ENLIGHTENING CONNECTIVITY

Smart Lighting User Guide

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www.tondo-iot.com

Contents

Smart Lighting Technology Primer

What is Smart Lighting?

Smart lighting is the evolution of traditional lighting systems into interconnected, adaptive, and intelligent networks that enhance energy efficiency, operational efficiency, and urban livability.

Smart Lighting integrates advanced technologies, open standards, and communication protocols to provide precise, real-time management of lighting infrastructure. Smart lighting is the digital platform for modern smart city ecosystems, enabling additional sensor-, metering, and controls-driven services that benefit urban development and sustainability.

A Brief History

The Mechanical Era

- **1944**: The first dusk-to-dawn streetlight photocell control was introduced, enabling lights to turn on and off automatically based on sunlight levels. This innovation eliminated the need for manual operation and became the foundation of automated lighting control.

The Solid-State Era

- **1959**: The introduction of solid-state interior dimming controls marked a shift from purely mechanical systems, allowing users to adjust light levels manually.
- **1977**: The first patent for streetlight dimming control was issued, laying the groundwork for energy-saving solutions on public roadways.
- **1991**: Combining photocell control with atomic clocks, new systems enabled precise dusk-to-dawn operation with 50% dimming during low-traffic hours.

The Digital Era

- **1996**: ANSI C136.10 standardized 0-10V dimming controls, providing a simple yet reliable protocol for dimmable lighting.
- **2011**: Wipperfürth, Germany, implemented the first DALI-based walkway light controls, introducing bi-directional communication for real-time monitoring and control.

- **2013**: ANSI C136.41 introduced onboard dimmable luminaire sockets, accelerating the adoption of network-controlled lighting.
- **2018**: Zhaga Consortium releases Zhaga Book 18 Ed. 1 low-voltage socket specification as an alternative to the high-voltage ANSI/NEMA C136.41 socket
- **2019**: Zhaga Consortium releases Zhaga Book 18 Ed. 2 which incorporates the DALI D4i control standard to their socket standard.
- **2019-2022**: The adoption of DALI-2 and DALI D4i lighting control protocols into global IEC and ANSI standards and Zhaga specifications facilitated the adoption of open, inter-operable lighting and sensor systems. These updates enabled controls and fixtures to store meta-data, energy consumption, and diagnostics data, enabling advanced asset management.

The Modern Era

- **2024:** Next-generation smart lighting controls such as Tondo's Edge IQ, with advanced hardware-based cryptographic security and artificial intelligence enter the market, reducing risk and driving new economic benefits.

Smart Lighting for Smart Cities

Modern smart lighting solutions go far beyond illumination. They incorporate capabilities such as:

- **Machine-Learning Artificial Intelligence:** Tondo's Cloud IQ incorporates Google's TensorFlow AI, providing a wide range of multi-purpose AI technologies that will scale and grow with your needs.
- **Adaptive Dimming**: Lights adjust automatically based on traffic, weather, and occupancy, saving energy without compromising safety.
- **Energy Monitoring**: Advanced controllers measure and report energy usage in real time, supporting Time-of-Use billing and ESCO (Energy Service Company) models.
- **Interoperability**: Open standards like DALI D4i and Zhaga ensure compatibility across devices, avoiding vendor lock-in and extending asset lifecycles.
- **Smart City Integration**: Smart lighting serves as a backbone for deploying sensors that monitor pedestrian and cyclist traffic, air quality, noise, flood levels, and more.

The Tondo Advantage

Tondo's Edge IQ and Cloud IQ solutions exemplify the latest in smart lighting control. By leveraging open standards, secure hardware, and advanced analytics, Tondo enables:

- **Reduced Operating Costs**: Energy savings from adaptive dimming and AI-automated control systems.
- **Fully-Managed Network and Cybersecurity**: Tondo manages all aspects of the technology platform for its customers including cellular data plans, eliminating the IT management burden on their organization
- **Scalability**: Support for thousands of luminaires and sensors within a single network.
- **Enhanced Security**: Two onboard cryptographic SoCs provide maximum protection for critical infrastructure.
- **Smart City Enablement**: Tondo's systems seamlessly integrate lighting and sensors, enabling cities to reduce operational costs by over 80% while supporting future IoT applications.

Smart lighting control is not just an upgrade to legacy systems—it is a transformative technology that drives the creation of intelligent, sustainable, and resilient cities.

Key Components of Tondo's Smart Lighting System

Tondo's smart streetlighting solutions integrate cutting-edge technologies and open standards to deliver energy efficiency, scalability, and enhanced operational capabilities.

By combining Edge IQ controllers, the Cloud IQ platform, and advanced connectivity options, Tondo provides cities with a robust infrastructure for modern smart lighting and broader smart city applications.

Edge IQ Controllers

At the core of Tondo's solution are the Edge IQ controllers installed directly on luminaires, internally to the luminaires, or inside lighting poles. Edge IQ controllers reduce the burden of lighting management, simplify decision-making, and create a city-wide platform for Smart Cities.

- **Integrated LTE Cellular**: High-speed connection to the Tondo Cloud IQ central management console without external "gateways" for improved scalability and reliability.
- **Bluetooth 5/Mesh**: Cost-effective high-speed wireless connectivity to a wide array of sensors, smart meters, and other Smart City devices.

- **Billing/Revenue Grade Energy Measurement**: ANSI 12.1 Accuracy Class .05 measurement and secure hardware-based data logging provides accurate energy usage data for utility billing applications and dependable municipal billing reconciliation.
- **DALI-2 Control**: Standards-based dimming levels, multi-fixture control, and asset management.
- **DALI D4i Control**: Standards-based energy metering and sensor control.
- **Intelligent Adaptive Lighting**: Tondo's machine learning AI adjusts lighting profiles based on traffic patterns, weather conditions, and time of day.
- **Tilt and Vibration Sensors**: Detects pole instability or damage for rapid maintenance response.
- **Astronomical Clock**: Patented Tondo technology provides precise scheduling more accurate than photocell-based solutions.
- **Advanced Cybersecurity**: Equipped with a cryptographic accelerator and hardware security module (HSM) for secure, encrypted communication.

Edge IQ Benefits:

- 40% greater operational savings over other smart lighting controls from energy savings, extended asset lifecycles, operational efficiencies, and carbon credit offsets
- Advanced cybersecurity for protecting critical infrastructure
- Advanced fault detection and resolution, minimizing downtime.
- Enhanced safety and reliability for urban environments.

Cabinet IQ Controllers

Tondo's Cabinet IQ is an advanced energy management and infrastructure monitoring solution designed to enhance the security, reliability, and operational efficiency of municipal and industrial power systems.

By integrating real-time energy monitoring, fault detection, and environmental sensing, Cabinet IQ provides a comprehensive approach to managing electrical infrastructure and preventing unauthorized access.

Advanced Energy Monitoring

- Revenue-grade metering compliant with ANSI C12.20 and IEC 62053-22 for accurate energy tracking.
- Supports Time-of-Use (ToU) billing models and real-time power quality analysis.
- Tracks voltage, current, power factor, frequency, and harmonic distortion.

Electrical Fault Detection & Grid Anomaly Alerts

- Detects voltage fluctuations, wiring issues, and phase imbalances.
- Identifies breaker failures, overload conditions, and unexpected power surges.
- Sends automated alerts via Cloud IQ CMS for proactive intervention.

Secure Cabinet Control & Data Logging

- Relay-based circuit on/off control for managing power distribution in electrical cabinets.
- Dry contact digital inputs, relay outputs & MODBUS integration for sensor connectivity.
- 365-day secure energy usage log with 48-hour UPS backup during power outages.

Infrastructure & Utility Monitoring Use Cases

- Electricity Quality Monitoring
- Electricity Theft Detection
- Streetlight Wire-Theft Prevention
- Service Breaker Condition Monitoring
- Tank and Vessel Level Monitoring
- Battery Level Monitoring
- Roadway Condition Monitoring
- Cabinet Flood, Fire, and Tamper Detection

Benefits of Cabinet IQ

- **Optimized Energy Usage**: Reduces costs through real-time monitoring and fault detection.
- Enhanced Grid Resilience: Detects service failures before they escalate.

- **Secure & Encrypted Communication**: End-to-end encryption ensures data integrity.
- **Multi-Function Infrastructure Monitoring**: Tracks energy, safety, and environmental factors in a single platform.
- **Scalable for Smart City Applications**: Supports utility cabinets, roadway infrastructure, and industrial power systems.

Cabinet IQ goes beyond energy management, acting as a comprehensive infrastructure control hub that supports the evolving needs of municipalities, utilities, and smart city networks.

Tondo Cloud IQ CMS

Tondo's Cloud IQ central management system (CMS) is designed to simplify the operation and monitoring of smart streetlighting networks.

- **Real-Time Monitoring**: Tracks the status of connected luminaires, providing insights into energy consumption, faults, and performance.
- **AI Analytics**: Transforms very large data into actionable insights and anomaly detection via alerts and notifications, and provides advanced automation for operational efficiencies.
- **Predictive Maintenance:** Monitors lighting assets to predict failures before they occur.
- **User Roles and Permissions**: Secure access control for administrators, managers, and technicians.
- **Scalable Architecture**: Deploys on any number of luminaires without performance degradation.
- **Smart City Applications:** Tondo's smart streetlighting provides the backbone for smart city networks, enabling the deployment of sensors and IoT devices across urban infrastructure.
- **Energy Efficiency and Sustainability**: 40% greater energy and GHG savings over other smart lighting systems. Support for Time-of-Use (TOU) billing, accurate energy reporting, and simplified energy services financing contract reconciliation.

Cloud IQ Benefits:

- Streamlined operations with an intuitive user interface.
- Data-driven decision-making for energy savings and maintenance planning.
- Supports all lighting and Smart City sensor, metering, and control use-cases.

Tondo Managed Cybersecurity

Tondo's Edge IQ, Cabinet IQ, and Cloud IQ solutions leverage a fully managed, closed security model, ensuring smart lighting deployments remain isolated, tamper-proof, and resilient to cyber threats.

Tondo's cybersecurity framework is not exposed to customers or the internet. All cryptographic operations, key management, and authentication are handled by onboard security hardware, eliminating customer intervention and security threats from user accessible security management systems.

Fully Managed Security & Network Isolation

- ☑ **No Customer Network or Security Exposure** – Tondo manages all connectivity, encryption, and access control.
- ☑ **Pre-Assigned Root Certificates** – Each Edge IQ controller is provisioned at manufacturing with customer-specific Cloud IQ root certificates.
- ☑ **No Public API or Internet-Facing Endpoints** – All authentication and data transmission occur over a secure, private network.
- ☑ **Automated Security Updates** – Edge IQ devices receive secure, over-the-air (OTA) firmware and security updates, with no user intervention.

Edge IQ Controller Security

Edge IQ leverages two key hardware components to secure device operation:

- ☑ Cryptocaccelerator (Primary MCU for Communication & Processing)
- ☑ Hardware Security Module – HSM for Cryptographic Operations)

Automated Certificate Management & HSM Protections

- ☑ Edge IQ controllers have a unique cryptographic certificate assigned at manufacturing.
- ☑ Root certificates remain permanently stored within the HSM and cannot be extracted or modified.
- ☑ All authentication and encryption processes occur inside the HSM, ensuring keys are never exposed to software.
- ☑ Certificates are automatically rotated and renewed, requiring no customer intervention.

Cloud IQ Security & Access Control

- ☑ **Multi-Factor Authentication (MFA) for Operators** – Ensures only authorized personnel access Cloud IQ.
- ☑ **Role-Based Access Control (RBAC)** – Limits system access based on user roles.
- ☑ **Private Network Communication** – Cloud IQ and Edge IQ communicate exclusively over a private, encrypted network, eliminating external threats.
- ☑ **Anomaly Detection & Automated Security Auditing** – AI-powered monitoring detects unusual patterns or unauthorized access attempts.

Cybersecurity Model: Isolated & Secure by Design

Unlike IoT-based solutions that expose security settings to customers, Tondo's cybersecurity framework is fully managed and isolated:

Security Aspect	How Tondo Handles It	Customer Involvement
Root Certificate Management	Assigned at manufacturing and stored inside HSM	None
Firmware Security	Secure Boot + OTA firmware updates	None
Key Rotation & Authentication	Managed inside HSM	None
API & Network Security	No public APIs, no internet exposure	None
Access Control	MFA & RBAC enforced by Cloud IQ	User Access Only

Summary: Tondo's Cybersecurity Model

- ☑ **Fully Managed Security** – No customer involvement in network or key management.
- ☑ **HSM-Protected Certificates** – Root certificates are permanently stored and secured inside Edge IQ's HSM.
- ☑ **No Public APIs or Internet Exposure** – All network communication is private, encrypted, and isolated.
- ☑ **Automated Updates & Anomaly Detection** – Security patches and intrusion detection occur without user input.

By leveraging Tondo's closed cybersecurity framework, municipalities and utilities gain enterprise-grade security without needing dedicated IT security teams.

Tondo Artificial Intelligence

Tondo's AI-powered Cloud IQ platform delivers intelligent automation, predictive analytics, and real-time optimization to enhance smart lighting and smart city operations.

By leveraging deep learning, machine learning, and real-time data processing, Tondo's AI solutions reduce energy consumption, enhance infrastructure security, and optimize operational efficiency.

Tondo AI: Today

Tondo's AI-powered adaptive lighting control can ensure efficient, safe, and standards-compliant illumination while minimizing operational costs.

- ☑ **Energy Intelligence** – AI-driven load balancing, electricity diagnostics, and event tracking improve the resilience of municipal power systems
- ☑ **AI-Based Adaptive Dimming** – Adjust lighting dynamically based on traffic, pedestrian movement, and environmental conditions when used with pedestrian and cyclist traffic sensors
- ☑ **Predictive Maintenance** – Identify anomalies in energy usage and forecasts failures in streetlight fixtures, reducing downtime.
- ☑ **Incident Detection & Smart Alerts** – AI automatically detects abnormalities such as power theft, sudden outages, or unauthorized energy usage, triggering real-time alerts.
- ☑ **Autonomous AI Adjustments** – Cloud IQ can dynamically adjust system settings based on real-time environmental and operational inputs.
- ☑ **Deep Learning Data Insights** – AI identifies patterns in historical data to optimize energy consumption, lighting schedules, and infrastructure planning.
- ☑ **Grid Anomaly Detection** – AI models analyze electricity patterns to detect unauthorized usage, power theft, or failing components in real time.
- ☑ **Infrastructure Health Monitoring** – Predictive analytics can monitor connected infrastructure, preventing costly failures.

Tondo AI: The Future

Tondo's AI roadmap includes next-generation applications that further expand the impact of AI-powered automation.

- ☑ **Multi-Modal Traffic Optimization** – AI-enhanced traffic monitoring adapts streetlighting based on congestion patterns and road conditions.
- ☑ **Real-Time Audio Analysis** – AI-based sound recognition for advanced public safety and security.
- ☑ **Smart City AI Ecosystem** – AI analytics for waste management, air quality monitoring, and adaptive energy use to further enhance urban sustainability.

Tondo AI: In-House AI Expertise and Technology Platform

Tondo's AI solutions are developed entirely in-house, ensuring that every aspect of Cloud IQ's intelligence, automation, and analytics is purpose-built for smart lighting and smart city applications. Unlike platforms that rely on third-party AI models or external contractors, Tondo's dedicated AI team can bring new solutions to its customers faster and at a lower cost.

- ☑ **Purpose-Built AI for Smart Cities** – AI models trained specifically on real-world municipal infrastructure data, ensuring greater accuracy and reliability.
- ☑ **Seamless AI Integration** – No reliance on external AI platforms or third-party AI solutions, which can limit functionality and increase operational complexity.
- ☑ **Faster Adaptation & Innovation** – With direct control over development, Tondo can quickly implement enhancements, new features, and customer-driven improvements.
- ☑ **Stronger Data Privacy & Security** – In-house AI means greater control over data processing, minimizing risk from third-party data exposure.
- ☑ **Optimized for Performance & Cost Efficiency** – Tondo's AI is designed specifically for lighting and Smart City infrastructure management, eliminating unnecessary overhead from generic AI models.

By keeping AI development and expertise in-house, Tondo delivers unmatched efficiency, security, and adaptability, making Cloud IQ the most powerful AI-driven smart city platform available today.

Lighting Control Methods

The Tondo Edge IQ supports full 0-10V, DALI-2, and DALI D4i specifications for lighting and sensor control, with support for Bluetooth 5 Low Energy and Bluetooth Mesh for reliable controller and sensor communications.

ANSI C137.1 - 0-10V Control

- A simple analog dimming protocol where a voltage signal (0-10V) controls the brightness of the luminaire.
- A 0V signal typically represents the lowest light output (off or dimmed), while 10V represents full brightness.
- Widely used in traditional and retrofit lighting applications due to its simplicity and cost-effectiveness.

Strengths

☑ Low-cost and easy to implement.

☑ Compatible with a wide range of existing lighting systems.

Limitations

☒ No true “off” condition at zero dimming level

☒ Inconsistent dimming curves across luminaires

☒ One-way communication—cannot provide feedback or diagnostics.

☒ Requires manual entry of asset information for each fixture

☒ Limited scalability and lacks advanced features like scheduling or scene-setting.

ANSI C137.4 - DALI-2 Control

- A digital communication protocol for controlling and dimming lights.
- Enables two-way communication, improving diagnostics and control features.

Strengths

☑ Supports some asset data including dimming level, power status, operating hours, fault status, driver temperature, group assignment, dimming profile, and dimming rate.

☑ Allows grouping, scene control, and individual addressing of luminaires.

☑ Standardized dimming control curves across all luminaire manufacturers.

ANSI C137.4 - DALI D4i Control

- An extension of DALI-2 designed for smart lighting and IoT applications.
- Includes power supply standards for sensors and communication modules.

Strengths

☑ Enhanced asset data including fixture manufacturer, fixture model, fixture firmware version, driver type, fixture serial number, lumens-per-watt, maximum luminous flux, rated power, voltage, current, ambient light level, occupancy detection, temperature, remaining lamp life.

☑ Energy monitoring, fault detection and diagnostics.

☑ Simple socketed IoT sensor connectivity with built-in power supply.

☑ Can run over Bluetooth Mesh for higher bandwidth support

Controller, Sensor, and Device Communications

Transparent Fully-Managed Network

Tondo manages all network technology in the background for you so that you don't need to worry about configuring addresses, gateways, manage capacity, communications issues, or any other IT-related tasks.

This section is provided only for those wanting to know more about the features and advantages of your Tondo system.

Bluetooth 5 LE

- ☑ A global standard "full-stack" protocol for maximum interoperability and device support.
- ☑ Very low-energy, high-bandwidth wireless protocol that supports long range communications and long life for battery-powered sensors.
- ☑ Bluetooth 5 LE uses additional error correction, allowing ranges up to 1,000 meters (1 km) in ideal conditions, while maintaining low energy consumption.
- ☑ Provides up to 2 Mbps bandwidth for high-data-rate applications and balances range and data rate effectively for smart lighting and IoT use cases.
- ☑ Ideal for bridging larger areas while supporting advanced sensors and meters.
- ☑ Supported by Tondo Mobile App for field installation and asset management activities

Bluetooth Mesh

- ☑ A distributed wireless protocol designed for city-wide scalability and resilience.
- ☑ Bluetooth Mesh excels at supporting large-scale IoT networks by enabling Edge IQ controllers to relay data across multiple hops, correcting for coverage problems common to cellular-only solutions in complex urban environments.
- ☑ Mesh supports distributed data aggregation, making it ideal for very large lighting systems and widespread sensor deployments.

- ☑ Connects fixtures to a broader wireless network, allowing centralized management.
- ☑ Extends range and scalability, ensuring reliable communication across large-scale installations without requiring extensive wired infrastructure.

Cellular Communications

Each Tondo Edge IQ controller comes equipped with an 4G LTE cellular communications radio that supports multiple global cellular networks with automatic fail-over in the case of a network outage.

Tondo includes and manages the cellular data plans for all Edge IQ controllers as part of your Tondo Cloud IQ software service. There are no data plans for you to manage or maintain.

Tondo Edge IQ controllers can be ordered for the following cellular networks:

Feature	EGPRS	NB-IoT	CAT-M1	CAT-1 bis
Data Rate	Up to 473 kbps	Up to 250 kbps	Up to 1 Mbps	Up to 10 Mbps
Latency	Moderate	High (1.6-10s)	Low (~10-15 ms)	Low (~50 ms)
Coverage	Good	Good	Good	Excellent
Power Consumption	High	Extremely Low	Low	Moderate
Use Cases	Basic IoT, legacy	Smart meters, sensors	Smart meters, sensors	Smart meters, sensors, video IoT, telematics

Asset Management

Tondo's Edge IQ controller can capture information about luminaires and any connected sensors or controls.

The information that the Edge IQ can capture automatically is dependent on whether a luminaire supports 0-10V, DALI-2, and/or DALI D4i lighting control as previously discussed. Any information not captured automatically may be added to Mobile IQ for collecting data manually in-field, or updated in Cloud IQ directly.

The Tondo Mobile App allows field installation and maintenance teams to add or update information that is not automatically captured by the Tondo Edge IQ controller.

Preparing for Edge IQ Installation

Preparing For Your Tondo Edge IQ Installation

Technical specifications for Edge IQ can be found in the Tondo Solutions Guide.

Tondo Edge IQ Controllers

- ☑ Verify ANSI C136.41-compatible luminaires or sockets.
- ☑ Confirm DALI-2 or 0-10V dimmable luminaires for adaptive lighting control.
- ☑ Ensure DALI D4i-compliant luminaires for advanced energy management, fault detection, and smart city sensor support.
- ☑ Ensure luminaires are connected to a compatible power source (90-480VAC).
- ☑ Confirm LTE service availability (CAT-M1, CAT1.bis, or NB-IoT) at the deployment location.

Tondo Mobile App

- ☑ Download and install the Tondo Mobile App on an Android-based smartphone or tablet.
- ☑ Ensure the device has Wi-Fi or cellular connectivity.
- ☑ Ensure Edge IQ controller serial numbers are available in the Evaluation Kit.
- ☑ Confirm that each Edge IQ controller is assigned to your organization.

Tondo Cloud IQ CMS

- ☑ Ensure valid user credentials for Cloud IQ CMS are available.
- ☑ Enable Multi-Factor Authentication (MFA) for secure login.
- ☑ Use a supported browser: Google Chrome, Firefox, or Microsoft Edge.
- ☑ Ensure JavaScript and cookies are enabled.
- ☑ Deactivate content blockers for https://dashboard.tondo-iot.com.
- ☑ Plan defined zones or logical groups for organizing controllers.
- ☑ Decide on pre-determined on/off schedules or dimming profiles based on roadway classification.
- ☑ Determine user roles (administrators, managers, and technicians).
- ☑ Notify Tondo Support if integration with an existing access control platform is needed.

