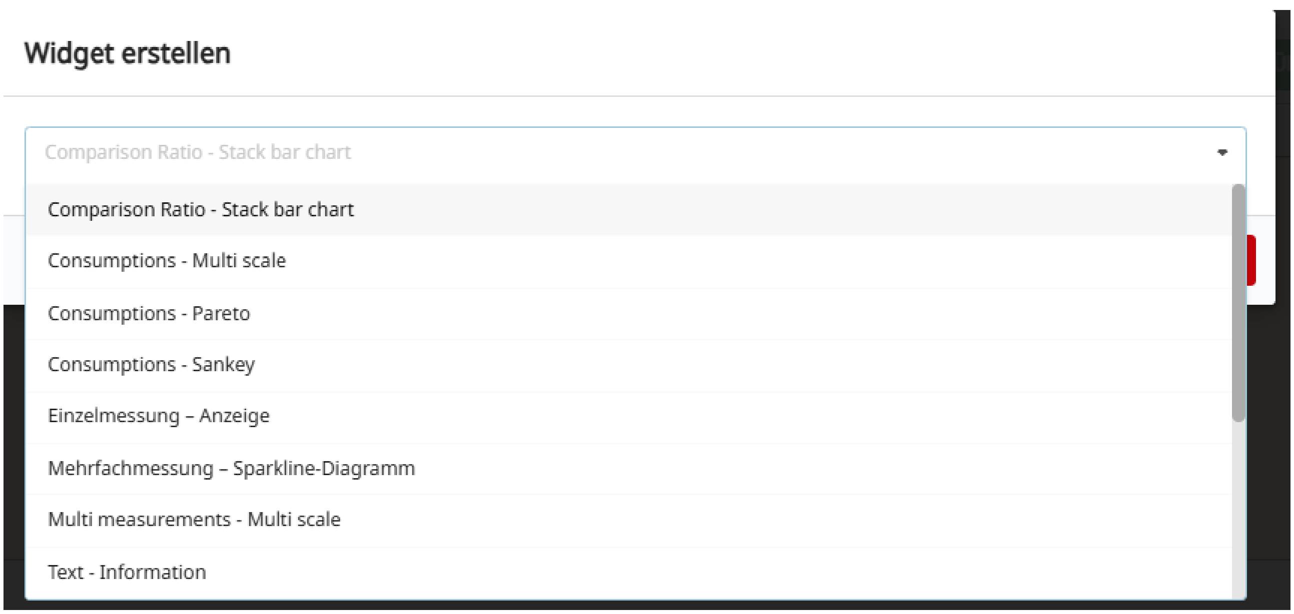

Figure 36: Widget selection and creation (own representation)

Once the required fields are completed for a widget, the measurement appears immediately and live data are displayed directly in the dashboard.