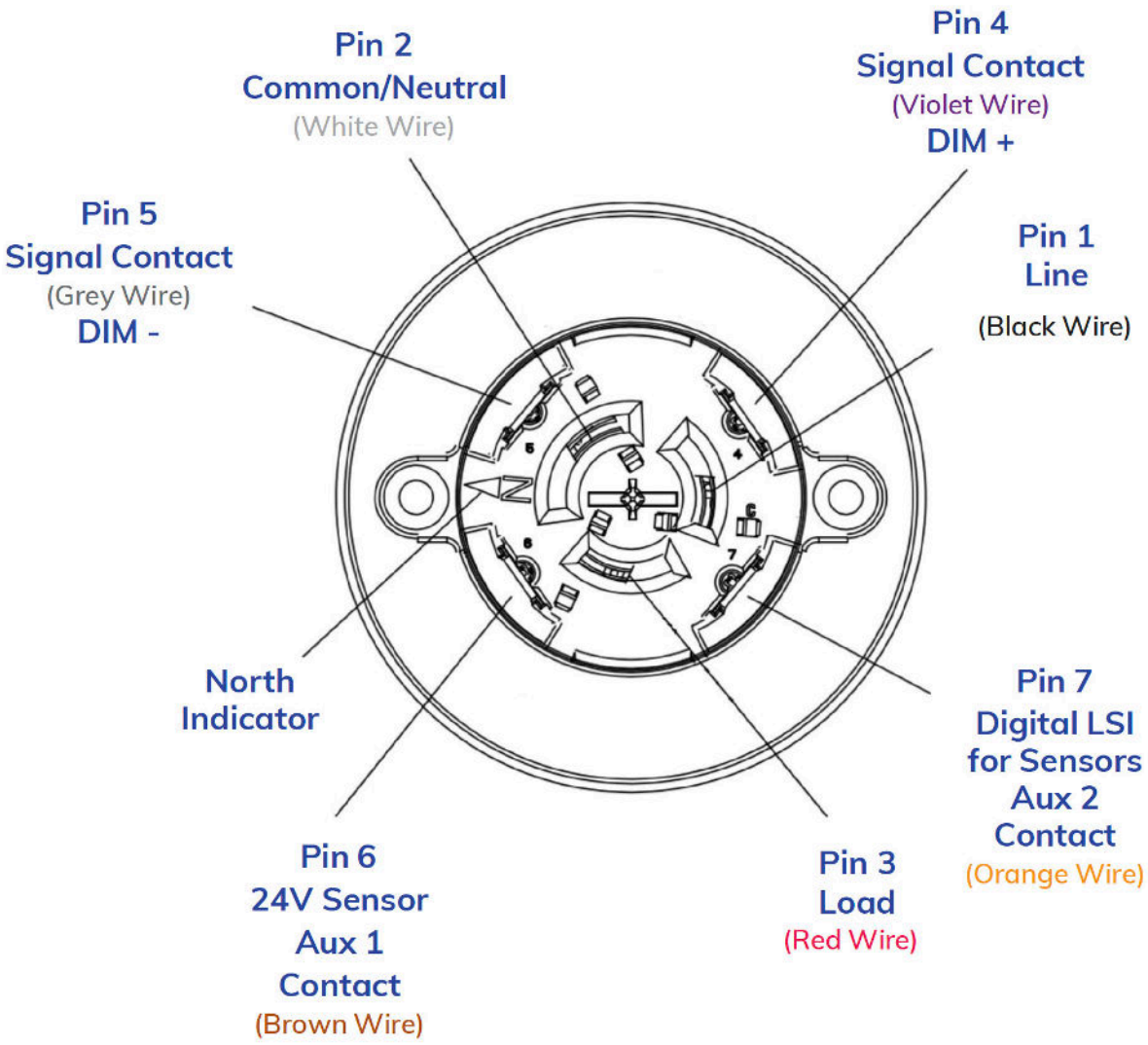
Edge IQ NEMA Socket Connection

This section provides specifications for the correct wiring of ANSI 136.41 and 136.10 NEMA sockets on luminaires that will be used with the Tondo Edge IQ external socketed controller.

The Tondo Edge IQ is compatible with both ANSI C136.41 Dimming Receptacles and ANSI C136.10 Switching Receptacles.

The Edge IQ also supports auto-sensing of:

- ☑ ANSI C137.1 0-10V or 1-10V
- ☑ ANSI C137.4 DALI-2/D4i luminaire drivers
- ☑ Any fixture with a simple mains-controlled driver



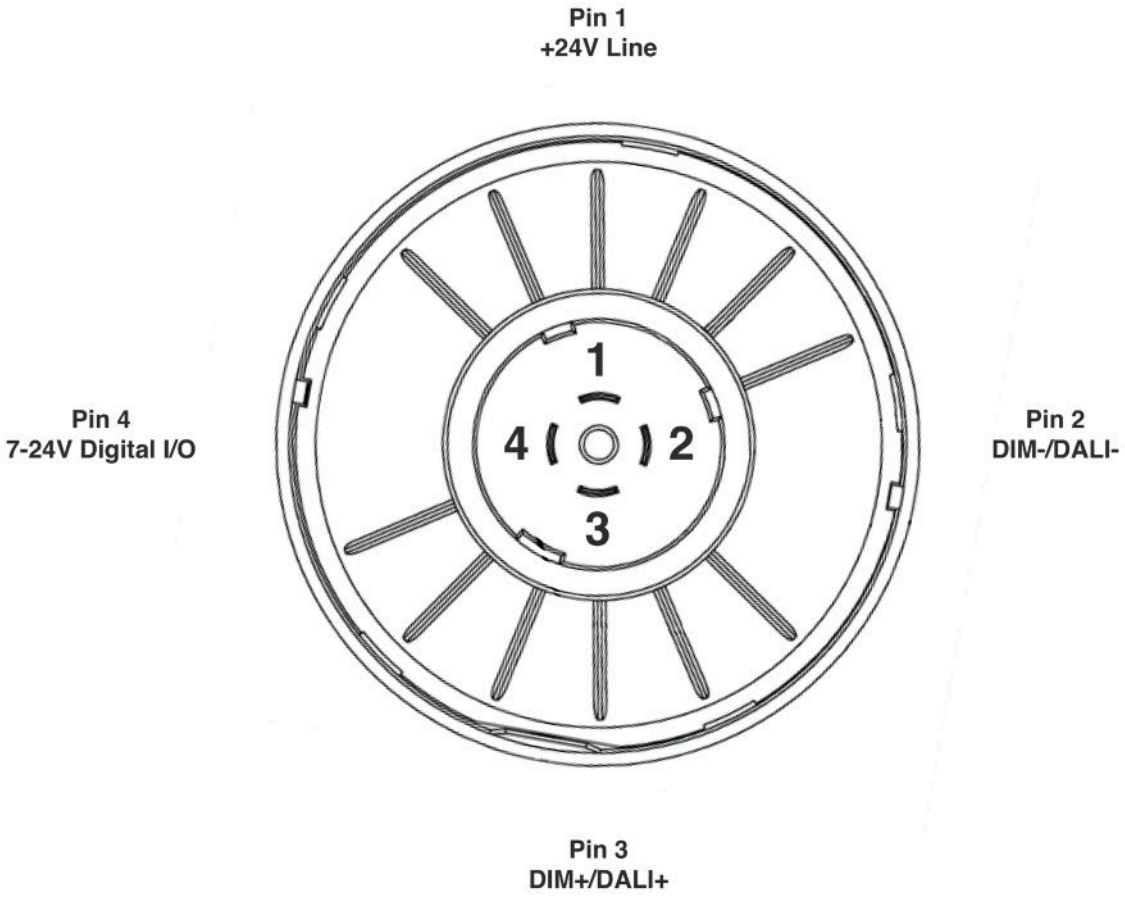
Usage with ANSI C136.41 NEMA Sockets

- When used with an ANSI C136.41 dimming receptacle, the Tondo Edge IQ provides a circuit of DALI, 0-10V control on the primary dimming connections of the NEMA socket (Pins 4 Violet & 5 Grey).
- LINE (Pin 1 Black) and NEUTRAL (Pin 2 White) should be connected to the supply circuit.
- A relay in the Tondo Edge IQ provides switching control of the mains power to LOAD (Pin 3 Red) and can be configured to work in conjunction with the primary dimming circuit or independently.
- DIM+ (Pin 4 Violet) connects to DALI+ or 0-10+ for dimming
- DIM– (Pin 5 Grey) connects to DALI- or 0-10- for dimming
- AUX1 (Pin 6 Brown) is used for direct-wired 24V sensor applications
- AUX 2 (Pin 7 Orange) is used for direct-wired digital line signal input (LSI) sensor applications
- When used with an ANSI C136.10 switching receptacle, LINE (Pin 1 Black) and NEUTRAL (Pin 3 Black) should be connected to the supply circuit. The relay in the Tondo Edge IQ switches mains power to any device attached to LOAD (Pin 3 Red). No dimming functions are enabled for this configuration.
- The Tondo Relay is limited to 10 Amp resistive / 3 Amp inductive load Exceeding this limit can damage the Tondo controller.
- Reversal of Line and Neutral would risk damaging the Tondo controller.
- The customer is responsible for ensuring that their luminaires provide for a Type 4/5 ANSI/UL 1449 surge protective device (SPD) with a minimum protection level of 10kV/10kA between the supply lines and the NEMA socket.
- Note: The Edge IQ controller is designed with keyed tabs so that the controller is always installed in the correct pin configuration.

Note: Installing a Tondo Edge IQ controller on an incorrectly wired ANSI NEMA socket can result in personal injury or death as well as damage or destruction of the tondo and/or luminaire.

Edge IQ Zhaga Socket Connection

This section provides specifications for the correct wiring of Zhaga Book 18 v3 sockets and DALI D4i drivers on luminaires that will be used with the Tondo Edge IQ external socketed controller.



Usage with Zhaga Book 18 v3 Sockets

- When used with a Zhaga Book 18 receptacle on a luminaire with a DALI D4i driver, the Tondo Edge IQ provides DALI D4i dimming control on the primary dimming connections of the Zhaga socket (Pin 3).
- LINE (Pin 1) should be connected to the supply circuit.
- DIM+/DALI+ (Pin 3) connects to DALI+ for dimming
- DIM–/DALI- (Pin 2) connects to DALI- for dimming or shared ground
- Digital I/O (Pin 4) connects to AUX for 7V-24V for DALI D4i data signaling
- The customer is responsible for ensuring that their luminaires provide for a Type 4/5 ANSI/UL 1449 surge protective device (SPD) with a minimum protection level of 10kV/10kA between the supply lines and the Zhaga socket.
- Note that the Zhaga controller is designed with keyed tabs so that the controller is always installed in the correct pin configuration.

Installing the Edge IQ Controller

Installing the Edge IQ Controller

1. Download the Tondo Smart Mobile App

☑ Download and install the Tondo Mobile App on an Android-based smartphone from the Google Play app store by **scanning the QR code in the image below with your smartphone camera.**

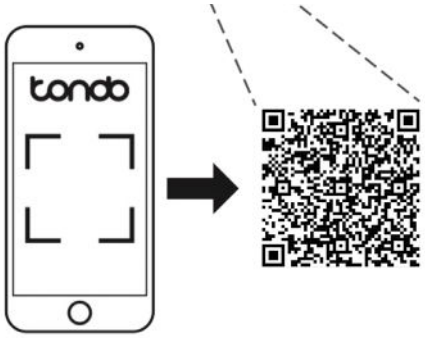


Figure 1: Download Mobile App

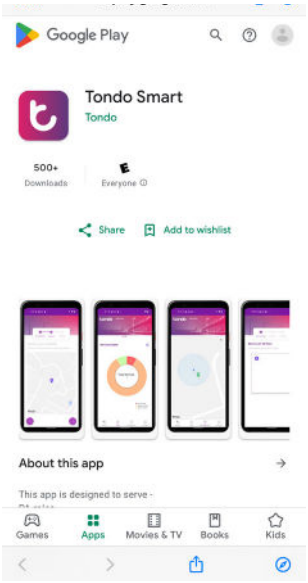
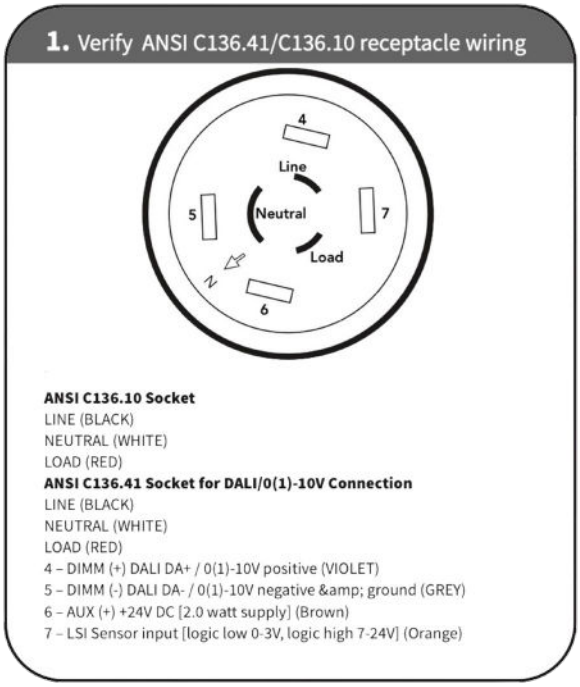


Figure 2: Tondo Mobile App on Google Play Store

2. Preparing the Luminaire

☑ Confirm the luminaire is compatible with Edge IQ controllers (NEMA DALI-2/D4i- and/or 0-10V dimming; Zhaga Book 18 v3/DALI D4i capable).



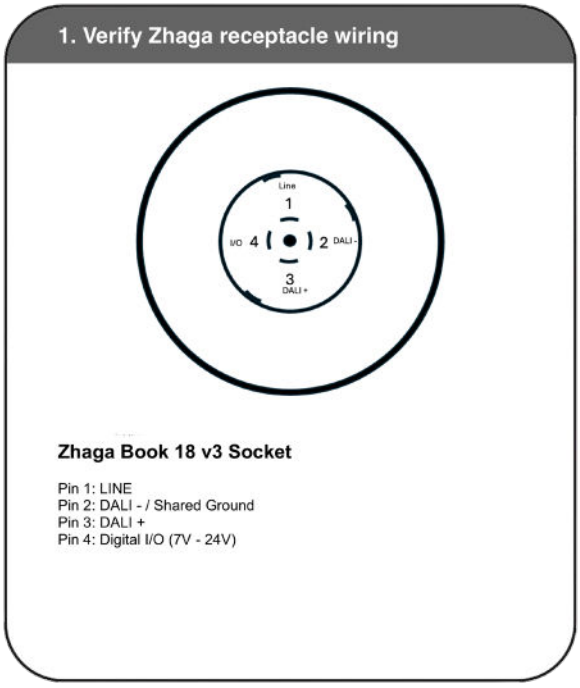


Figure 3: Verify Receptacle Wiring

3. Ensure Luminaire Power is Turned Off Before Installation

☑ Ensure power is turned off at the power source feeding the pole and fixture.

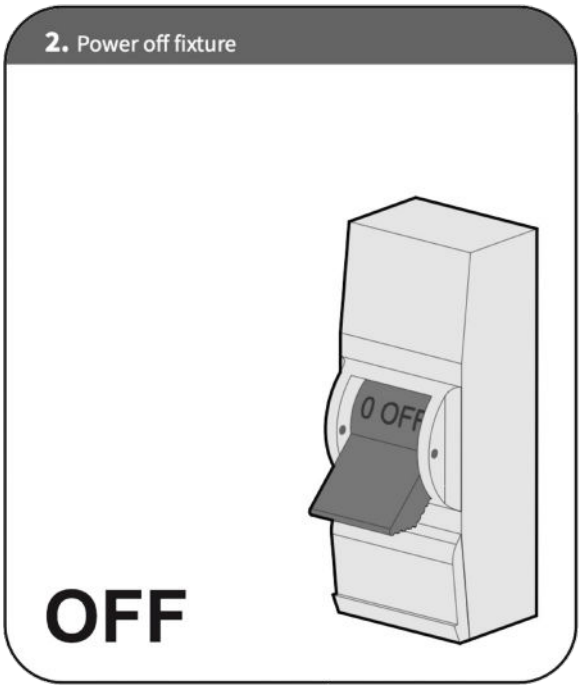


Figure 4: Power Off Fixture

4. Install the Edge IQ Controller

☑ Attach the Edge IQ controller to the luminaire via the ANSI / NEMA or Zhaga socket.

☑ Secure the device, pushing firmly down and fully-rotating clock-wise until the controller is locked in place.

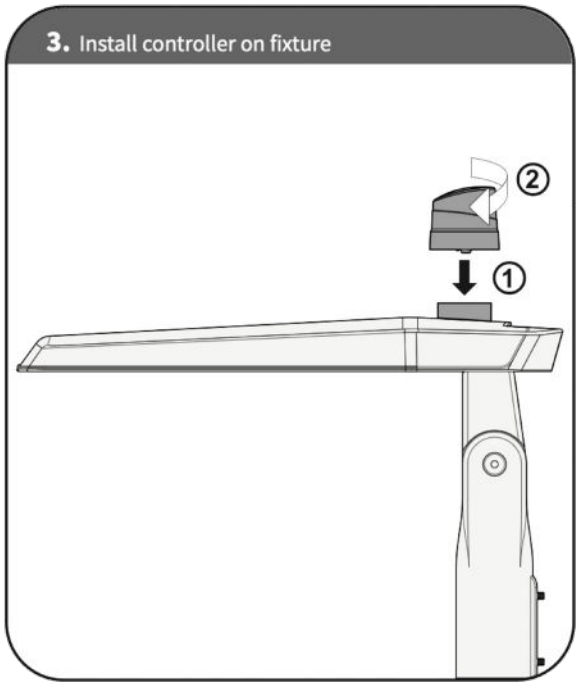


Figure 5: Install Controller on Fixture

5. Login to Mobile App

☑ Login to the Tondo Mobile app with the credentials you have been provided with by Tondo.

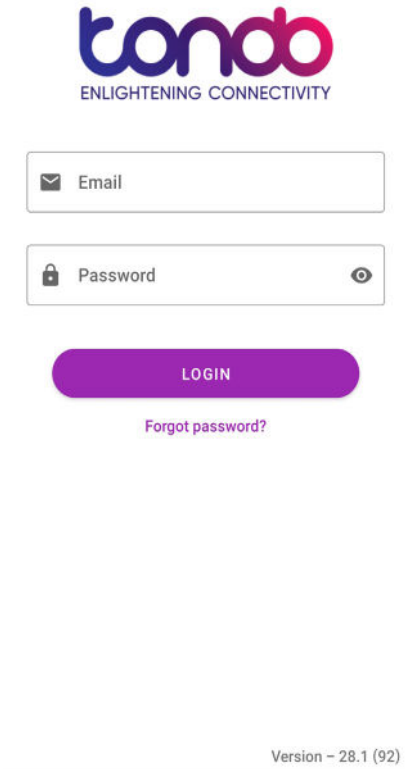


Figure 6: Tondo Mobile - Login

6. Scan the Edge IQ QR Code

☑ Select Scan Devices from the Installer Actions options on the Mobile app home screen.

Note: A unique ID is assigned at manufacturing time along with a security certificate protected by the Hardware Security Module (HSM) in the Edge IQ and coded to each customer's Tondo Project. The Edge IQ will not activate on any other Project or system.

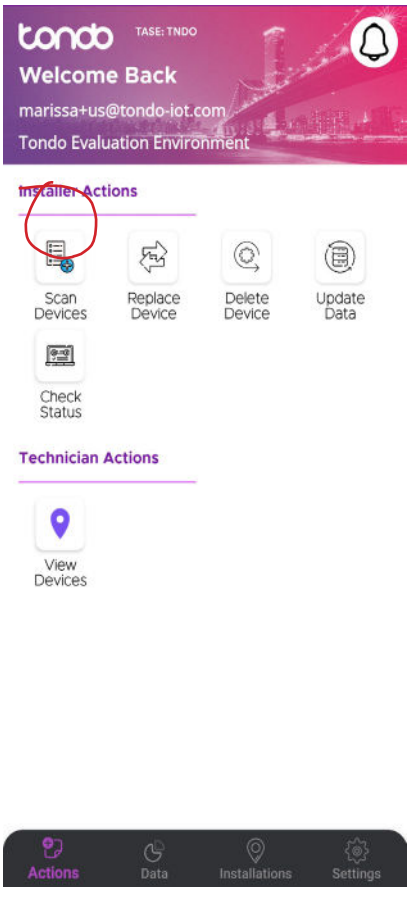


Figure 7: Tondo Mobile - Home

☑ Using the **Scan Device** option, scan the Edge IQ controller's unique identifier located on its label.

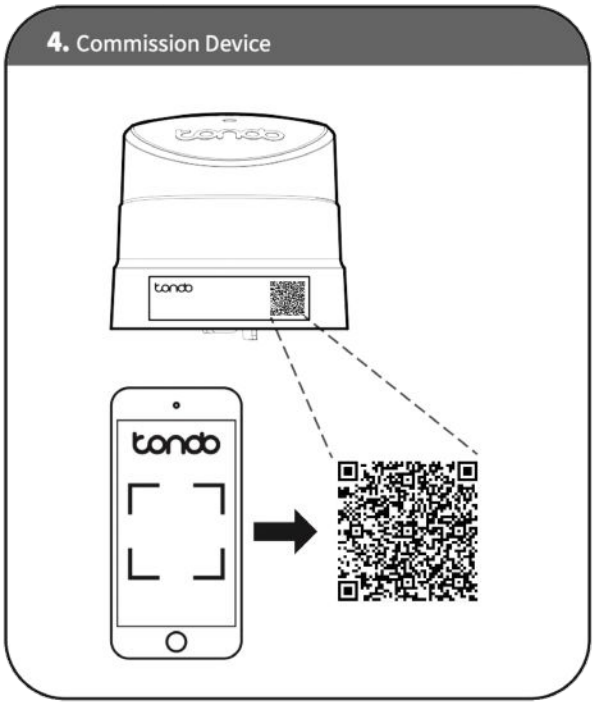


Figure 8: Tondo - Edge IQ Commissioning

☑ You will then receive the message. "Device Installed Successfully" that confirms the controller is commissioned to your Tondo system.

7. Fill In Required Asset Data

☑ If using a DALI-2 or DALI D4i fixture, some data may be pre-filled, and any additional custom fields requested by a customer will appear here for the Installer to add.

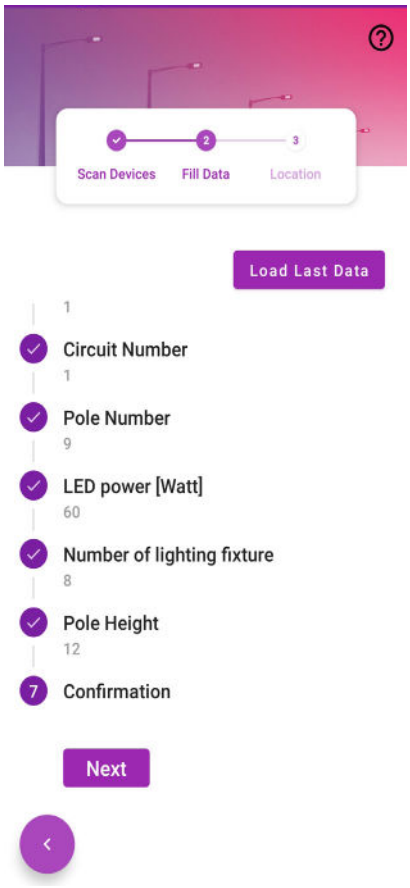


Figure 9: Tondo Mobile - Asset Data

8. Update Location Precision

GPS technologies are only accurate to within ±3 meters. Tondo can improve on that.

☑ The Installer - while next to the pole - will be prompted to update the position of the Edge IQ controller by moving the map pin to improve the position. Otherwise an Installer can accept the default GPS position.

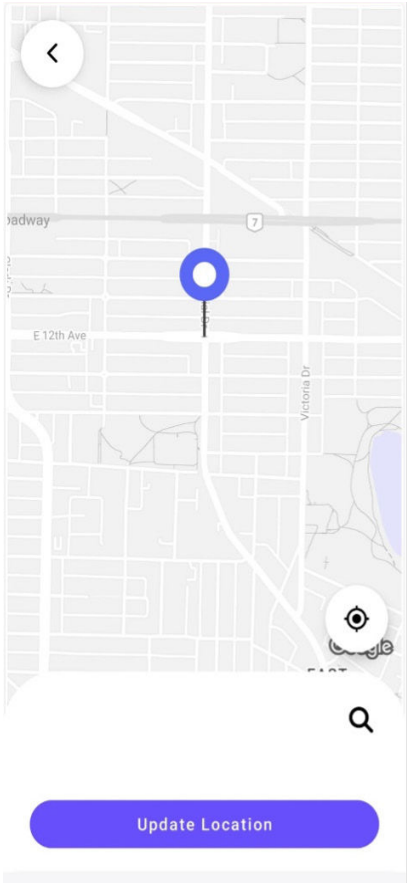


Figure 10: Tondo Mobile - Update Location

9. Installation Verified

☑ Ensure the controller is connected to an LTE network, and check the Tondo Mobile app for a confirmation message indicating successful installation.

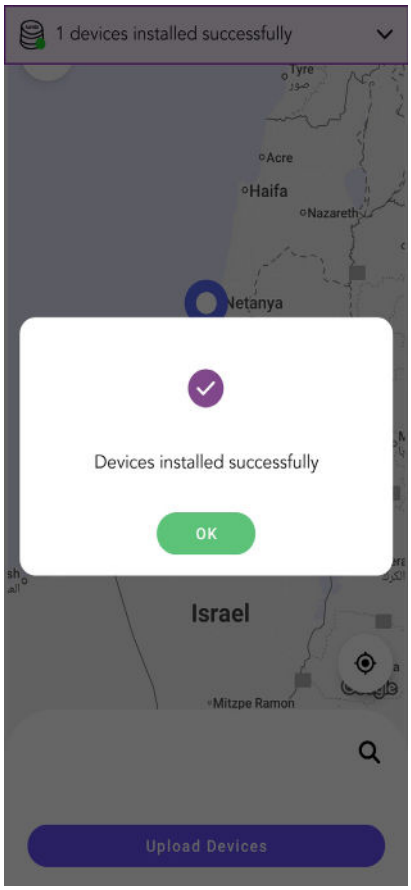


Figure 11: Tondo Mobile - Edge IQ Installed

10. Power On Fixture

☑ Turn power back on at the power source feeding the pole and fixture.

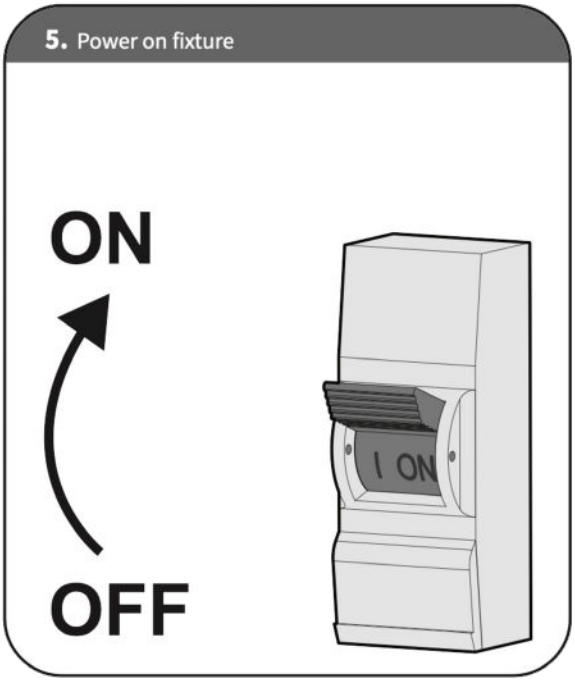


Figure 12: Power On Fixture

11. Activation Verified

☑ View Mobile app until notification of successful installation is received.

Figure 13: Verify Activation

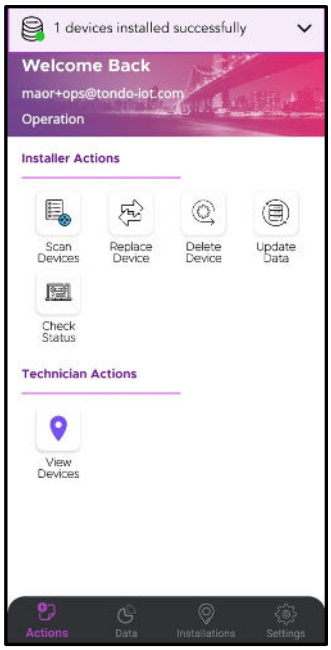


Figure 14: Activation Message

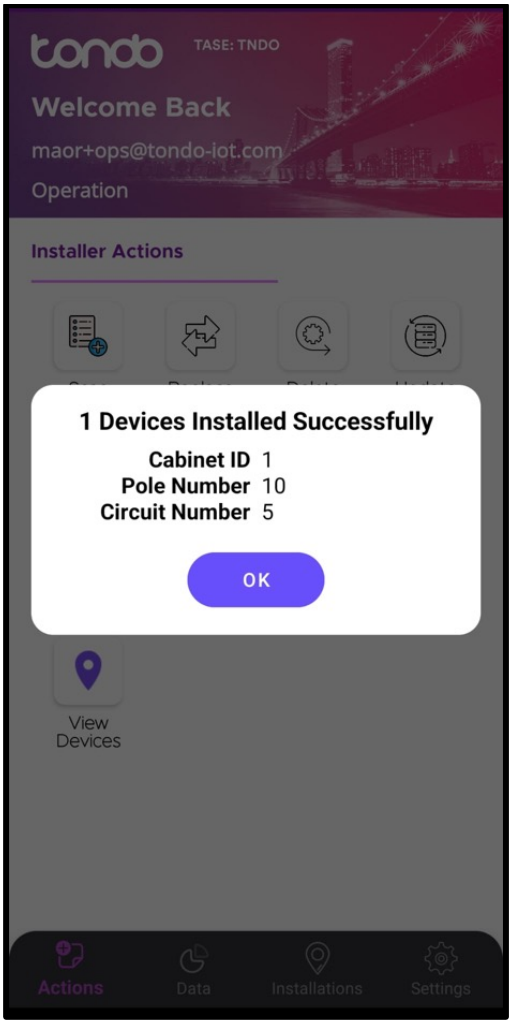


Figure 15: Device Installation Completed

12. Additional Functionality

The Tondo Mobile app offers functionality grouped by Installers and Technicians.

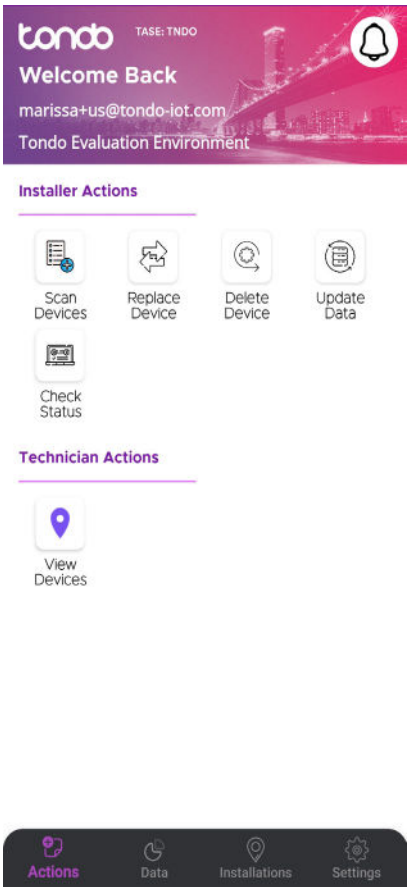


Figure 16: Tondo Mobile - Home

- An **Installer** is responsible for deploying new or replacing existing devices. An Installer will physically install the device, which will self-activate.
- A **Technician** is a maintenance technician responsible for troubleshooting in-field.

Installers

For Edge IQ controllers and other Tondo devices they have been granted access to, **Installers** can:

- **Scan Device** to prepare a new Edge IQ controller for installation
- **Replace Device** to replace an existing Edge IQ controller or other device
- **Delete Device** to de-commission an Edge IQ controller or other device
- **Update Data** in an Edge IQ controller or other device.
- **Check Status** of an installed and activated Edge IQ controller

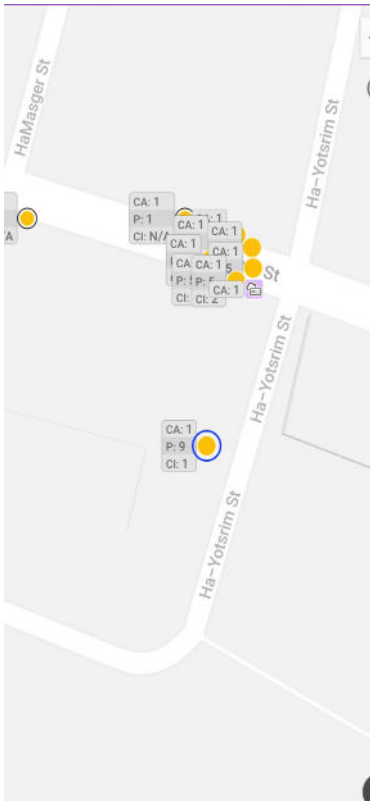


Figure 17: Tondo Mobile - Map View

In addition to the capabilities of an Installer, a **Technician** can use the View Devices option for Edge IQ controllers and devices they have been granted access to, and:

- **View Incidents** (Alerts and Events) on a device

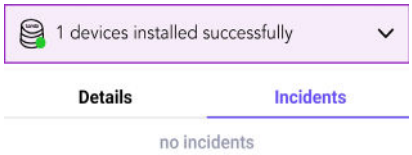


Figure 18: Tondo Mobile - View Incidents

Cloud IQ Operations & Management

Lighting and Sensor Management with Cloud IQ

Objective

This Guide is divided into two key sections to streamline your evaluation process.

This section focuses on the hands-on portion Evaluators will use, while the following section, “Cabinet IQ and Cloud IQ Supplemental Features”, covers additional capabilities.

1. Logging In

Access the Cloud IQ platform at **https://dashboard.tondo-iot.com** using the credentials provided by Tondo.

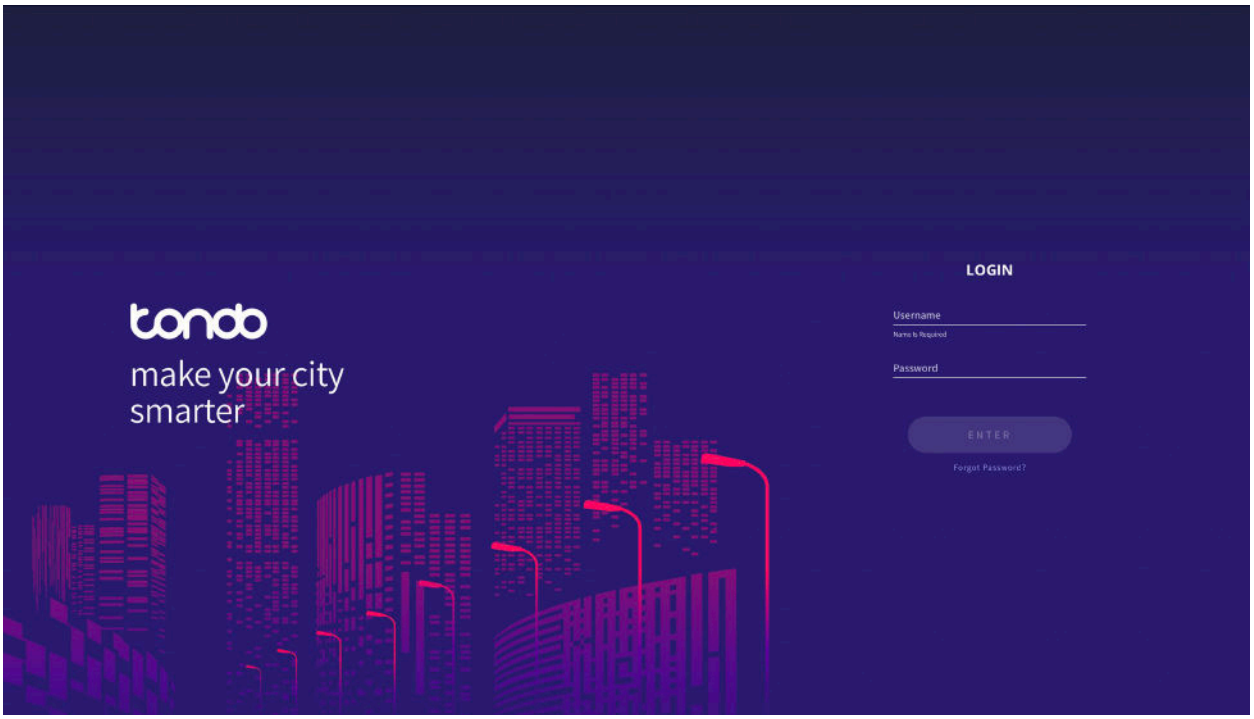


Figure 19: Dashboard Login

For additional access security, Tondo requires multi-factor authentication (MFA) with MFA codes sent to the user's smartphone via WhatsApp end-to-end encryption.

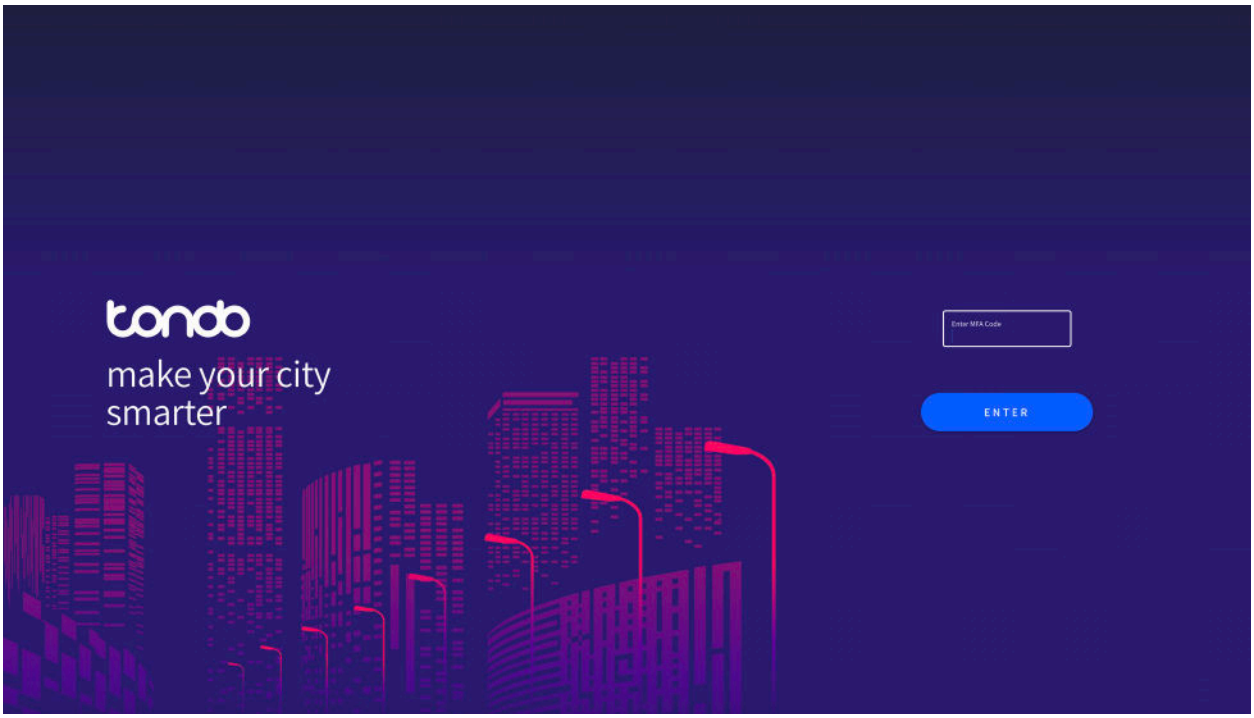


Figure 20: Dashboard Login - MFA

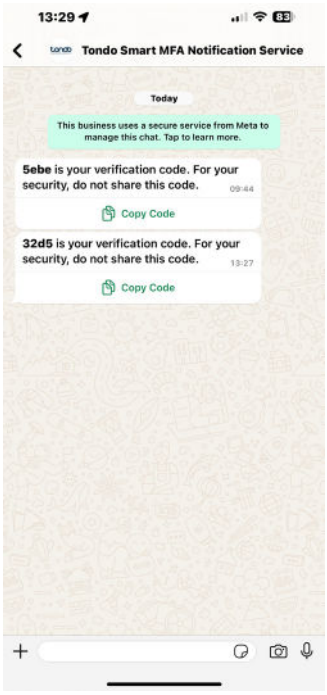


Figure 21: Dashboard Login - MFA Code Whatsapp

1.1 Creating User Profile

When logging in for the first time, you will be prompted to update your user profile information.

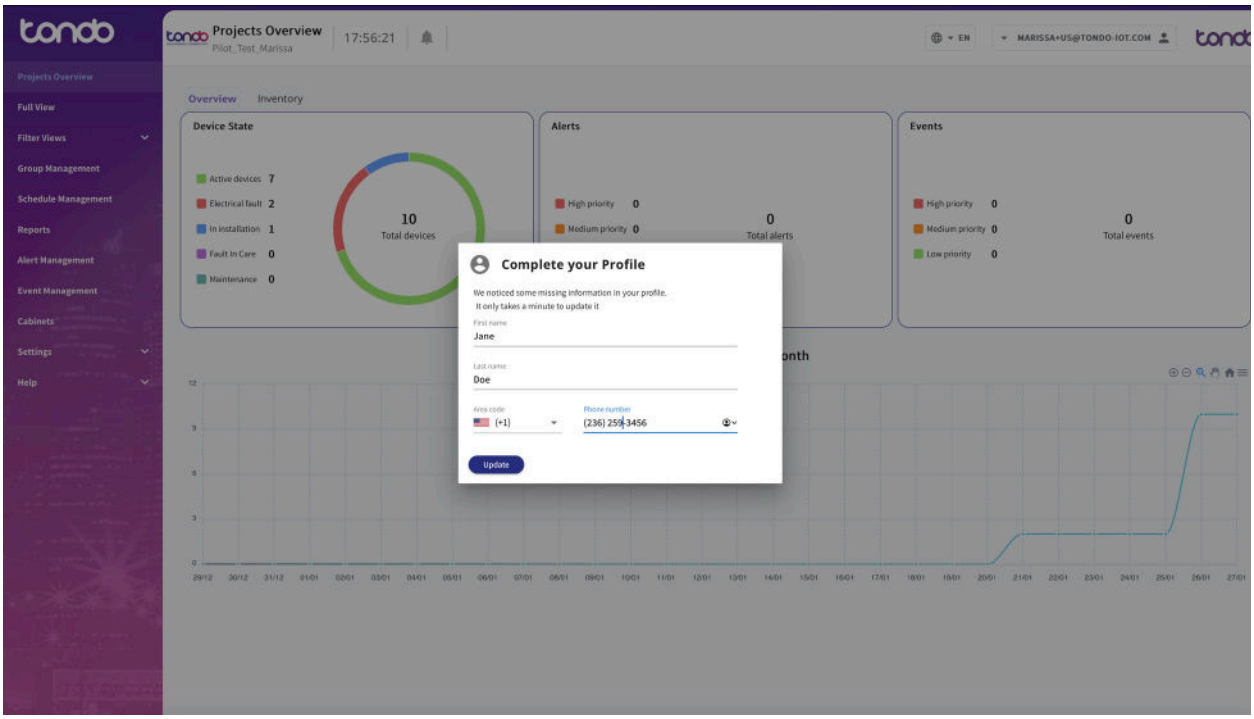


Figure 22: Login - Create User Profile

2. Project View

If you have more than one Project, or a larger Project is segmented into smaller Projects, you will be navigated automatically to Choose A Project after logging in. If only one Project has been created for you, this view will be skipped.

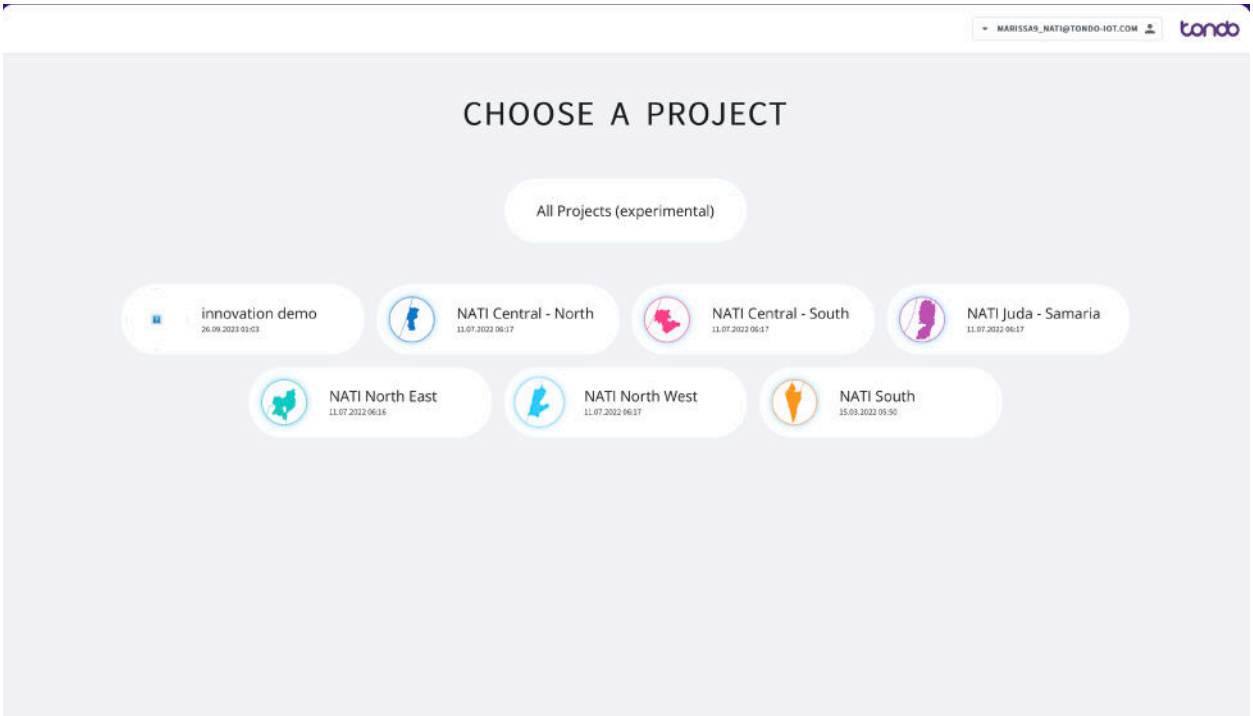


Figure 23: Project Selection

Note: All network, cybersecurity, and communications settings are fully managed by Tondo, including cellular data plans.

These settings are not available on Cloud IQ or accessible by customers for security reasons and to relieve customers of the burden of managing the network platform.

2.1 User Guide and Online Help

Tondo provides detailed in-app documentation. The documentation can be accessed in the left-hand panel of the CMS view that include text, images, and video guides.

2.2 Project Summary Views

The Project Overview view provides a high-level overview of the system's status.

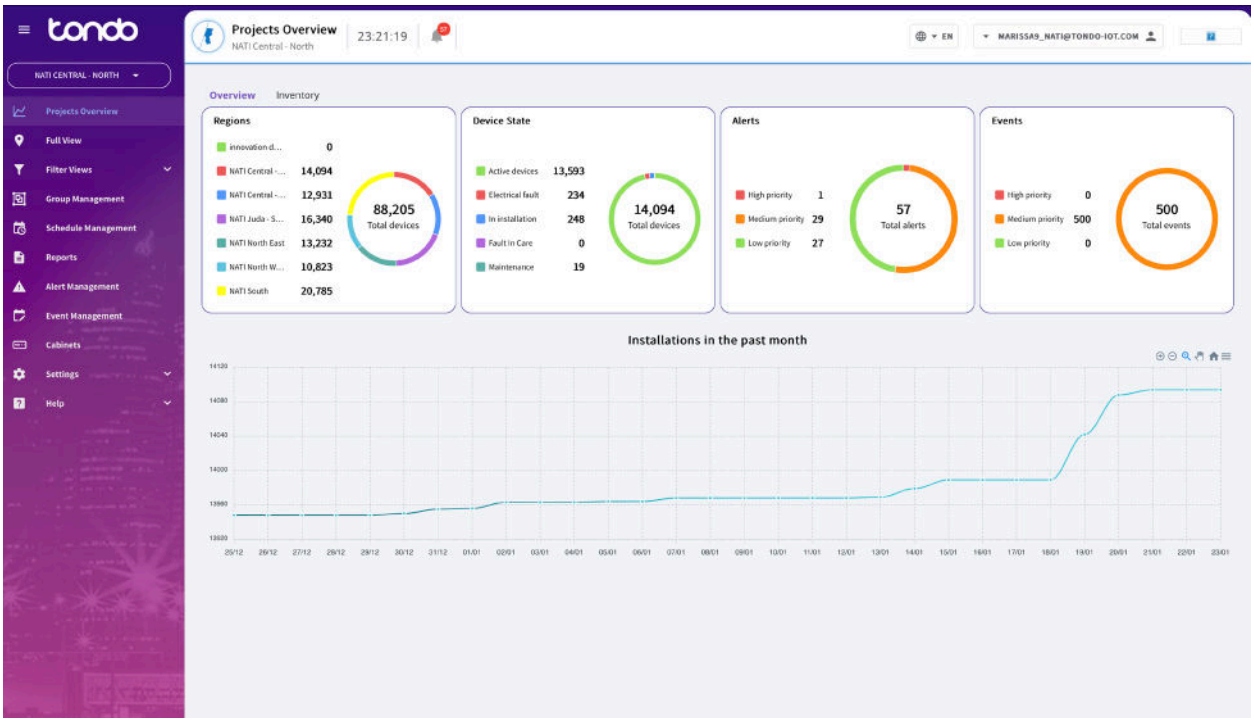


Figure 24: Project Overview

The Project Overview includes:

- Each Project and its Inventory
- Your current Project segmented by Device State
- Alerts by Priority level and Number
- Events by Priority level and Number

Benefit: The Dashboard offers a centralized view of system health and performance, enabling efficient operational control and decision-making.