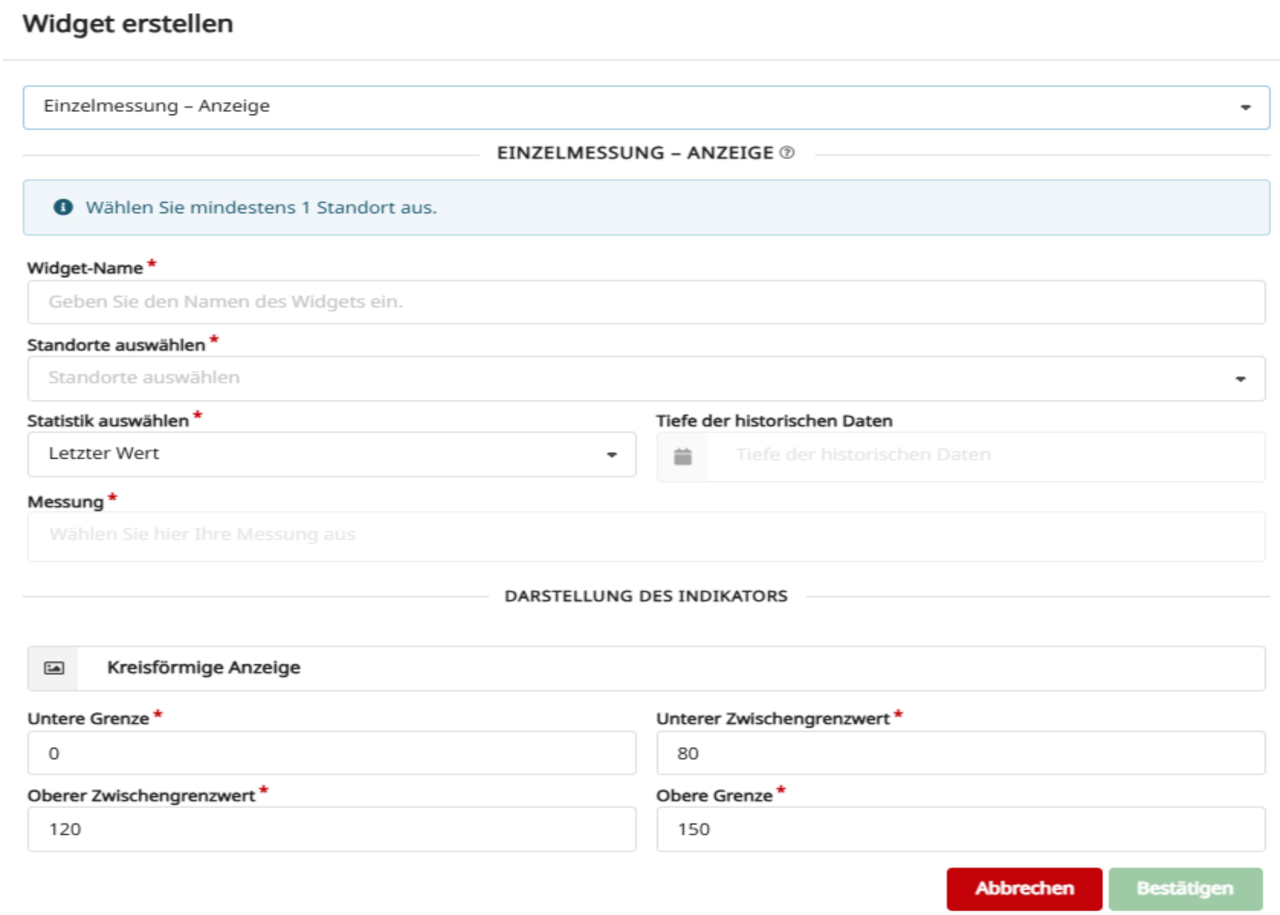

Figure 37: Widget configuration (own representation)

Figure 37 shows the configuration interface for a single measurement. Once all required fields are filled in, the measurement appears directly in the dashboard. Measuring data is also displayed immediately. The individual widgets are positioned using a simple drag-and-drop mechanism. Savings are always automatic.

3.3.7 Telemetry behavior and operational checks

In normal operation, energy telemetry is transmitted periodically (commonly in ten-minute steps for index-style values), while additional operational indicators may be transmitted depending on configuration and licensing. After completing configuration, verify that data is received continuously and that the user interface remains stable and responsive. Sustained reception without interruptions and consistent assignment of sensors to equipment confirm that the overall system integration is complete and ready for analysis and reporting.

6. Integration & API Usage

This chapter describes how ECO Adapt interfaces with third-party systems and how data are exchanged between field devices, gateways, and the cloud platform. Integration is typically implemented either via industrial field protocols (for on-premises systems such as SCADA/BMS) or via cloud telemetry (for centralized analysis and dashboards).

6.1 Integration with Third-Party Systems

ECO Adapt supports interoperability at the field layer through standard industrial communication interfaces. For local integration into industrial automation and building systems, the energy metering device supports Modbus TCP/IP and BACnet/IP over Ethernet and Modbus RTU via RS485. This allows consumption and power data to be polled by SCADA, building management systems, or other supervisory applications where on-premises monitoring is required.

For cloud-based integration, Power-Adapt uses LoRaWAN (868 MHz) as the wireless link from measurement unit to a dedicated gateway. The gateway forwards data to the cloud via the site's internet connection, enabling centralized visualization and analytics in the Power-Cloud environment without requiring new Ethernet/RS485 wiring to each measurement point.

Predict-Adapt and Power-Adapt differ in their internet uplink concept. Predict-Adapt connects via a cellular modem installed at the measurement unit. The modem is factory-pre-configured; commissioning typically requires inserting and configuring a SIM card with internet capability, and the modem is powered through a USB port at the measurement unit.