Selecting the Inventory tab (*see inset*) adjacent to the default selected Overview tab will show an Inventory summary view of your Project.

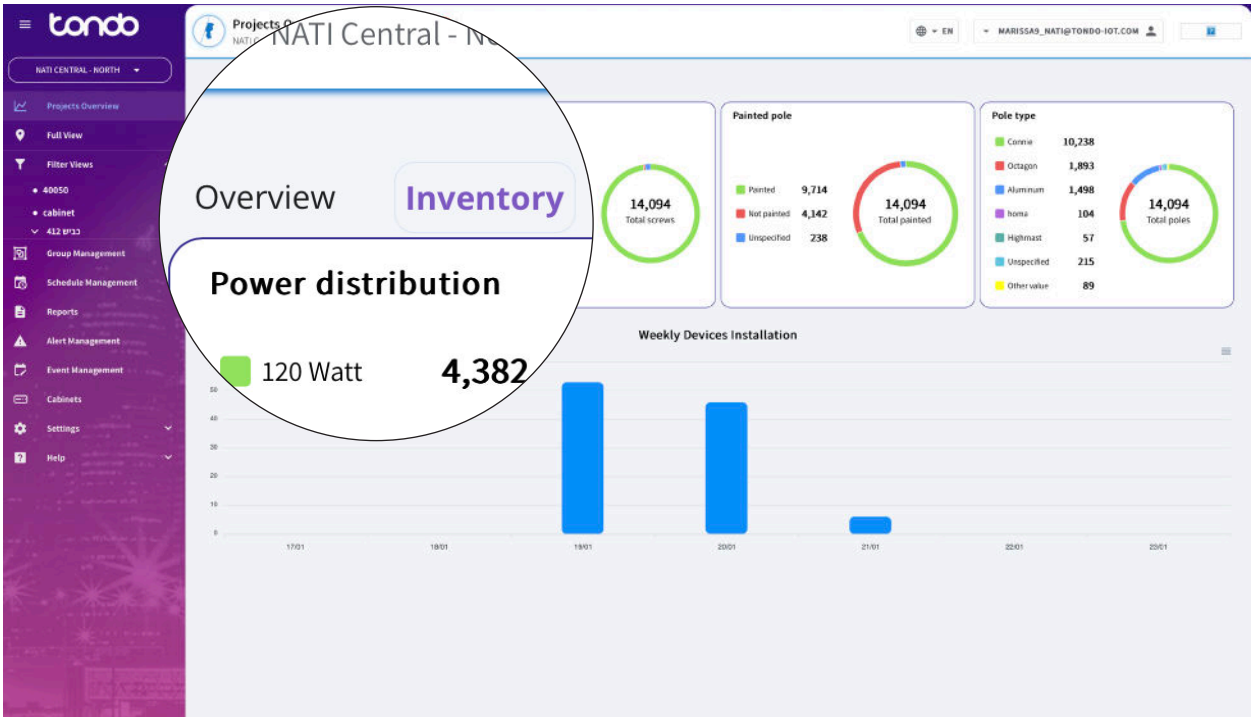


Figure 25: Projects Inventory

3. Full (Map) View

The Full View is a map view of all of your Tondo-connected assets, including the Edge IQ controller. If you have other Tondo products such as Cabinet IQ, sensors, SCADA (Supervisory Control and Data Acquisition) controls, smart meters, and other devices, they will also appear here.

Selecting the Legend icon (*see inset*) will describe the labels for the icons located on the map that represent your connected assets.

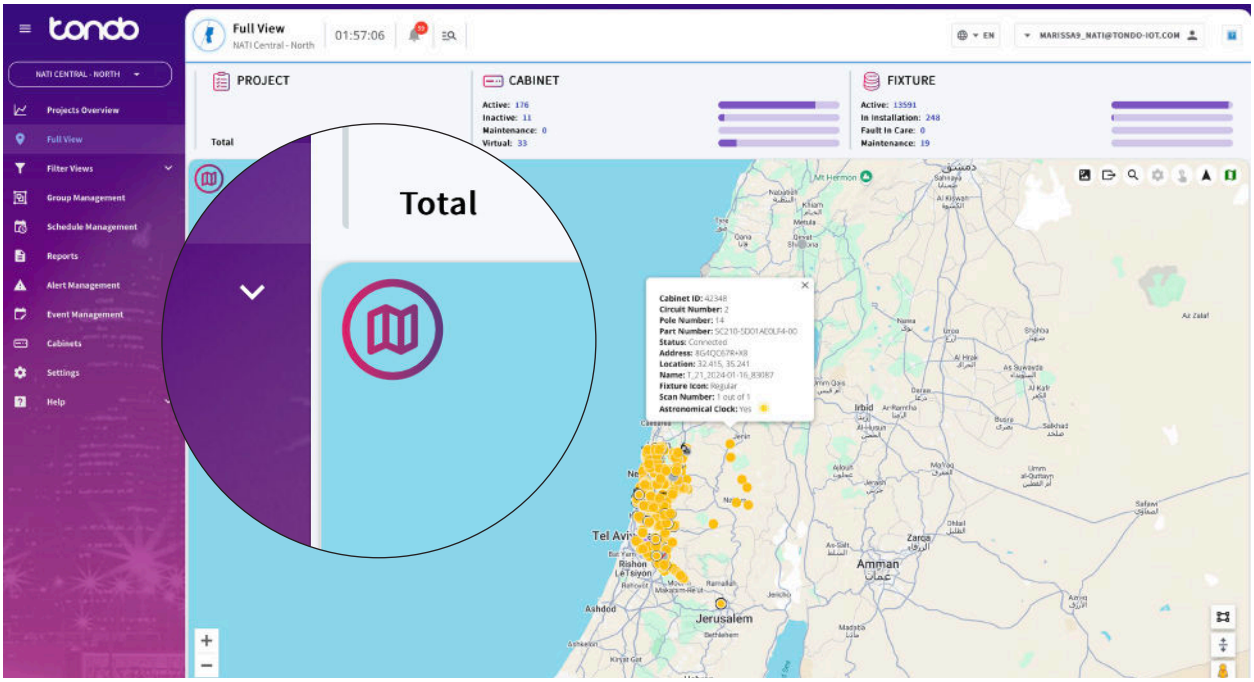


Figure 26: Full View Map View

- Hovering over an asset icon on the map will show a tooltip summarizing the asset details according to the asset type.
- Standard Google Maps functions apply to the map view.

3.1 Asset Icon Legend

In the Full View (Map View), the legend for the standard icons is shown below:

Regular Fixture


On/Off


Partial Communication


Lack of Voltage


Electrical Fault


Burnt Lamp


In Installation


Maintenance


Fault In Care

Regular Cabinet


On/Off


Fault


In Installation

Security Fixture


On/Off


Partial Communication


Lack of Voltage


Electrical Fault


Burnt Lamp

Underground Fixture


On/Off


Partial Communication


Lack of Voltage


Electrical Fault


Burnt Lamp

Highmast Fixture


On/Off


Partial Communication


Lack of Voltage


Electrical Fault


Burnt Lamp

3.2 Fixture Details

Double-clicking an asset icon opens an asset Detail view.

It is important to note that all Tondo displays are context-sensitive. This means that in any view, only the relevant and available information is displayed or made available within a search.

For example, if you select a Fixture (such as that below), the information that appears in the detail is specific to Fixtures and their controllers.

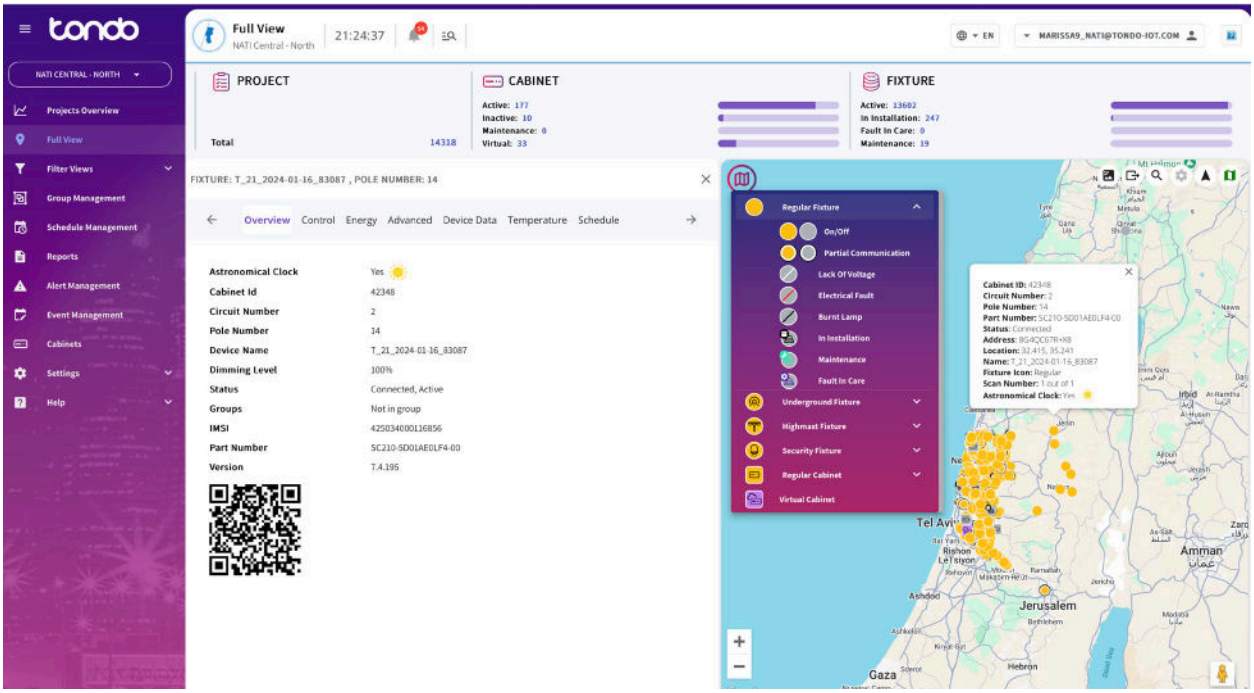


Figure 27: Full View - Fixture Detail Overview

If you select a Motion Sensor, different information detail relevant to Sensors would appear.

- There are seven tabs within the Fixture Detail view: *Overview, Control, Energy, Advanced, Device Data, Temperature, and Schedule*
- The default fixture Overview tab above shows much of the same information as in the tooltip, as well as Dimming Level, Group Membership, the IMSI cellular ID number, Part Number, firmware Version, and for Tondo controllers, a QR code that is used by Tondo Support for technical support purposes.

3.3 Fixture Dimming Status and Manual Override

Selecting the Control tab adjacent to the default Overview tab displays the current state of dimming control. You may also over-ride any dimming profile for the selected fixture which will remain until the next scheduled event for that fixture is applied.

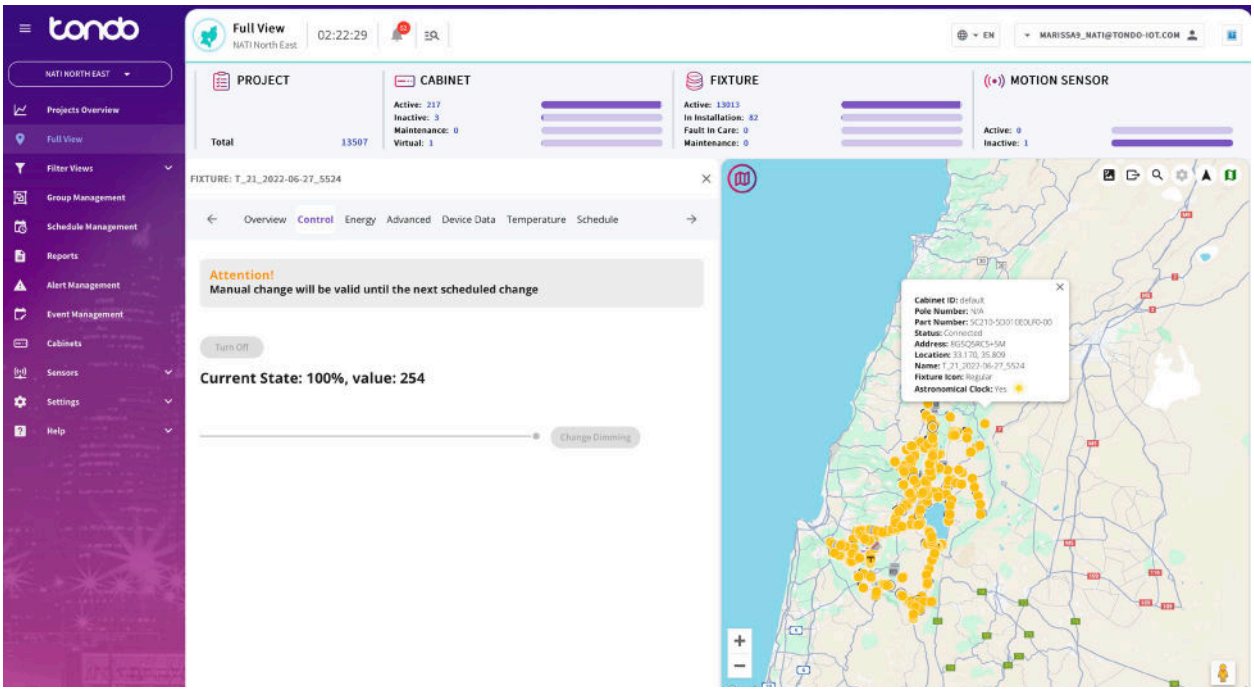


Figure 28: Full View - Manual Fixture Dimming

3.4 Fixture Energy Status Detail

Selecting the Energy tab adjacent to the previous Control tab displays Energy information for the fixture, with Power Consumption as the default display.

There are four buttons that will display information for the fixture: Power Consumption, Voltage, Current, or Power Factor.

3.4.1 Energy Status - Power Consumption

The default Power Consumption display can be used to easily identify power consumption patterns by either scrolling through the Period list, or scaling the adjacent Chart view to show a visual display of energy consumption patterns.

- For example, in the Chart and Power Consumption view shown below, you can see that there are two dates, January 21 and 25, where the energy did not go to zero as normally expected. This may be investigated further to discover whether there was an energy theft or manual-override issue as the cause.

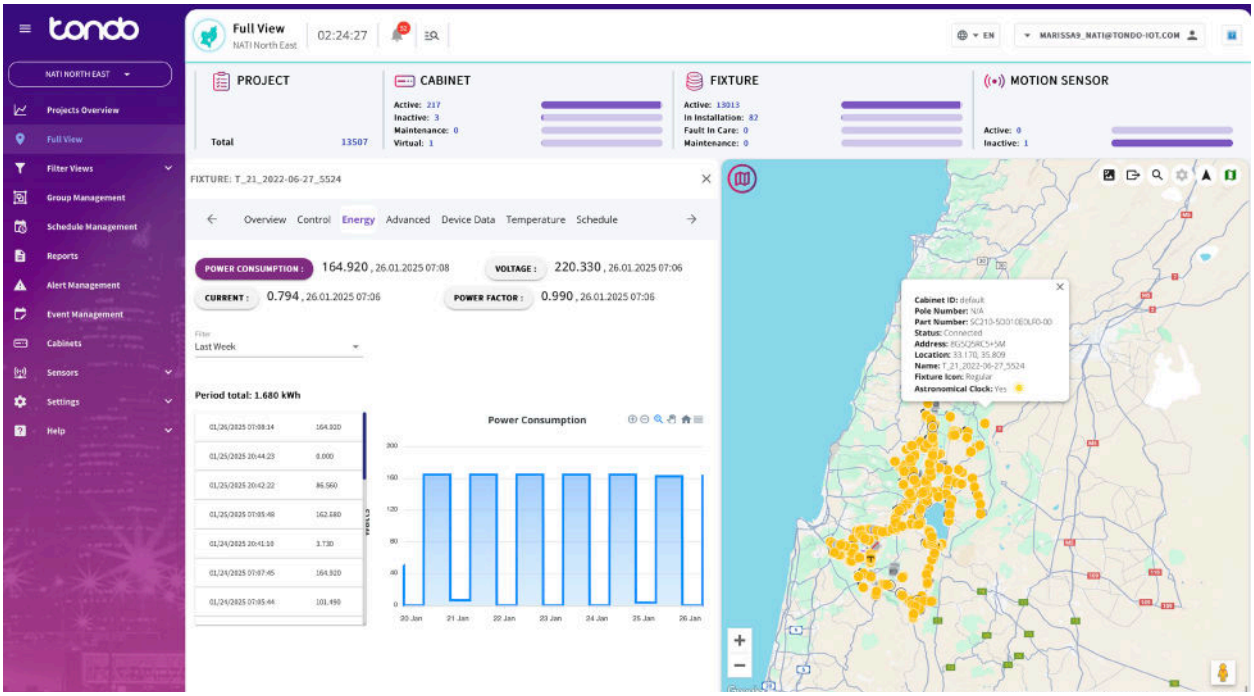


Figure 29: Full View - Fixture Energy - Power Consumption

3.3.2 Energy Status - Voltage

Selecting the Voltage button adjacent to Power Consumption, the Voltage history is displayed as below.

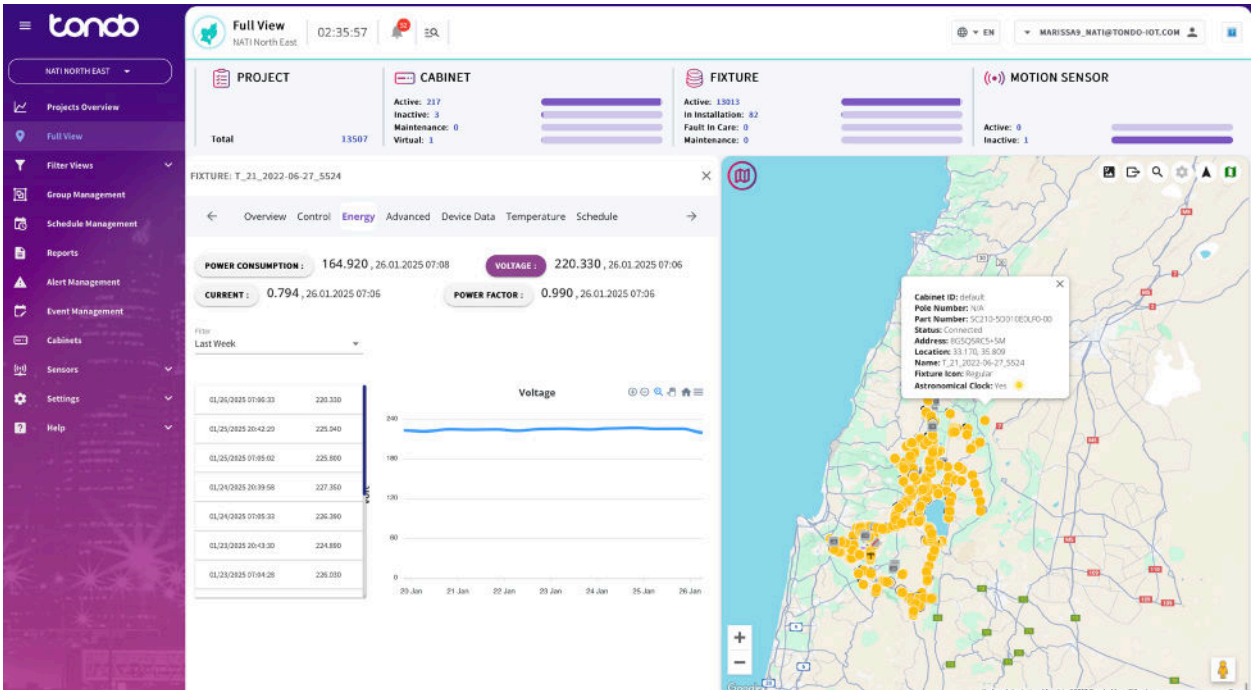


Figure 30: Full View - Fixture Energy - Voltage

As with the Power Consumption display, the Voltage display shows a list view and visual chart view for a selected period.

The Voltage display can be used to diagnose over-voltage or under-voltage events that indicate power quality issues. Although modern luminaires are designed to compensate for these conditions, their surge suppression circuits have a limited lifecycle, and if not corrected, over-voltage conditions can shorten the lifecycle of the luminaire's driver and lamp components.

3.4.2 Energy Status - Current

Selecting the Current button below the Power Consumption button will display the current in both a list and chart view for a selected period.

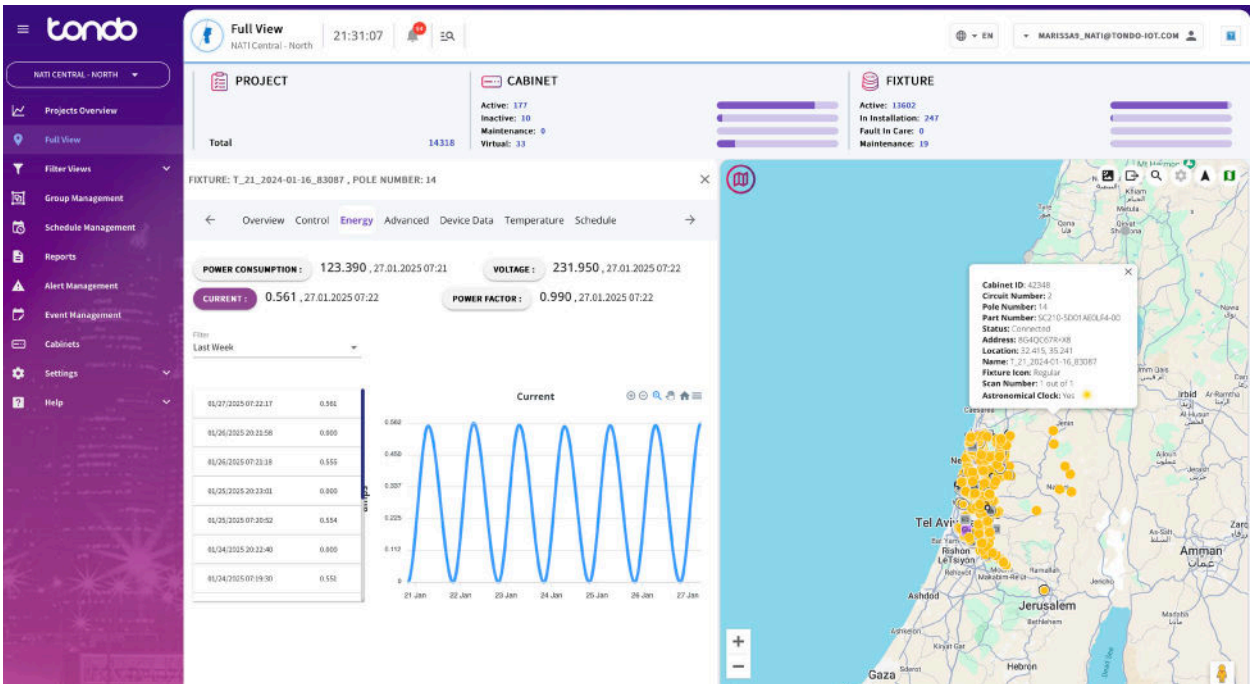


Figure 31: Full View - Fixture Energy - Current

By correlating current data with operational schedules (e.g., dusk-to-dawn lighting), unusual patterns could indicate fixtures operating outside of their schedule, such as stuck-on lights. Patterns in current draw can help schedule preventative maintenance before a component fails, minimizing downtime and reducing repair costs.

3.4.3 Energy Status - Power Factor

Selecting the Power Factor button adjacent to the Current button will display the Power Factor for the fixture for the selected period.