When planning integration, treat these connectivity paths as part of the system boundary: Power-Adapt requires LoRaWAN coverage between device and gateway and reliable internet access at the gateway location; Predict-Adapt requires cellular coverage and a properly configured SIM card (details in Figure 7).

6.2 Data Exchange & Formats

Within the cloud platform, device data are organized in a structured manner so that sensors and measurement channels can be assigned clearly to equipment and sites. This structure is important for reliable aggregation, comparison across assets, and consistent interpretation over time. In commissioning practice, once transmission is active, live data become visible shortly after configuration and the platform can present data from Predict and Power in parallel and time-synchronized form.

For reporting and performance analysis, the platform supports importing production data in CSV format with two columns. The first column contains the date in YYYY-MM-DD format, and the second column contains the production value in the defined unit; example lines use a semicolon separator. This allows users to relate energy consumption to output quantities and derive operational KPIs such as specific energy consumption when the production variable is meaningful for the monitored process.

Time-series visualization (e.g., load curves) is designed to remain readable across different time ranges using aggregation rules. Recent time windows are typically visualized with higher temporal resolution (commonly ten-minute steps for transmitted index-style values), while longer analysis ranges are displayed with coarser aggregation.

Additional notes: the available materials describe device-side protocol integration and cloud telemetry concepts, but do not specify a programmable API layer (endpoints) for the cloud platform, nor do they provide formal procedures for backup/recovery beyond export-oriented functions.

7. Expected Impact of the Solution

The expected impact of ECO Adapt results from combining condition monitoring (Predict-Adapt) and energy monitoring (Power-Adapt) in one cloud-based environment. In operation, this integration provides two complementary value streams: improved technical reliability through early detection of abnormal machine behavior, and improved energy performance through transparent load profiling and identification of inefficient operating regimes. The cloud platform supports these outcomes by presenting condition and energy data in a structured, time-synchronized manner, enabling both technical users (maintenance) and organizational users (energy management) to work from a consistent dataset.

Qualitative benefits include stable data transmission from field devices to the cloud, reproducible measurements under laboratory and industrial conditions, and a user-friendly cloud structure that supports systematic monitoring workflows.

Quantitative benefits are typically realized through reduced unplanned downtime, fewer unnecessary maintenance interventions, and measurable energy savings achieved by reducing idle operation and improving load management. In the observed implementations, energy-related improvement opportunities were identified based on distinguishable operating phases (full load, partial load, idle), and condition monitoring differentiated clearly between an abnormal asset state and a stable reference condition, which is a prerequisite for quantifiable improvements over time (e.g., trend-based maintenance planning and baseline-driven energy targets).

7.1 Conclusions from the CZ Pilot Action Implementation of the Solution

At the Czech company INOS Service s.r.o. the main energy consuming work is welding. At present all welding is done manually and the company is planning to install one welding robot machine. For calculation of investment it is necessary to measure the energy consumption and the operation time of specific welding stations.

On a visit on 9th of December the setting of the measurement system was discussed and agreed with the company. Best setting is to provide aportable EM System measuring Box for max. 3 welding stations, which can easily be installed at any welding station at the production facility.

After some first connection problems the system worked well an stable and data could be collected.

Figure 38: typical welding station

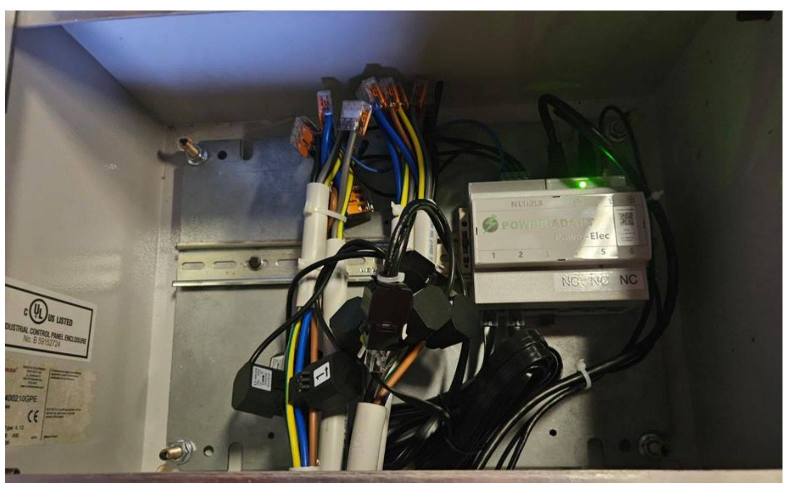

Figure 39: inside EM System measuring box for max.3 stations

Energy data and welding operation time is now continuously recorded and give value information for business calculation and investment planning..