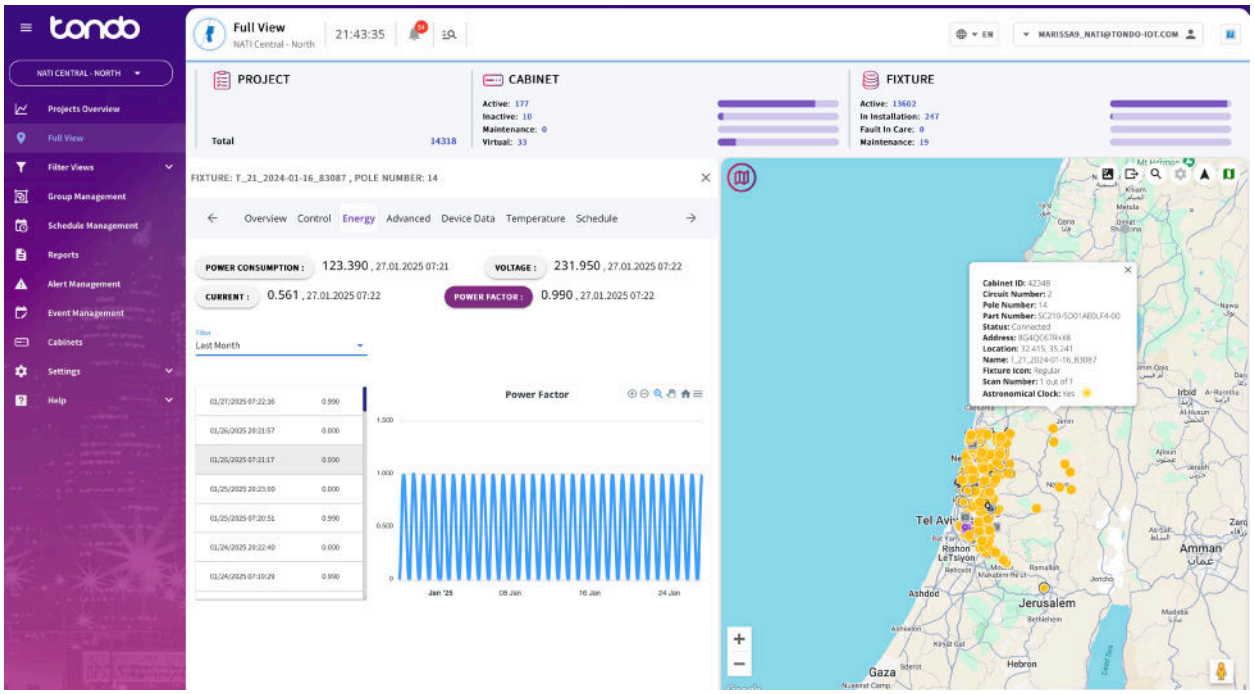


Figure 32: Full View - Fixture Energy - Power Factor

The Power Factor represents the efficiency of the luminaire and its use of power for lighting. For most utility rate plans, the Power Factor is important to monitor for contractual compliance. Most utility rate plans contain a requirement for all fixtures to stay above a specified Power Factor threshold, and contain a financial penalty for dropping below that threshold. For LED lighting, we expect an efficiency of 99% or Power Factor of 0.99, with utility penalties triggered at 90% or lower.

3.5 Advanced Technical Data

Selecting the Advanced tab adjacent to the Energy tab displays technical information about the Tondo Edge IQ controller.

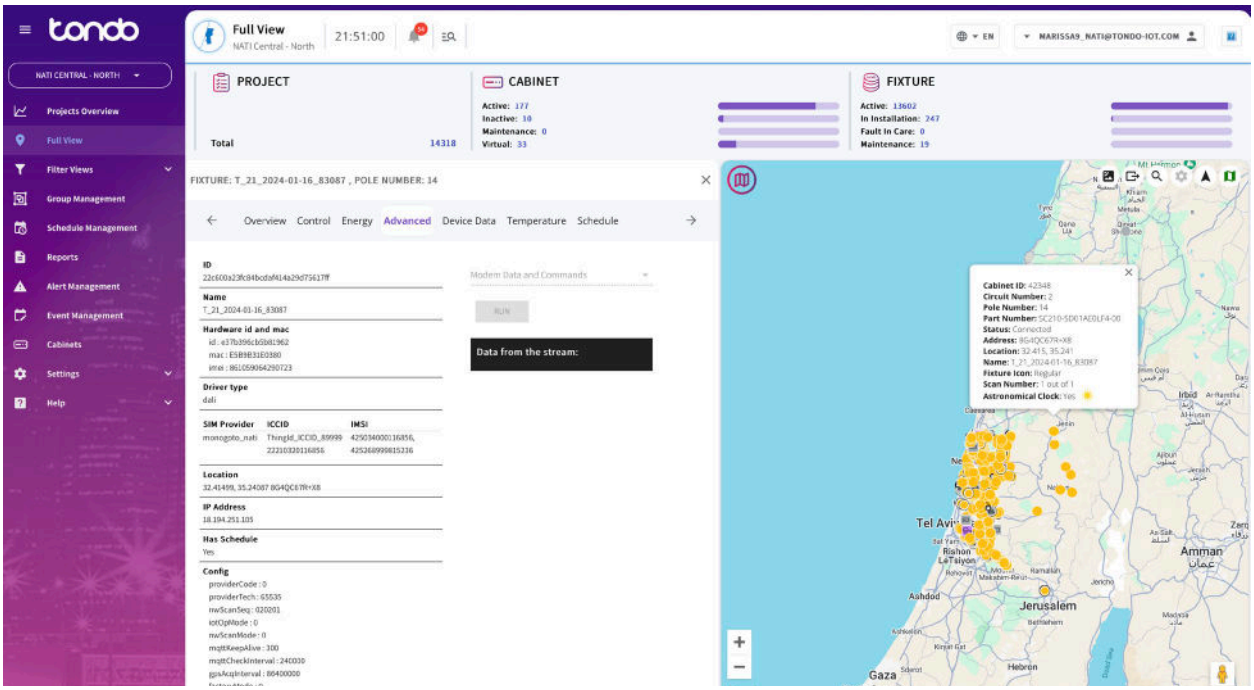


Figure 33: Full View - Fixture Advanced Information

This information is used for technical support call resolution. Tondo manages the technologies and network for its customers to avoid the burden of managing technology and ensure customers remain focused on their operational responsibilities.

In general, a Tondo customer does not need to concern themselves about this information.

3.6 Device Data

Selecting the Device Data tab adjacent to the Advanced tab displays asset information that is either collected automatically by the Tondo Edge IQ controller, or added by a field installer or maintenance personnel using the Tondo Mobile app, or that has been added manually by a Tondo Cloud IQ user.

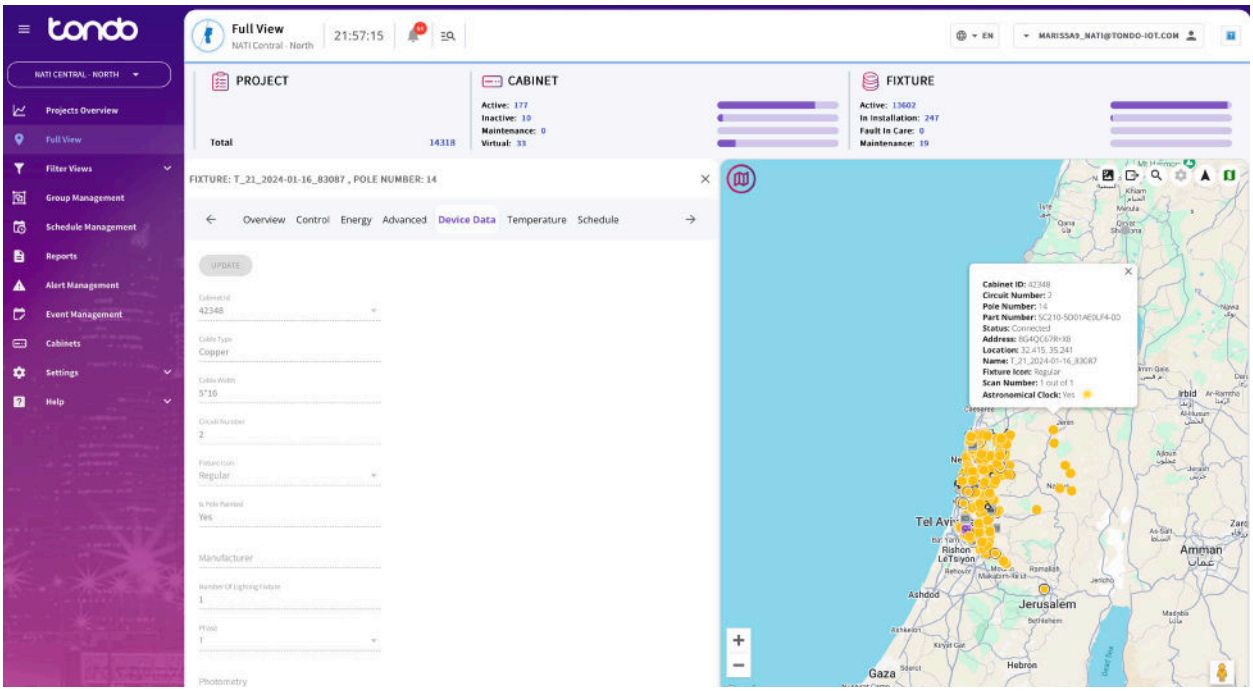


Figure 34: Full View - Fixture Device Data

The fields may be customizable according to a customer's needs with any number of custom fields and exposed to either the Mobile app, Cloud IQ, or both.

This information can be integrated into GIS and asset management applications used by a customer to ensure that GIS and asset data is always current. Many municipalities integrate GIS data into their OpenData portals for governmental transparency initiatives. Data from Tondo's Cloud IQ can also be integrated with maintenance dispatch applications and streetlight status information on city websites to minimize 311 calls and eliminate the necessity of streetlight outage reports.

3.7 Operating Temperature

Selecting the Temperature tab adjacent to the Device Data tab displays the operating (not ambient) temperature inside the Tondo Edge

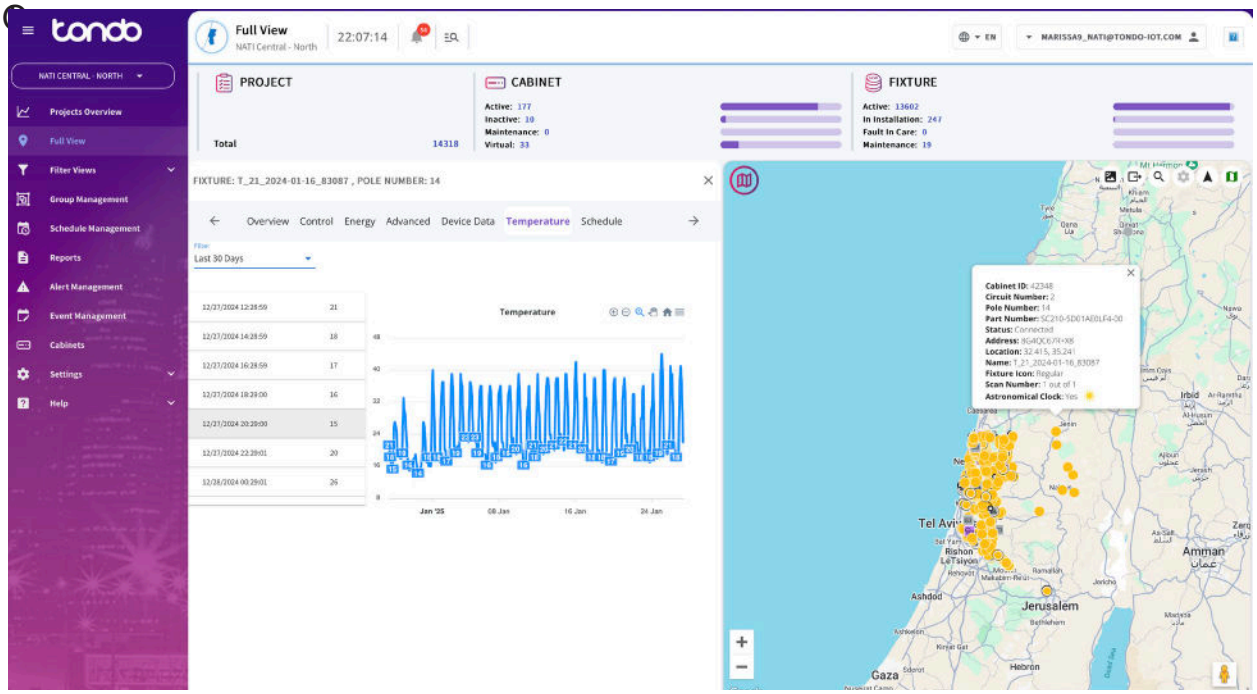


Figure 35: Full View - Fixture Temperature

This temperature reading can be used to diagnose failures that may be related to excessive operating temperature of the Edge IQ controller. If the Edge IQ is operating within its rated operating temperature, it can assist with diagnosing operating anomalies at the fixture.

Tondo's Edge IQ is deployed on hundreds of thousands of fixtures in extremely high temperature desert environments and in environments well below freezing levels.

3.8 Dimming Schedule Status

Selecting the Schedule tab adjacent to the Temperature tab displays the Edge IQ fixture lighting schedule status.

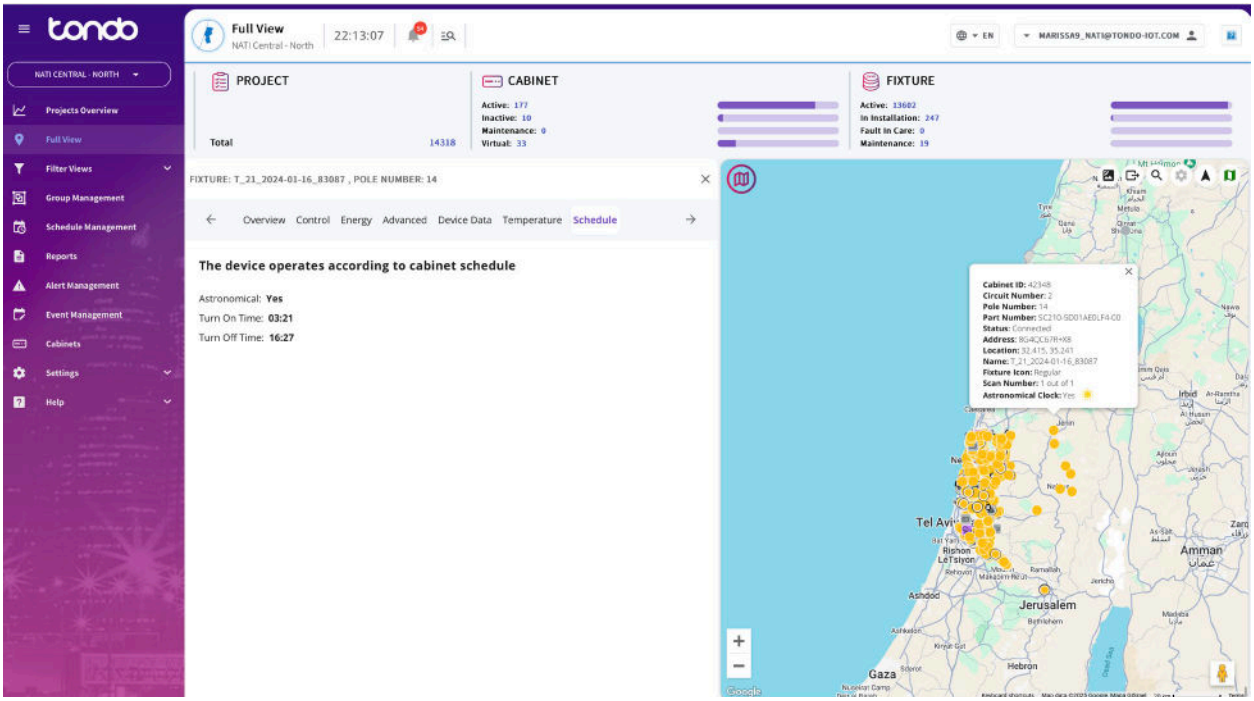


Figure 36: Full View - Fixture Dimming Schedule

In the illustration above, we see that this fixture is controlled via a custom schedule that the customer has specified and that schedule is controlled by Tondo's patented astronomical clock technology that provides high-accuracy high-availability timekeeping and control.

4. Filtered Views

Custom filtered views that a customer may use regularly may be created or accessed by selecting Filtered Views from the sidebar.

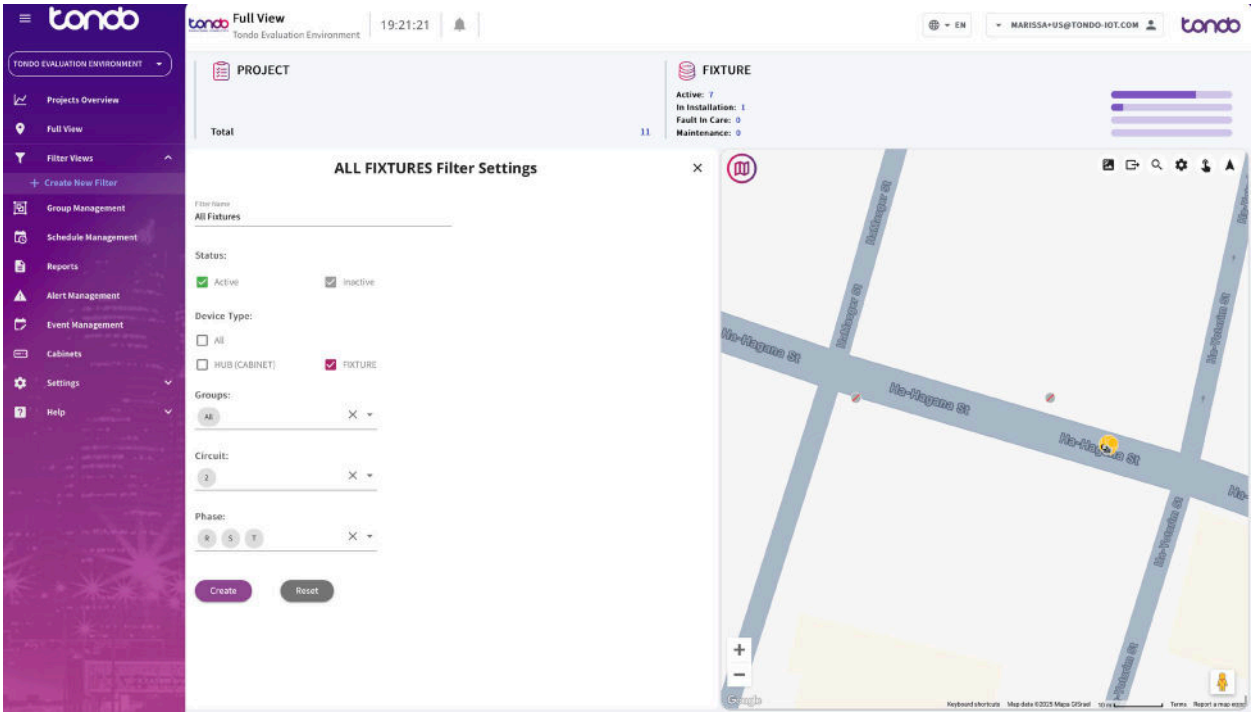


Figure 37: Filter View - Create Filter

In the example above, we are creating a filter to view All Fixtures and excluding Tondo Cloud IQ lighting cabinet controls to focus on fixture-related tasks.

We can create focused views for Devices, Status, Group Membership, Circuits, and Phases, and other criteria a customer may require.

In the illustration (see inset) below, we can see how a series of custom Filtered Views can help us organize our lighting and control asset views according to our desired workflow.

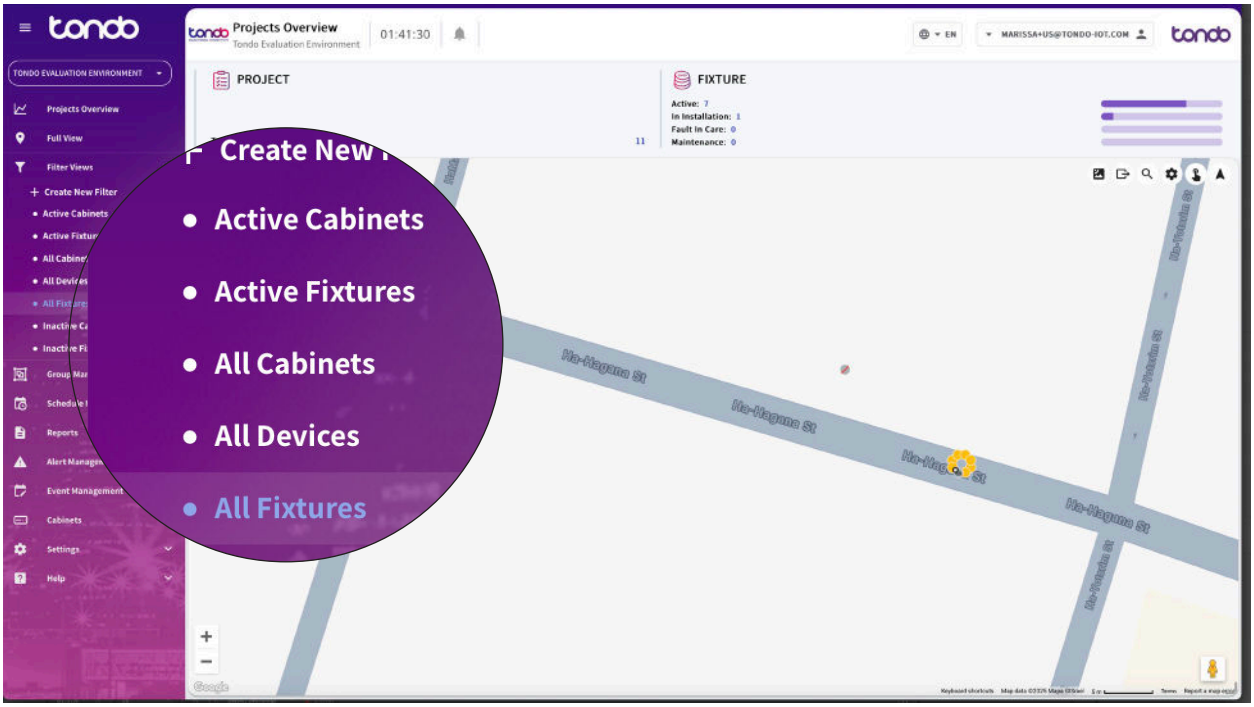


Figure 38: Filter View - Filtered View Show All Fixtures

5. Group Management

Groups can not only provide the functionality of Filtered Views, but can also be used to apply lighting schedules (e.g. dusk-to-dawn or dimming profiles) and assign users or teams responsibilities for locations, device types, circuits, and restrict access or simplify areas of responsibility.

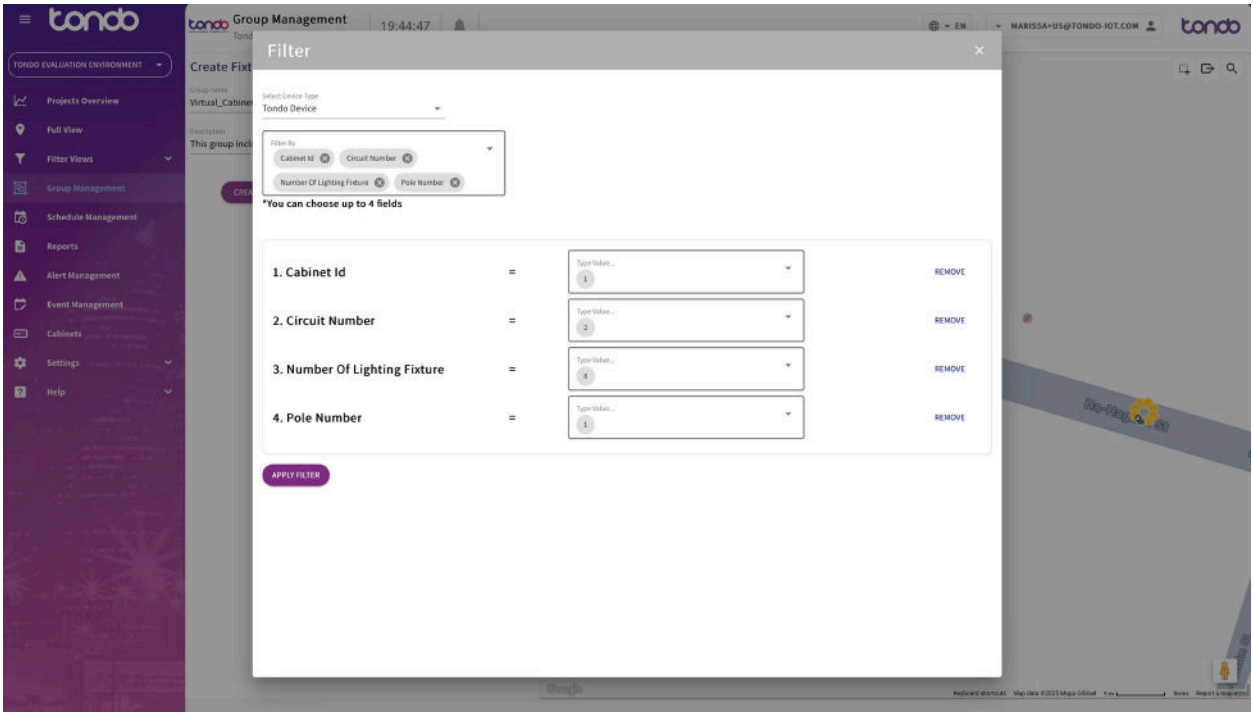


Figure 39: Group Management - Device Group Filter

5.1 Create Fixtures Group

Once we've refined our Filter search as shown in the preceding section, we can see the results below.

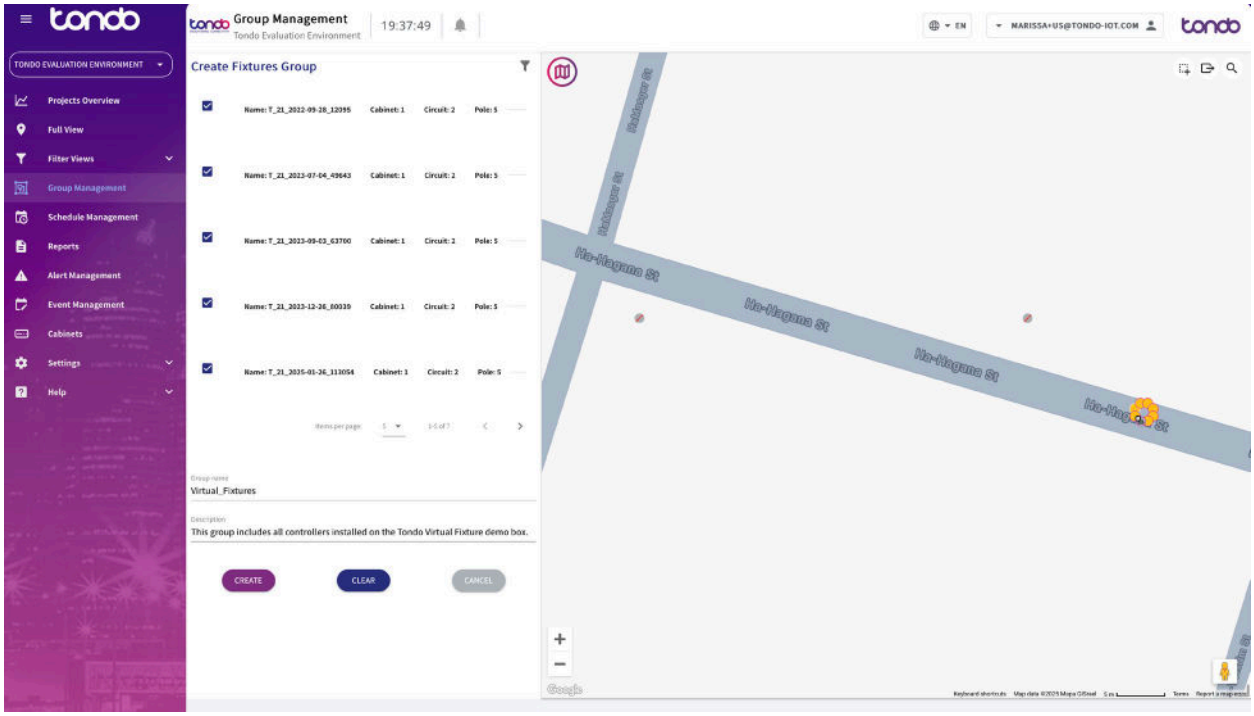


Figure 40: Group Management - Create Device Group

From there, we can repeat that process and as with custom Views, we can see below how our Groups are organized by type of device.

Other helpful grouping approaches might include location, fixture type, cabinet ID, wattage, or other static values (those that do not change regularly). Generally you'll want to organize your Groups according to how you allocate responsibilities for your operations teams.

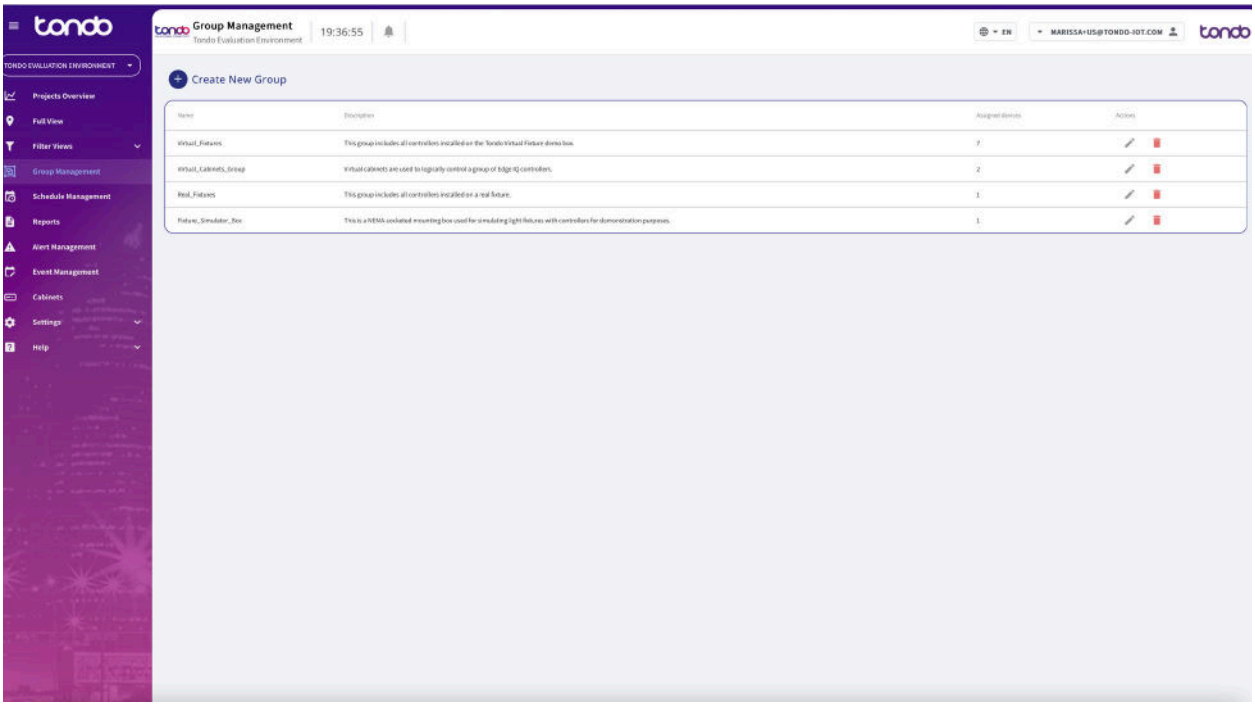


Figure 41: Group Management - Device Groups List

6. Lighting Schedule Management

Schedules allow us to specify:

- Lighting profile (the light “curve”)
- Lighting group (as defined in Group Management)
- What time lighting starts and ends
- What days of the week each lighting profile is applied to

We can create any number of lighting profiles with precisely controlled dusk and dawn times or a custom start and end time we choose.

We can create lighting profiles for each roadway classification or surface type. The illustration below shows how we can create a lighting profile designed to be applied to a Local roadway classification (less than 1,500 vehicles per hour) with an R3 surface type (paved asphalt in good condition) and for low adjacent pedestrian and cyclist traffic (10 or fewer pedestrians and 10 or fewer cyclists per hour):

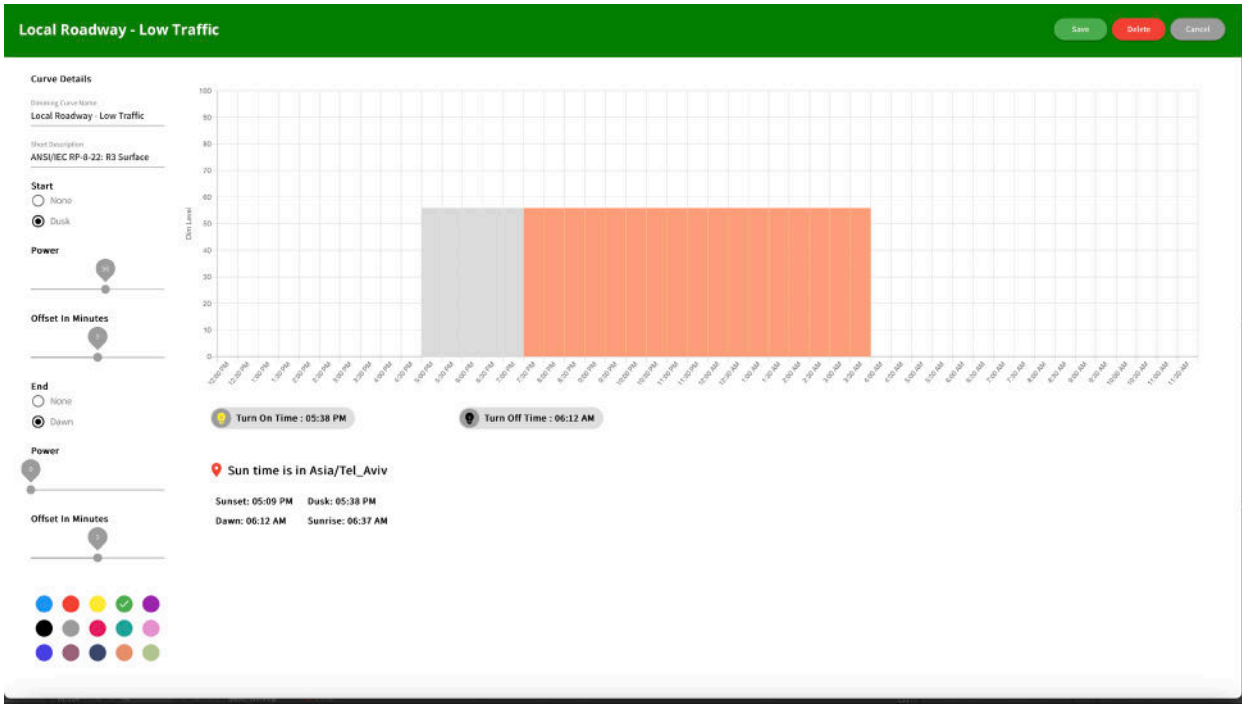


Figure 42: Schedule Management - Local Roadway Lighting Profile

By applying lighting curves compliant with ANSI/IES RP-8-22 standards, we can reduce excess lighting and save up to 50% in energy costs over typical "dusk-to-dawn" lighting.

The illustration below shows how our Schedule created above is applied for low traffic levels on a Local roadway, and a second Schedule designed for moderate traffic levels is applied on Fridays and Saturdays, **saving 46% in energy costs and extending the lifecycle of LED lamps by up to 160% due to the reduced stress from higher LED operating temperatures:**

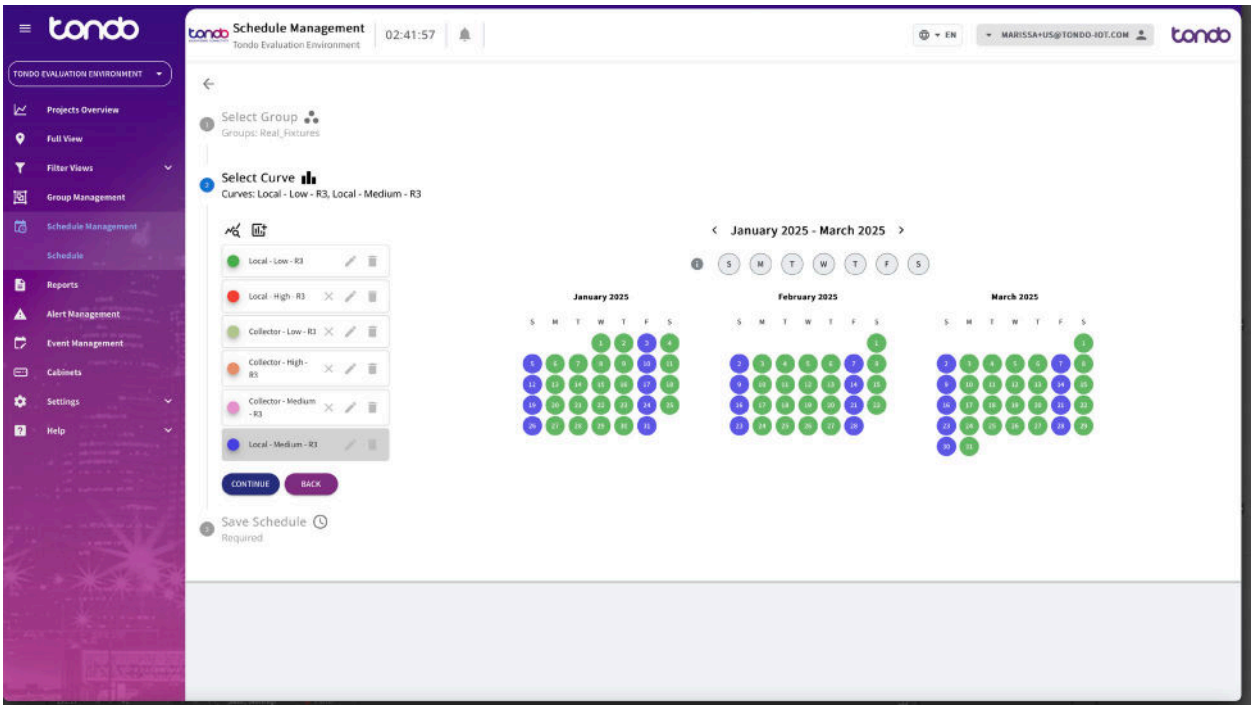


Figure 43: Schedule Management - Local Roadway Schedule

7. Reporting

Tondo Cloud IQ provides reporting for:

- Inventory Management
- Activity Logs
- Power Consumption
- Project Installation

Reports can be output to CSV, XLSX, or JSON file formats for use in spreadsheets and business analytics tools, or importing into GIS tools such as ArcGIS.

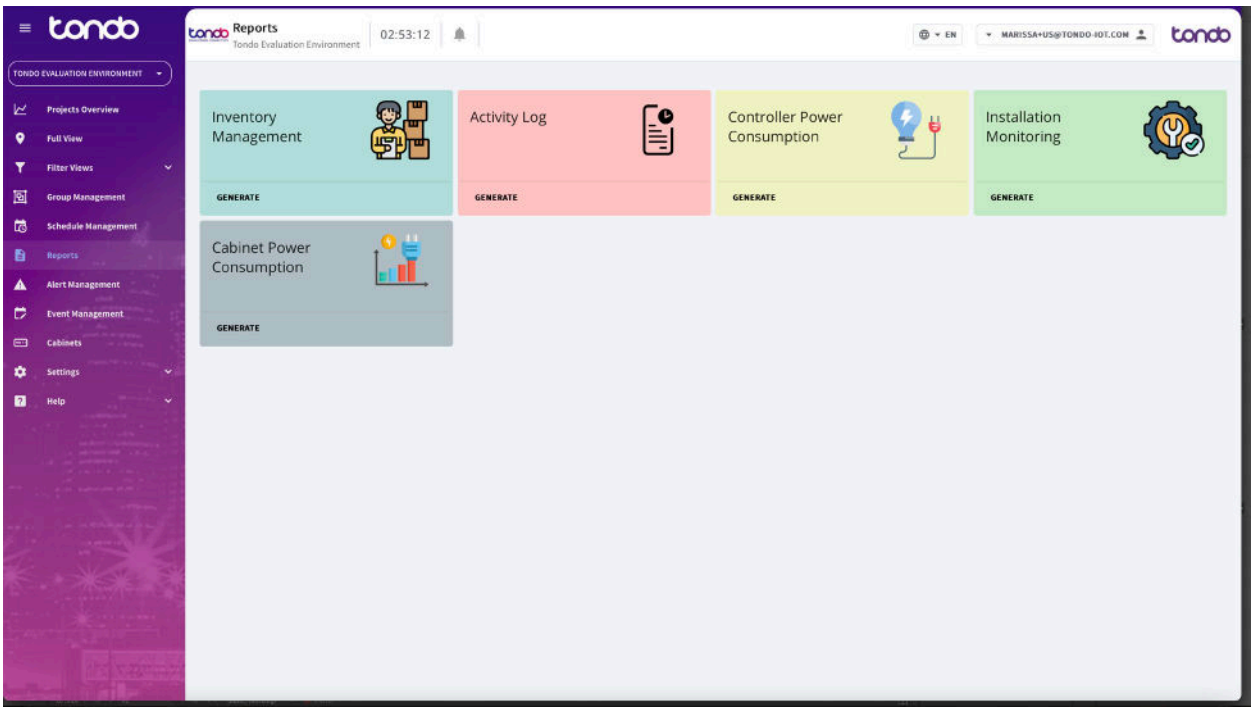


Figure 44: Reports Selection

7.1 Inventory Management Reports

Tondo's Inventory Management reports enable you to report on any connected assets including controls, sensors, smart meters, or other devices that may be connected to your Tondo system.

When creating reports, Tondo provides a contextual filter to enable you to select any device attributes that have been collected for your devices.

Contextual filters make sure that the criteria remains "dynamic" according to your collected data. For example, if you decide to collect new data in a custom field later, that new data will appear automatically in your report filter options.

One of the significant advantages of using DALI-2 and DALI D4i compliant fixtures is that Tondo controllers will automatically collect any information made available by the fixture manufacturer without the need for manual data entry by installers or operations teams.

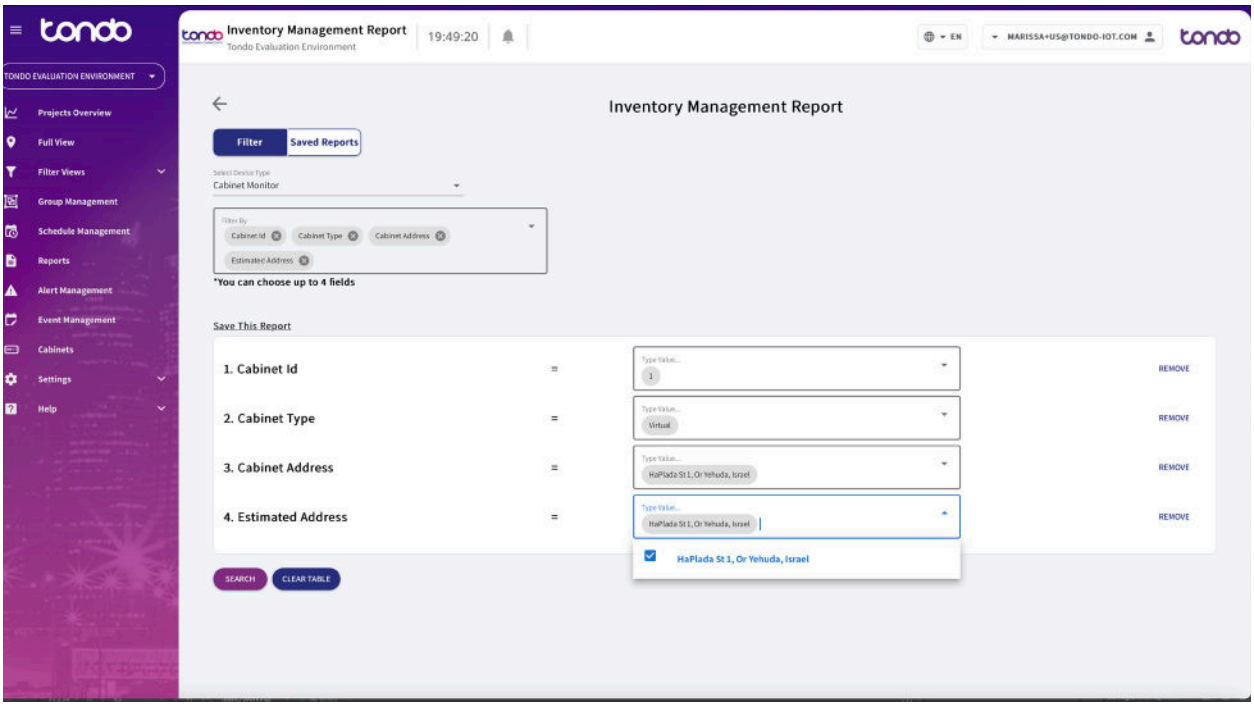


Figure 45: Inventory Management - Filtered Search

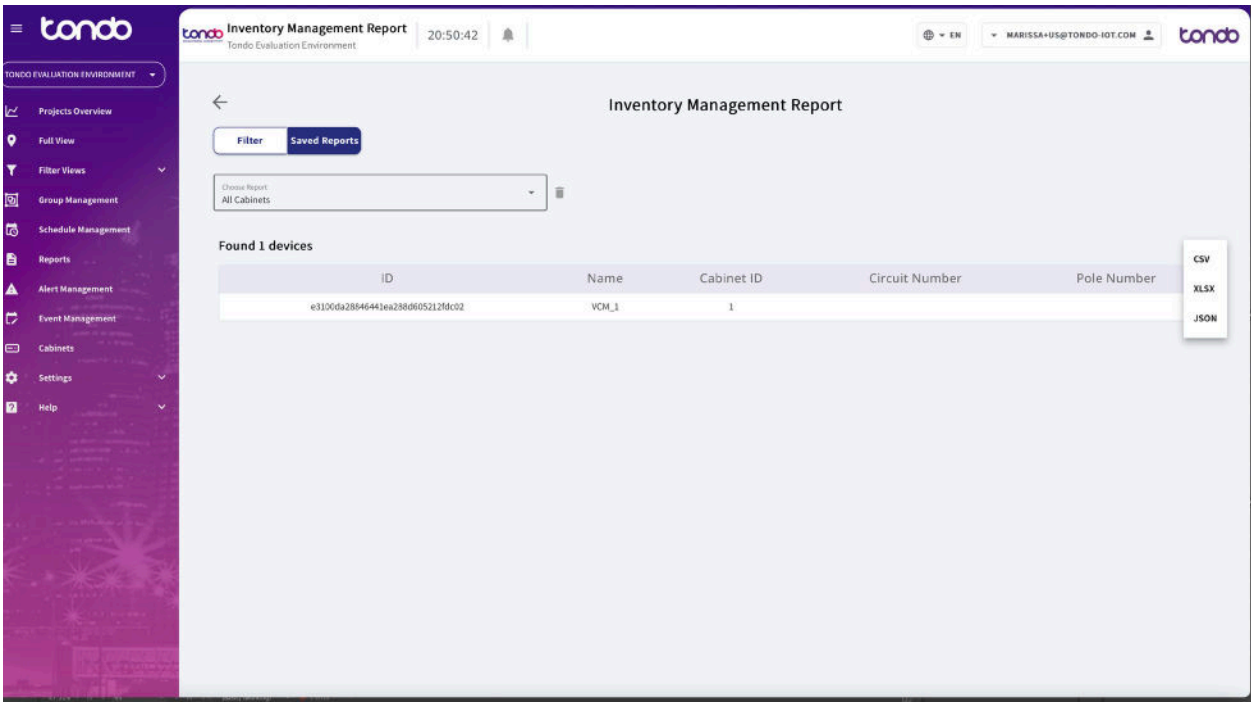


Figure 46: Reports - Inventory Management Report

Again, once a report is run, the results may be viewed or exported to CSV, XLSX, or JSON formats for easy import into other applications such as your spreadsheet, asset management, business analytics, or GIS systems.

The available columns in the report are dependent on the asset information collected.

7.2 Activity Log Reports

Activity Log reports provide reporting on the power-on periods of individual fixtures and their power consumption for a given range of dates.

These reports can help identify and measure any power consumption anomalies where a fixture may have shown up in Alerts or Notifications.