7.2 Conclusions from the Austrian Pilot Action Implementation of the Solution

The second pilot action focused on Power-Adapt for energy monitoring in a realistic industrial use case (compressor system) and included an assessment of commissioning behavior, transmission stability, and the interpretability of resulting load profiles. The installation confirmed stable communication between measurement module, gateway, and cloud during initial operating hours and produced a stable signal profile despite typical electromagnetic influences inside the cabinet.

Figure 40: Monitored compressor (own illustration)

Shortly after activation, initial live data was available. This data showed the typical load cycles of the compressor system: clearly recognizable switching between idle and full-load operation, as is characteristic of speed-controlled and load-controlled compressors. The real-time visualization confirmed the correct acquisition of the phase currents and voltage values.

During commissioning, particular attention was paid to synchronization with the Predict component, as status and energy data will later be correlated as part of the overall evaluation.

The ECO Adapt system architecture enables the automatic time-based assignment of all measurement data. Figures 41 and 42 show this initial measurement data in the configuration platform.

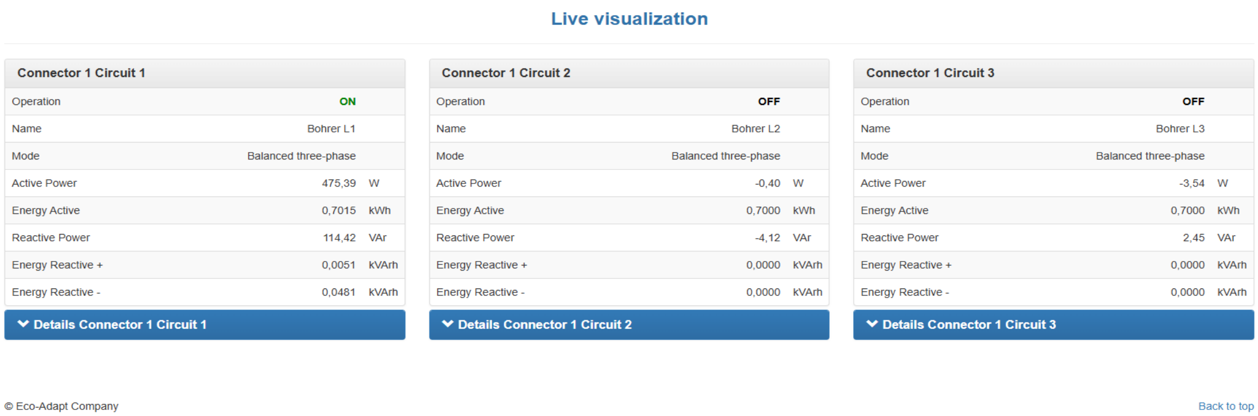

Figure 41: First measurement power adapt (own illustration)