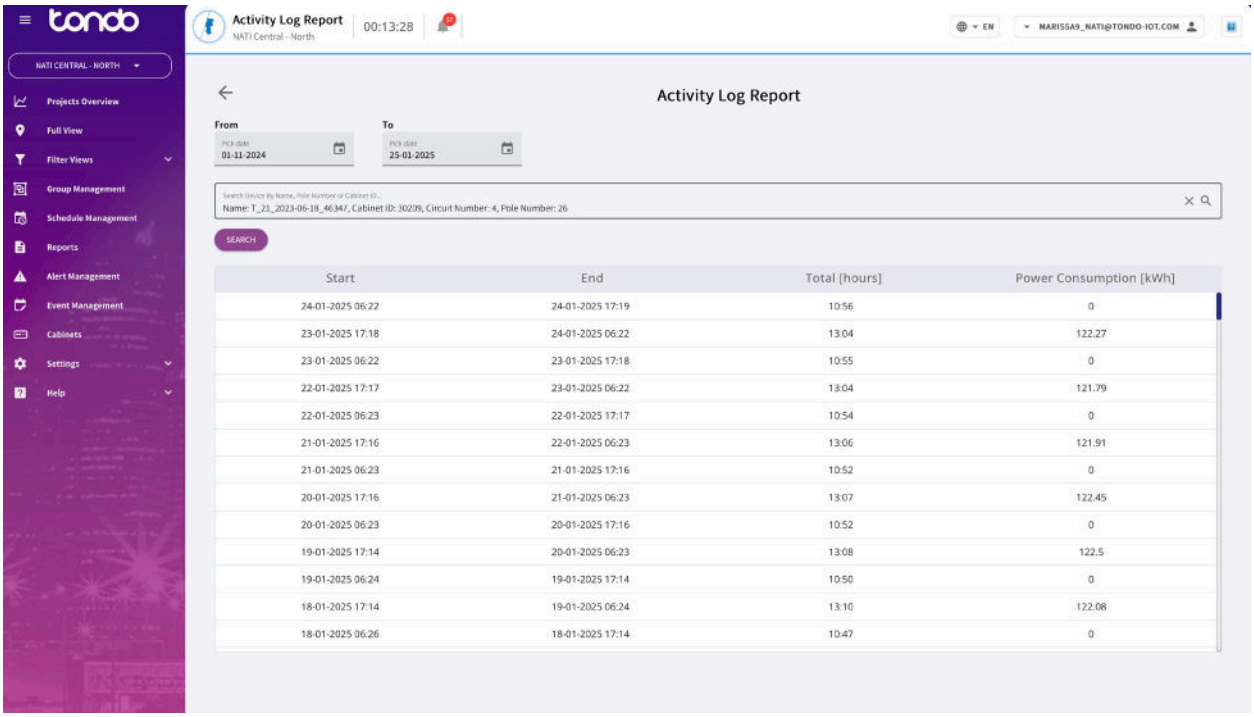


Figure 47: Reports - Activity Log

7.3 Controller Power Consumption Reports

Controller Power Consumption reports generate reports on individual Edge IQ controllers or groups. As with other reports, these can be easily output to CSV or Excel format for import into spreadsheets, analytics or other software applications.

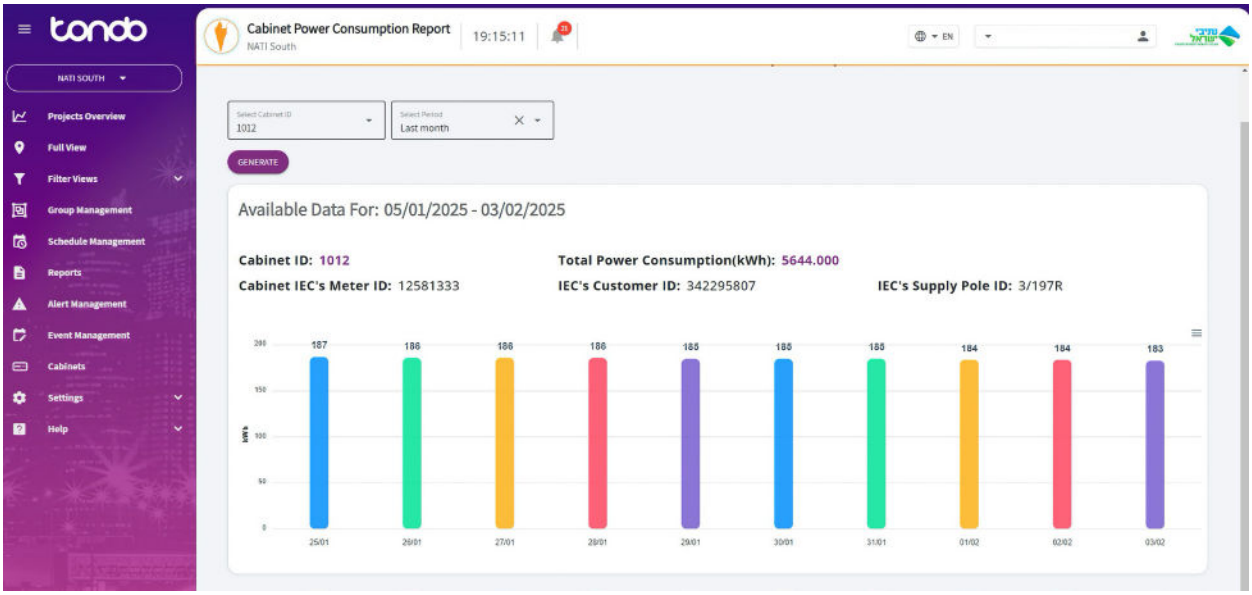


Figure 48: Reports - Controller Power Consumption

7.4 Installation Monitoring Report

Installation Monitoring reports enable you to report on the efficiency, success, and failure of installed Tondo controllers by field personnel during your Tondo Smart Lighting project deployment.

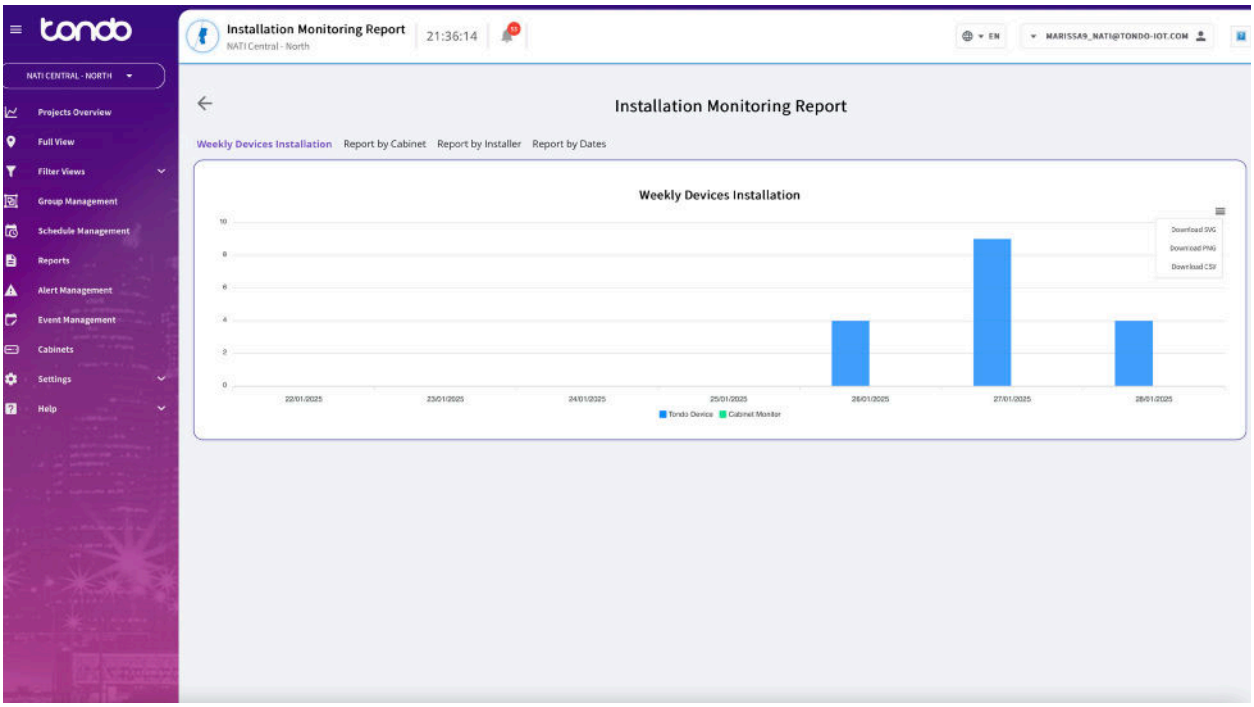


Figure 49: Reports - Installation Monitoring Weekly Summary

There are four types of standard Installation Monitoring reports:

- Weekly Devices Installation - a quick progress report by week
- Report by Cabinet - a detailed report by Cabinet location
- Report by Installer - a detailed report by Installer
- Report by Date - a detailed report by Cabinet or Installer

These reports output:

- Cabinet ID
- Pole Number
- Pole Height
- Circuit Number
- Date
- Device ID
- Location
- Installer
- Status

From this data, we can extract actionable insights. For example, failure rates by installer can tell us whether there is a training success or failure, or productivity by day-of-week to see whether there are process improvements we can address.

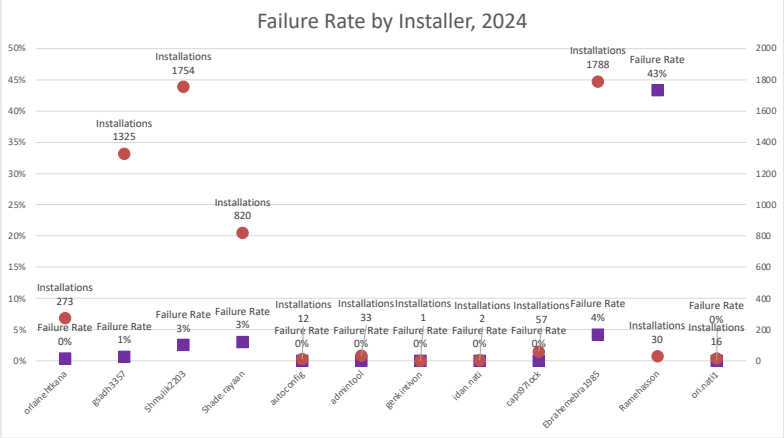


Figure 50: Failure Rate By Installer - Excel Chart

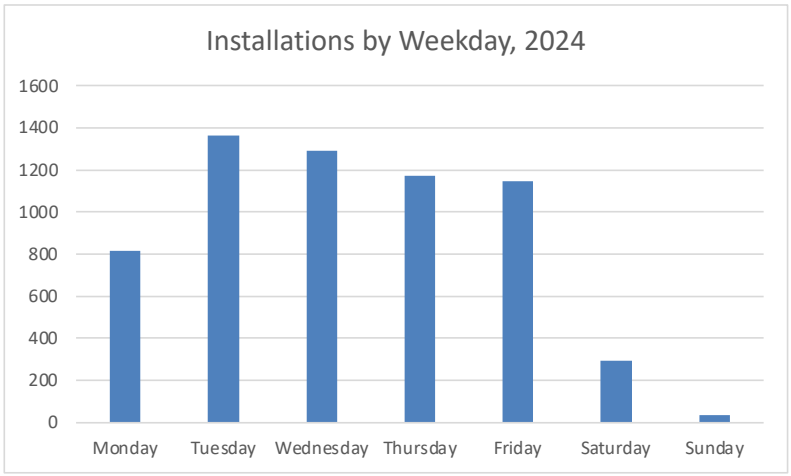


Figure 51: Installations by Weekday - Excel Chart

7.5 Cabinet Power Consumption Report

The Cabinet Power Consumption reports show energy consumption for all fixtures selectable by one or more cabinets - virtual or physical Cabinet IQ cabinets.

Of course, on a new installation, you won't have data to work with quite yet, The illustration below shows energy consumption from a real-world installation of 14,000 fixtures.

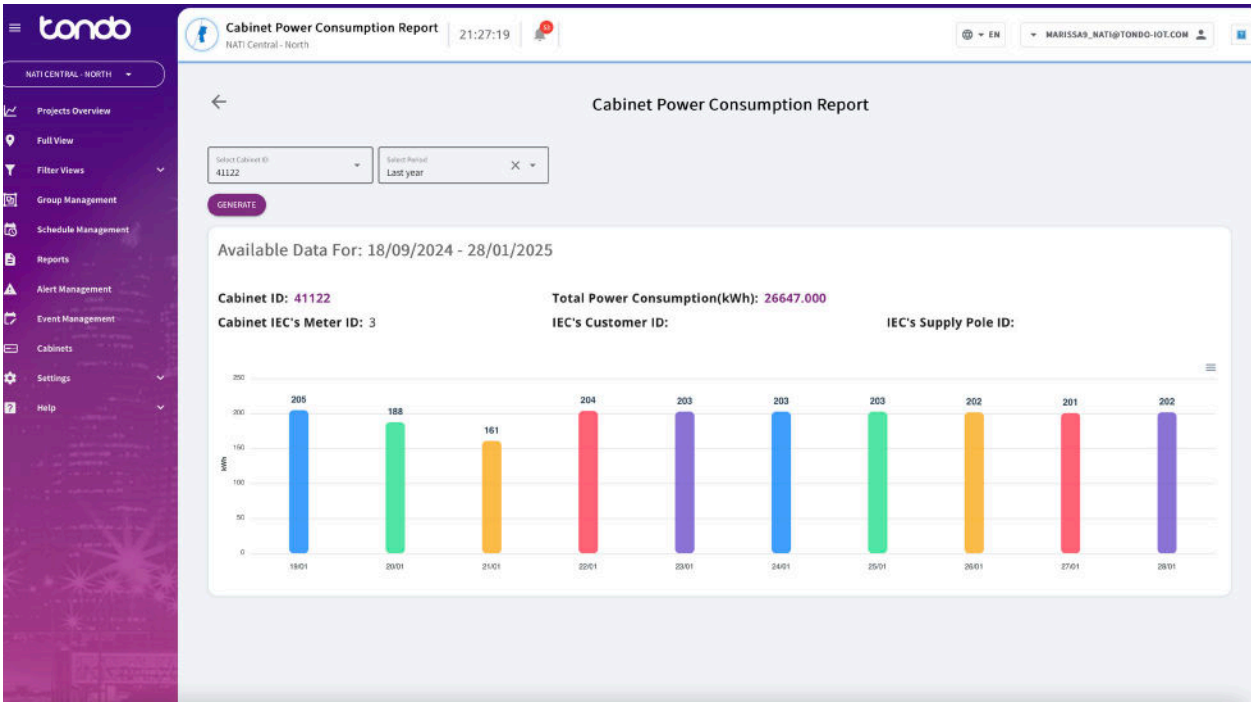


Figure 52: Reports - Cabinet Power Consumption Reports

8. Incidents

Incidents are a general category for **any recorded system anomaly, including Alerts and Events**. Examples of Incidents include electrical faults, voltage spikes, and communications failures.

For a new Project, Tondo configures a few basic Incidents. However, a customer may configure their own Incident types.

Customers do not need to configure their own threshold values - these are managed by Tondo's artificial intelligence engine in Cloud IQ to identify anomalies simplifying the process for operations teams.

Incidents are viewed according to each specific Cabinet (virtual or Cabinet IQ):

- Select Alert Management from the sidebar
- Use the available Filter capability to narrow your focus on a date range, type of Alert, Managed Area, or Cabinet Description
- Select the Cabinet you are concerned with
- Select the General/Table toggle (see inset below) in the Cabinet Detail view

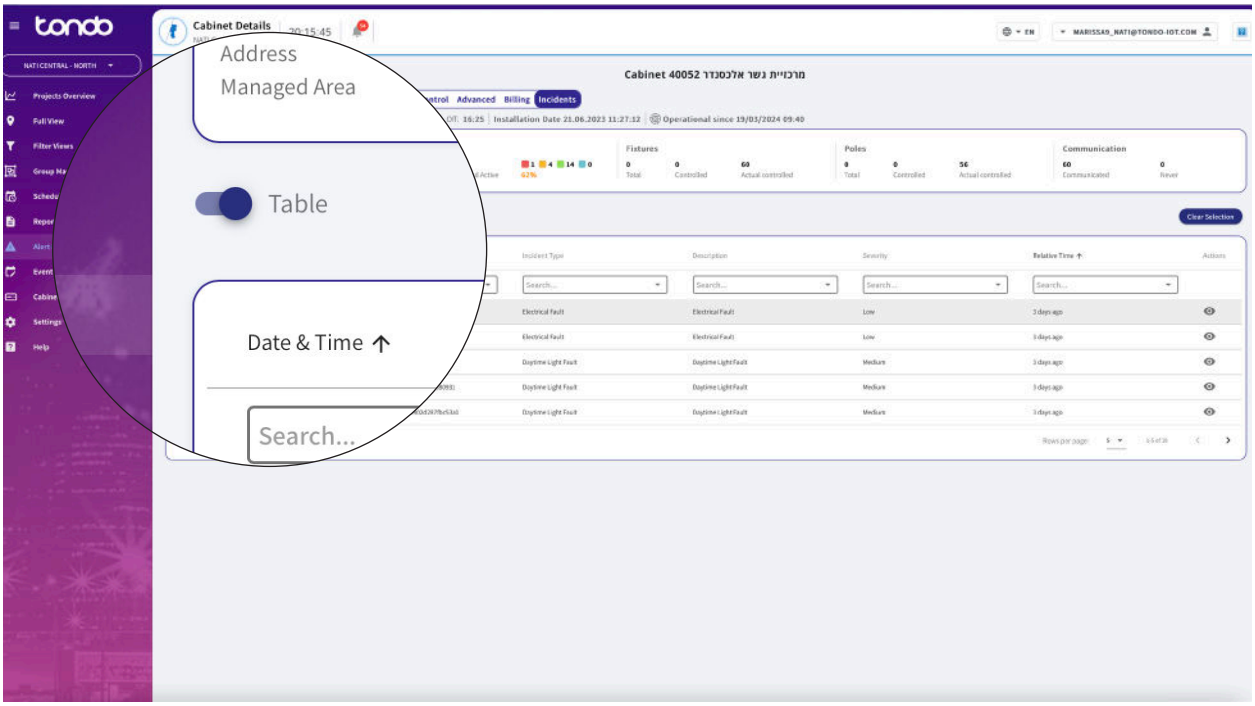


Figure 53: Alert Management - Incident List General/Table Toggle

The following illustration shows an example of this Incident Details view:

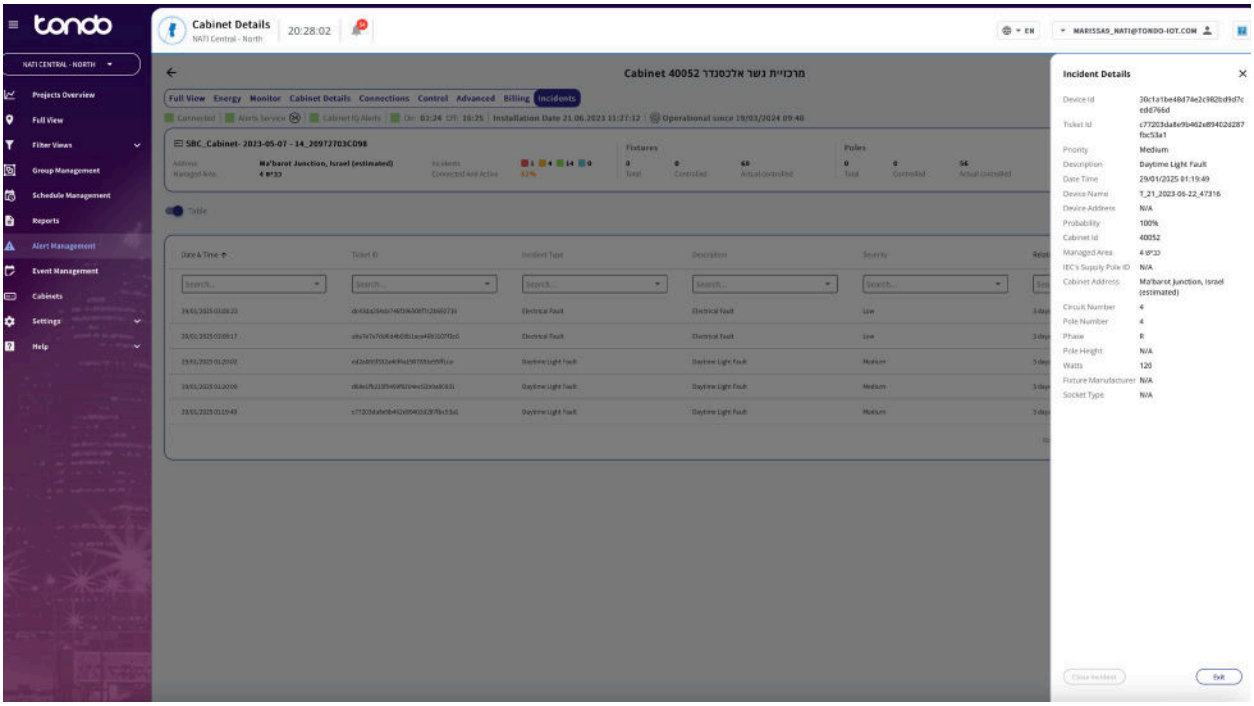


Figure 54: Alert Management - Cabinet Details Incident Details

Only "open Incidents are ever displayed - the Tondo AI detects when any Incident is no longer occurring, and automatically closes an incident. However, a customer may choose to manually "Close Incident" from the Incident Details view if they choose. This automated approach greatly reduces the operational workflow burden of manually managing Incidents.

8.1 Alert Management

Tondo provides Alert and Event Management. Although the data on which Alerts and Events are largely the same, there are key differences between them:

- **Events** - a change in status or system activity regardless of threshold or condition.
- **Alerts** - a notification triggered by a threshold or condition in Event data.

With Tondo's built-in machine learning AI, Events and Alerts are automatically classified and prioritized, and Cloud IQ can be used to filter Events and Alerts so that customers only receive actionable insights from the system without being distracted by unnecessary data.

Customers can request custom Event types to be monitored, and custom Alert types that classify and prioritize data for operational efficiency gains.

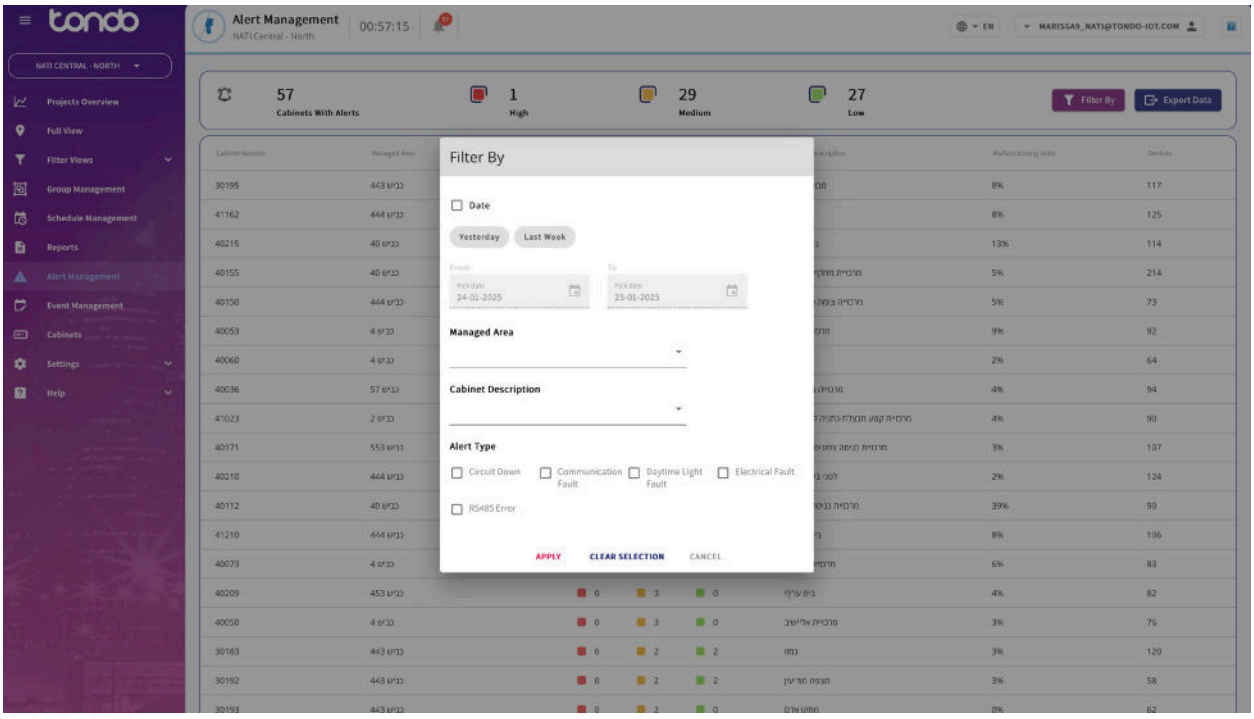


Figure 55: Alert Management - Filtering by Alert Type

8.2 Event Management

Events are the “dynamic” data streams received by the Tondo system dependent on what devices are connected to your Tondo system. Devices include Tondo controllers, their built-in sensors, and any sensors, energy meters, or other devices that are connected to a Tondo controller via direct-wire or wireless connection.