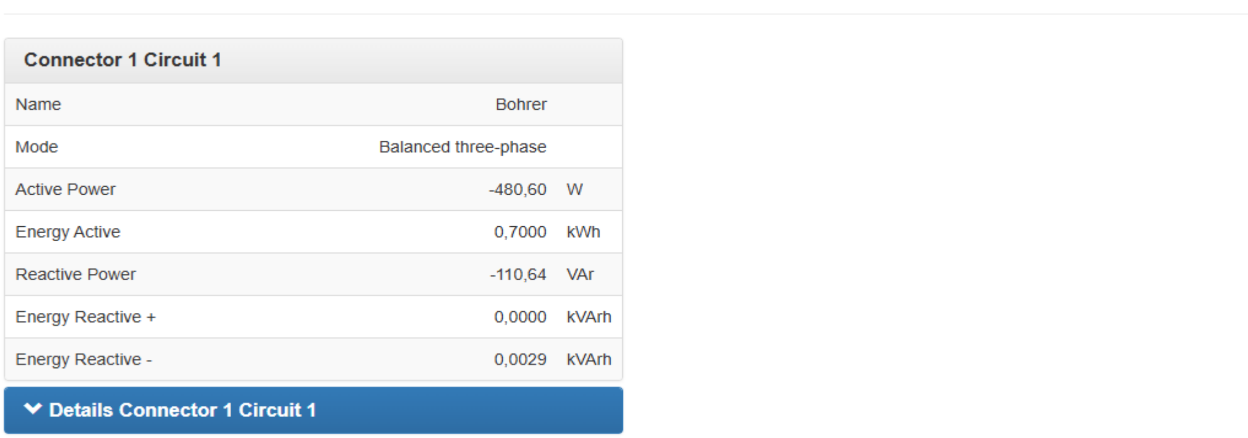

Figure 42: First measurement power adapt (own illustration)

The measured compressor data presented a clearly structured load profile in which idle phases and main load regions were distinctly visible. Performance indicators were represented correctly in the cloud. By comparing full-load, part-load, and idle phases, initial efficiency potentials were identified. Specifically, long idle times were highlighted as energetically unfavorable, while stable power intake during full-load phases indicated a mechanically intact operating state. Additionally, the relationship between power intake and useful compressed air delivery suggested optimization potential through improved load management.

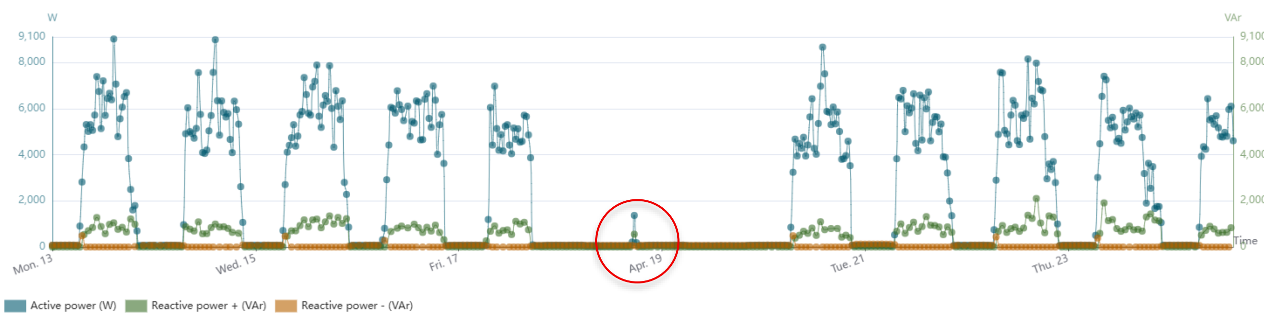

Figure 43: timeline of air compressor energy consumtion

Air compressor date timeline showed up some pressure loss of the air system. For analyzation the compressor was switched on over the weekend and it started up due to pressure reduction in the system at sunday morning. Therefore the system was checked and the problem could be solved.

A further impact point is the integrated cloud view: condition and energy data can be displayed in parallel, time-synchronized and traceable, which supports combined interpretation (e.g., distinguishing energy inefficiency caused by operating strategy from energy increases caused by mechanical degradation). The dashboards provide structured presentations aligned with different user groups and form a practical basis for continuous monitoring and reporting.

After the sensors and measuring modules were installed, the gateway was connected to the cloud and registered there using a unique device identifier. The Predict and Power components of the pump, roller, and compressor system were then created in the cloud as separate system structures. Data transmission began immediately after activation, so live data was visible within the first few minutes after configuration.

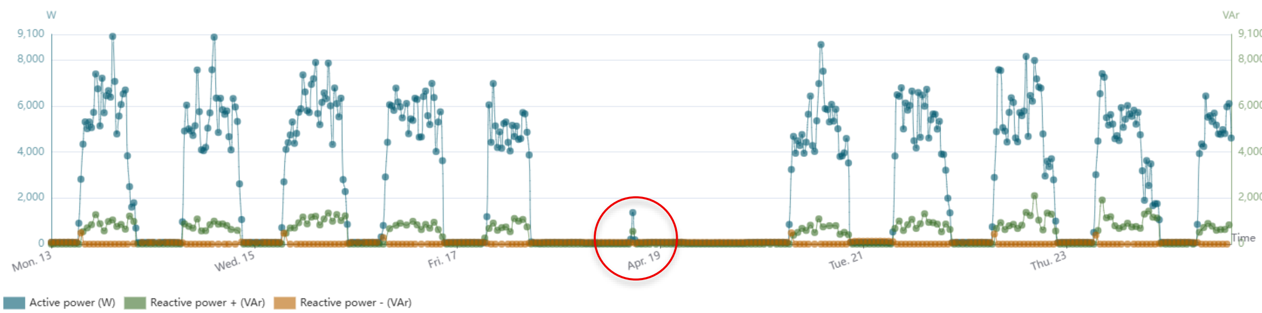

Figure 44: timeline of air compressor energy consumtion

7.3 Conclusions from an Predict Adapt Implementation use case

The Predict-Adapt analyzation tool is also available, but was not necessary to be implemented in the two pilot projects at DANUBE DNA project. It is helpful and can be used for condition monitoring, therefore this system is also included in this technical description.

The predict pilot action focused on validating Predict-Adapt in two intentionally contrasting machine states: one asset with a known pre-damage indication and one asset expected to be healthy. This setup allowed verification of both fault sensitivity and reference-state stability.

Prior to this, the maintenance staff reported a suspected bearing failure, which manifested itself in the form of increased operating noise and slightly elevated housing temperatures.

The engine shown in Figure 38 is the one where the pre-existing damage is suspected and on which the system is being tested. This system therefore offered ideal conditions for verifying the sensitivity of the Predict system regarding damage indicators.

Figure 45: Engine with prior damage

After power supply and network connection, configuration and the first measurement were carried out. Figure 45 shows the first measured values.

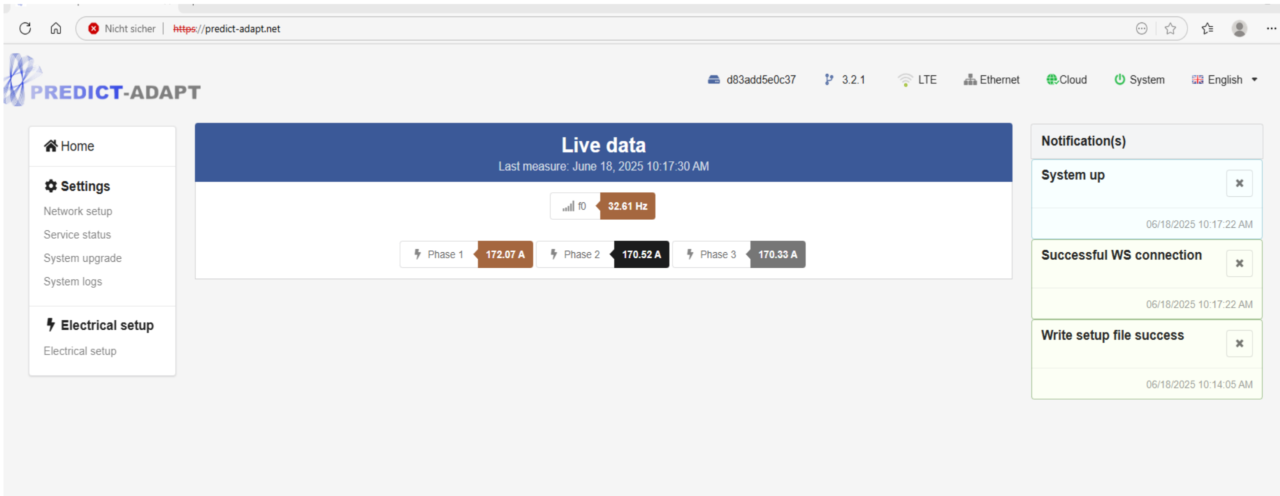

Figure 46: Electrical setup predict adapt

In the installation on the roller system without a known pre-damage indication, measurements confirmed an inconspicuous operating state. Values and trend-based indicators remained within normal ranges and were consistent with laboratory values. This confirms that the system can capture stable “healthy” states reproducibly and establish a reliable baseline for future trend analyses.

Overall, the first pilot action showed that Predict-Adapt can distinguish between normal and abnormal machine states and that reference-state definition materially improves later interpretation of deviations. This supports condition-based maintenance by enabling earlier intervention planning and by reducing reliance on purely interval-based maintenance.