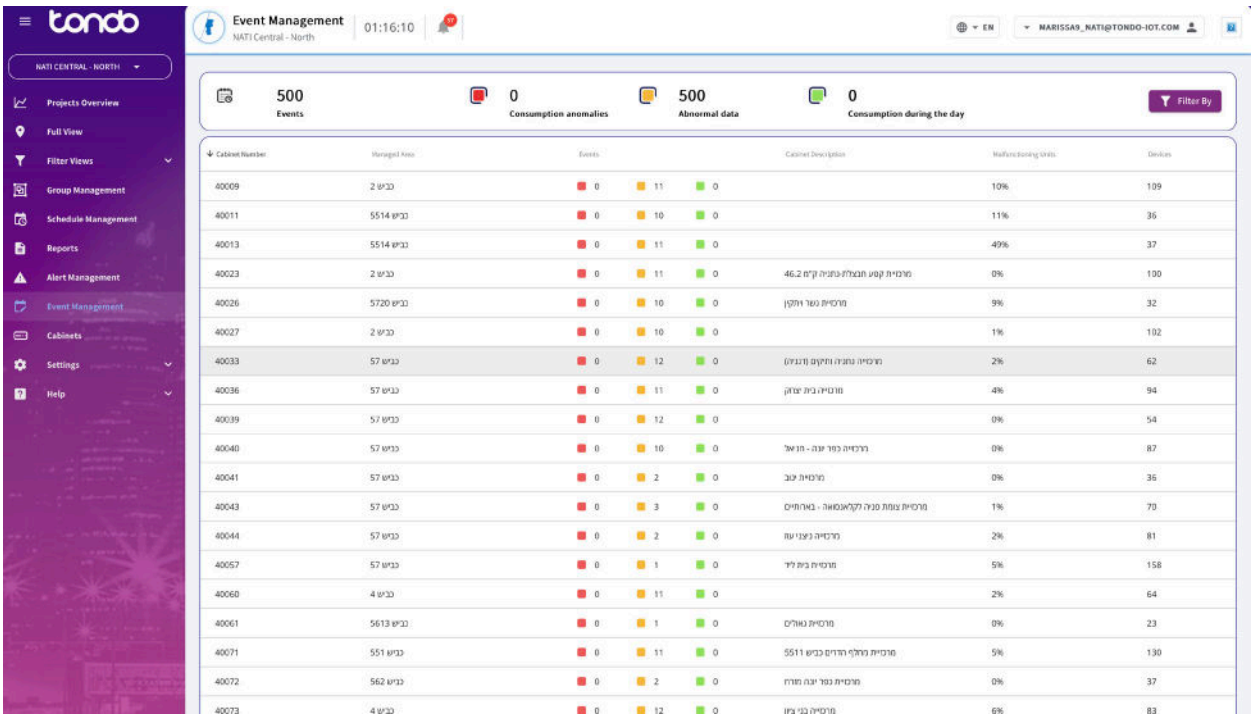


Figure 56: Event Management - List View

Examples of Events include:

- Over-voltage
- Under-voltage
- Power supply failure
- UPS battery failure (Cabinet IQ controller only)
- UPS discharging (Cabinet IQ controller only)
- Communication failure
- Pole tilt
- Vibration
- Operating temperature

- Activation
- Deactivation
- Dimming status
- Energy consumption
- Sensor data

Events can be used by the Tondo Alert notifications system that utilizes AI machine learning to monitor for anomalies and patterns to classify Events into Alerts and provide operations teams with actionable insights.

9. Cabinet Control and Cabinet IQ

In a Tondo environment, a Cabinet - whether a utility cabinet or lighting control pedestal - can be physical or virtual.

- **Physical Cabinet IQ**: a physical cabinet is a Tondo Cabinet IQ controllers that deliver electrical service to, control, analyze energy delivery for, or manage a group of streetlight poles and fixtures. Cabinet IQ also provides relay switch control and digital I/O control for a variety of control and monitoring use-cases
- **Virtual Cabinets**: a Virtual Cabinet is a logical collection or group of Tondo Edge IQ controllers that control, analyze, and manage a group of streetlight fixtures

Technical specifications for Cabinet IQ can be found in the Tondo Solutions Guide.

Cabinet IQ is not required for enabling Tondo's Edge IQ controls, but can complement Edge IQ on-fixture controls with advanced energy analytics at and between the secondary electrical service point and the light fixture.

9.1 Cabinet IQ Components

The Cabinet IQ controller consists of the following components

9.1.1 Energy Meter

High-accuracy energy measurement, power monitoring, and fault detection.

- **Voltage & Current Measurement**: Measures voltage (V1, V2, V3) and current (I1, I2, I3) using Hall Effect sensors.
- **Digital Inputs (IN1-IN6)**: Configured for breaker status, alarms, or sensor monitoring.
- **Relay Outputs (RO1, RO2)**: Allows automated power switching and remote control.
- **Communication:** Uses RS-485 for data transfer to the Cabinet IQ controller.

9.1.2 Cabinet IQ Controller

Function: Central processing unit that manages data from the energy meter, relays, and external sensors.

- **RS-485 Communication**: Collects real-time power data from the energy meter.
- **DC Power Input (24VDC)**: Receives power from the UPS-backed power supply.
- **Cloud Connectivity**: Secure LTE connection for real-time monitoring, automation, and alerts.

9.1.3 Power Supply System

Function: Provides stable 24VDC power to the Cabinet IQ system.

Power Supply Unit

- Converts AC input (220V) to 24VDC output.
- Supplies power to the energy meter and Cabinet IQ controller.

48-Hour UPS Module

- Ensures continuous 24VDC power backup in case of an outage.
- Connected to two 12V batteries in series (24VDC).
- Monitors battery status (DC OK, Battery Fail, Battery Discharge indicators).

Hall Effect Sensors

Non-contact current sensing for accurate power monitoring.

- Installed on I1, I2, I3 inputs of the energy meter.
- Measures phase-level power consumption in real time.

Wiring & Communication

Provides structured electrical connections for safe operation, connecting:

- **RS-485 Bus**: Energy meter & Cabinet IQ gateway.
- **Power Lines**: 24VDC distribution from UPS and power supply.
- **Battery Backup**: Ensures system resilience against power failures.

9.2 Cabinet IQ Wiring Diagram

A wiring diagram for Cabinet IQ is shown below. Cabinet IQ can be DIN rail mounted into an existing cabinet or provided with its own enclosure.

Note: Cabinet IQ may be ordered configured with any Smart Energy Meter with similar capabilities to the SATEC EM133 according to a customer's design specifications, or to match utility- and regulator-approved use for their area.

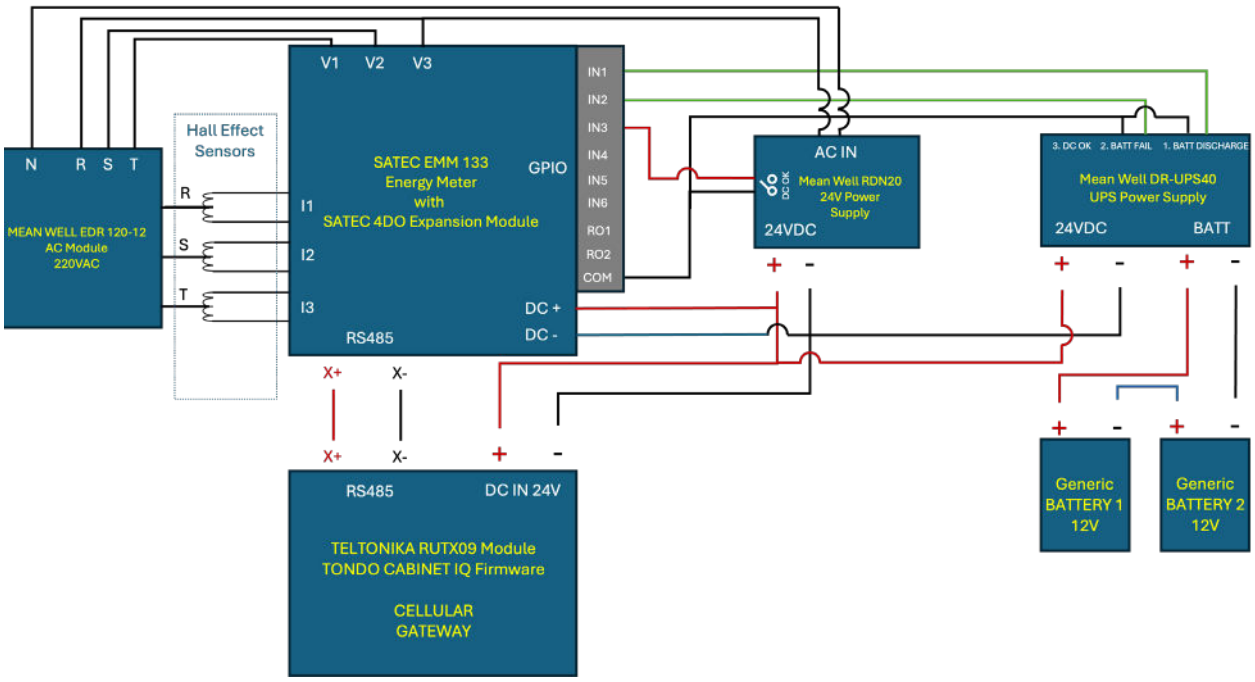


Figure 57: Cabinet IQ Wiring Diagram

9.3 Cabinet IQ Use Cases

Tondo's Cabinet IQ enables cities, utilities, and private sector operators to manage energy distribution, critical infrastructure, security, and environmental monitoring efficiently.

The following sections describe just some of the use-cases for Cabinet IQ categorized by municipal and utility market segments.

9.3.1 Public Works

Infrastructure & Facility Monitoring

- **Streetlight Wire Theft Detection** – Detect unauthorized tampering and trigger alerts.
- **Remote Circuit Control & Load Shedding** – Optimize energy use and prevent overload.
- **Smart Parking & EV Charging Load Management** – Monitor and balance EV infrastructure.
- **Public Restroom & Facility Monitoring** – Automate maintenance alerts for water leaks and usage levels.

9.3.2 Transportation & Mobility

Traffic & Roadway Systems

- **Adaptive Roadway Lighting** - Monitor pedestrian and cyclist traffic levels to automate changes to lighting profiles based on roadway classification standards
- **Traffic Signal & Smart Signage Control** – Optimize signal timing and pedestrian crossings.
- **Railway & Level Crossing Monitoring** – Automate train approach detection and barrier control.
- **Smart Bus Stop & Transit Shelter Power Management** – Control shelter lighting and heating dynamically.

9.3.3 Environmental & Sanitation Services

Water, Wastewater & Flood Management

- **Flood & Water Level Monitoring** – Prevent roadway flooding with automated drainage control.
- **Groundwater & Waterway Monitoring** – Real-time tracking of contamination and flow levels.
- **Smart Irrigation & Water Usage Control** – Optimize municipal irrigation schedules based on sensor data.
- **Sewer Blockage & Overflow Detection** – Automate wastewater flushing to prevent system failures.

- **Smart Waste Bin Monitoring** – Use bin-level sensors to optimize waste collection routes.

9.3.4 Emergency & Public Safety

Disaster Preparedness & Security

- **Public Emergency Alert & Warning Systems** – Automate sirens and public safety notifications.
- **Wildfire & Smoke Detection** – Deploy sensors for early detection of fire hazards.
- **Remote Lockout & Access Control** – Secure critical electrical and data enclosures.
- **Tamper Detection for City-Owned Infrastructure** – Protect against unauthorized access to power systems.

9.3.5 Municipal Energy & Utility Departments

Smart Grid & Utility Management

- **Electricity Theft & Unauthorized Usage Detection** – AI-driven energy fraud prevention.
- **Voltage & Frequency Stability Monitoring** – Detect grid fluctuations that may impact city services.
- **Transformer & Feeder Circuit Load Balancing** – Prevent power failures and outages.
- **Smart Demand Response & Peak Load Management** – Automate energy adjustments based on usage trends.

Water Treatment & Flow Control

- **Smart Water Metering & Leak Detection** – Detect inefficiencies and prevent municipal water losses.
- **Tank & Reservoir Level Monitoring** – Automate overflow prevention for storage facilities.
- **Wastewater & Contaminant Monitoring** – Ensure compliance with environmental regulations.

9.3.6 Facilities Management

Smart Energy & Facility Optimization

- **Building Energy Optimization & Smart HVAC Control** – AI-powered efficiency in city and commercial buildings.
- **Remote Elevator Condition Monitoring** – AI-driven analytics to predict elevator failures.
- **Smart Manufacturing & Industrial Process Monitoring** – Optimize power consumption in factories and plants.

9.3.7 Climate Resilience & Sustainability

Environmental Monitoring & Climate Adaptation

- **Real-Time Waterway Pollution Monitoring** – Detect chemical and bacterial contamination in city rivers.
- **Air Quality & Pollution Monitoring** – AI-driven pollution tracking and mitigation planning.
- **Landslide & Ground Stability Monitoring** – Deploy soil moisture sensors for early landslide detection.
- **Seismic & Earthquake Detection** – AI-based analytics for real-time earthquake risk assessment.
- **Smart Coastal & Tsunami Monitoring** – Automate flood sirens and digital warning systems.

9.3.8 Electric Utility Companies

Power Distribution & Grid Operations

- **Voltage & Frequency Anomaly Detection** – Ensure power stability and equipment protection.
- **Smart Metering for Substations & Municipal Buildings** – Enable revenue-grade energy tracking.
- **Remote Circuit Breaker Control** – Automate power rerouting to prevent outages.

9.4 Managing Cabinet IQ with Cloud IQ

The Cabinets screen displays the number of cabinets in the project, data on alerts, sunset and sunrise times of the project according to a list of managed areas associated with the project.

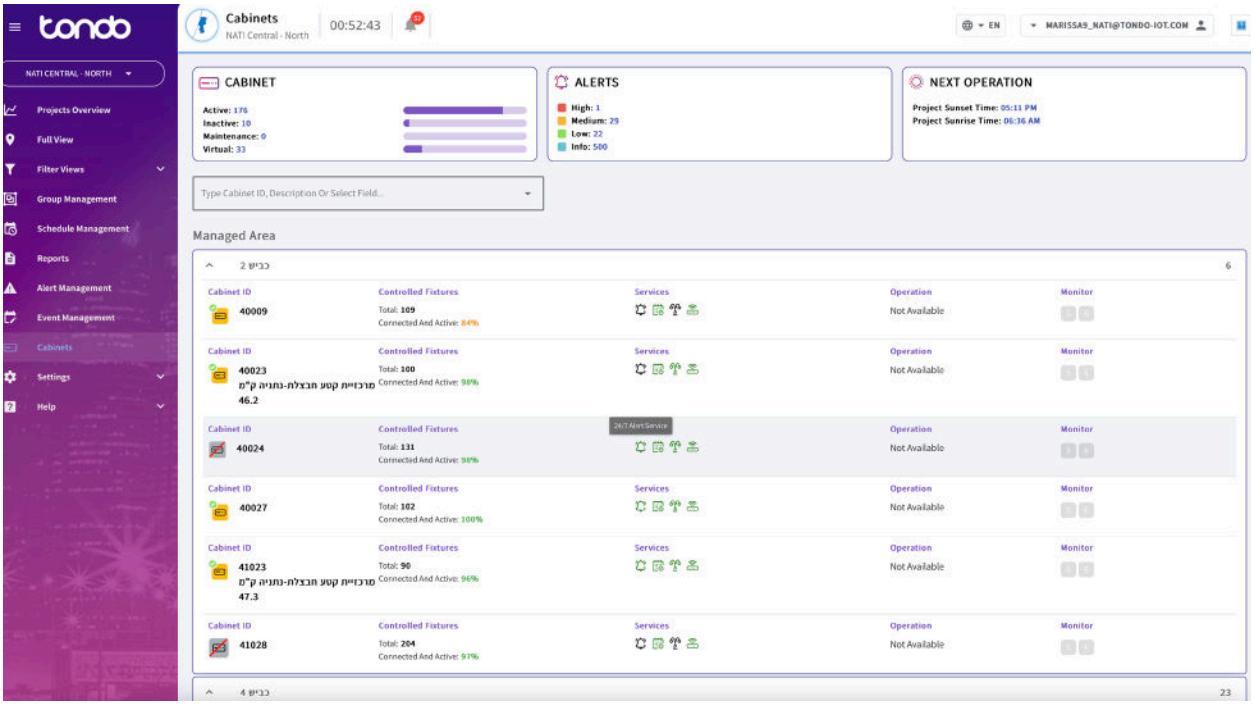


Figure 58: Cabinets - List View

9.5 Virtual Cabinets

A Virtual Cabinet is used to group Edge IQ controllers and any connected sensors to Edge IQ controllers in a convenient way that is familiar to lighting operations teams.

9.6 List View

Cabinet IQ controllers can be installed into existing lighting control cabinets/ pedestals to provide advanced energy management for streetlighting assets.

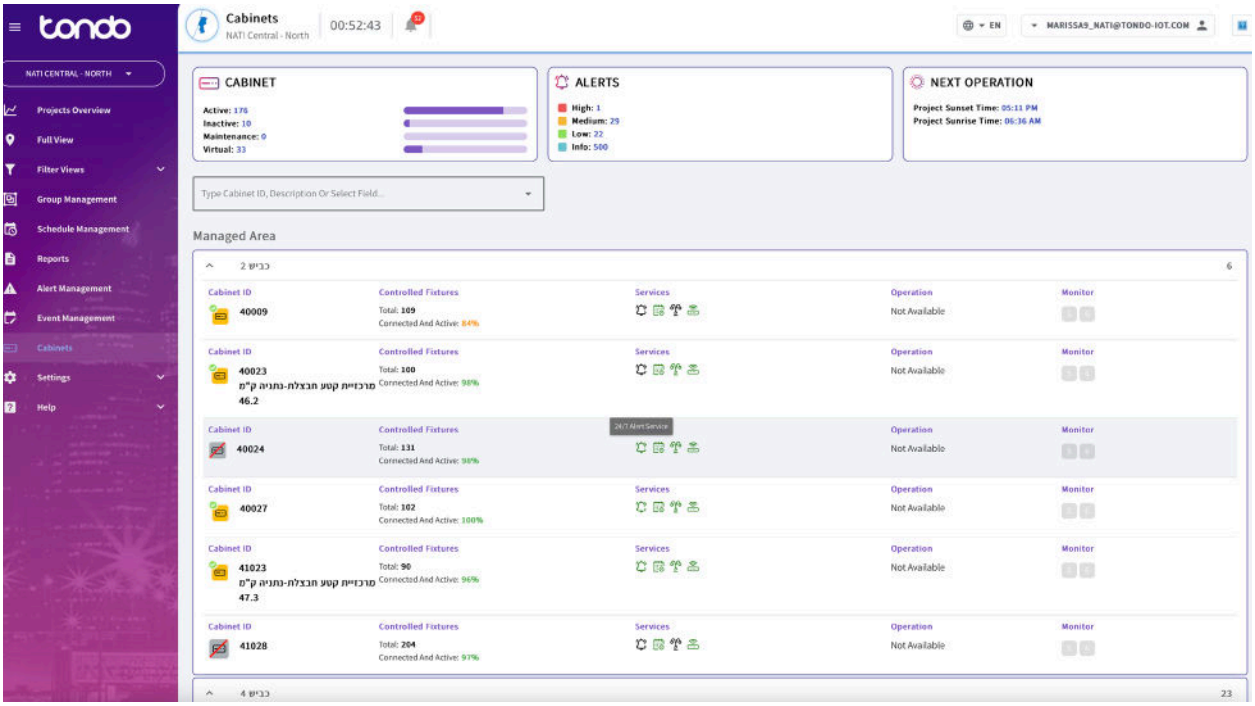


Figure 59: Cabinets - List View

Cabinet IQ can also be installed on-pole or in-pole for a variety of advanced control and higher-bandwidth applications that include:

- Public safety cameras
- Traffic monitoring
- EV charging control
- Public WiFi

9.7 Full View

Selecting a physical Cabinet IQ from the list view shown on the preceding page displays a map view of the cabinet's connected lighting assets including Edge IQ controllers with:

- Automatically numbered circuits
- Fixtures controlled
- Poles controlled
- Communication status to each fixture or device
- Devices with current alerts
- Filtering by alerts, circuits, or phase

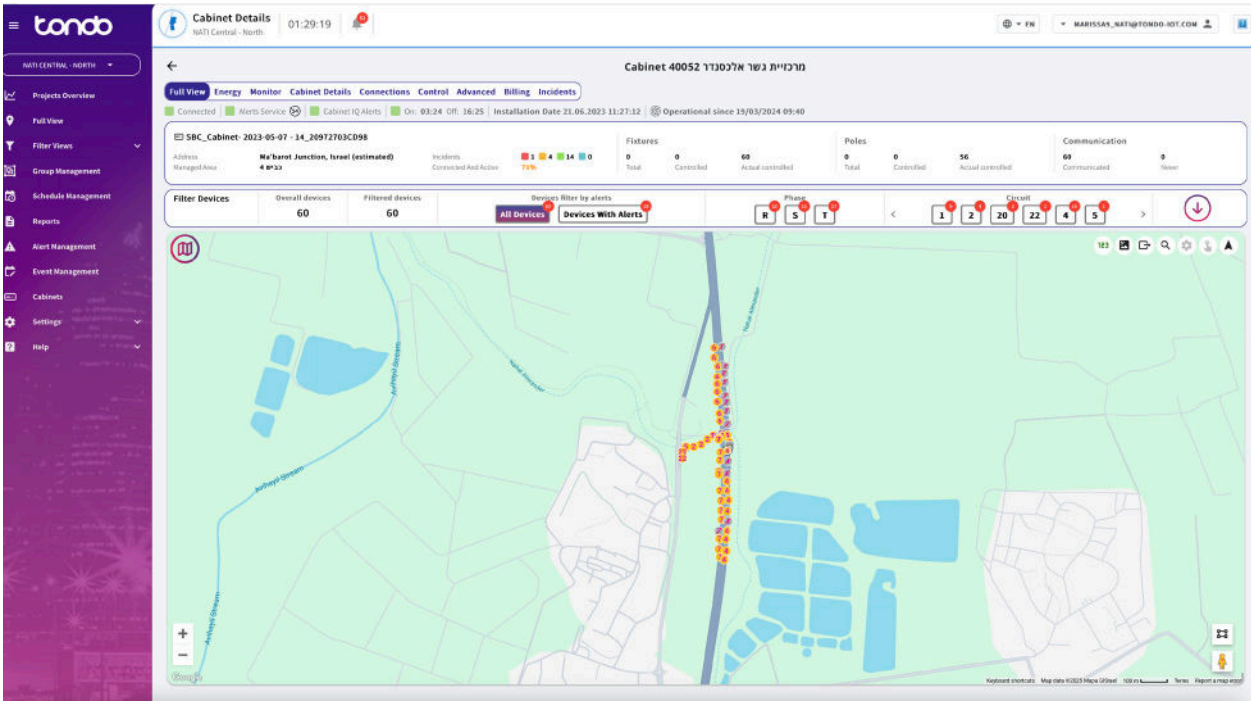


Figure 60: Cabinets - Cabinet Device Full (Map) View

9.8 Energy View

Selecting the Energy tab adjacent to the Full View tab shows:

- Voltage
- Current
- Power Demand (kW)
- Power Factor
- Reactive Power (kVAR)
- Apparent Power (kVA)

By monitoring Voltage, Current, Power Demand, Power Factor, Reactive Power, and Apparent Power, Cabinet IQ can provide:

- Early failure detection before outages occur.
- Real-time energy optimization to reduce waste.
- Smart streetlight wire-theft and energy-theft detection using AI-based anomaly detection.
- Utility-grade power quality monitoring for long-term cost savings.

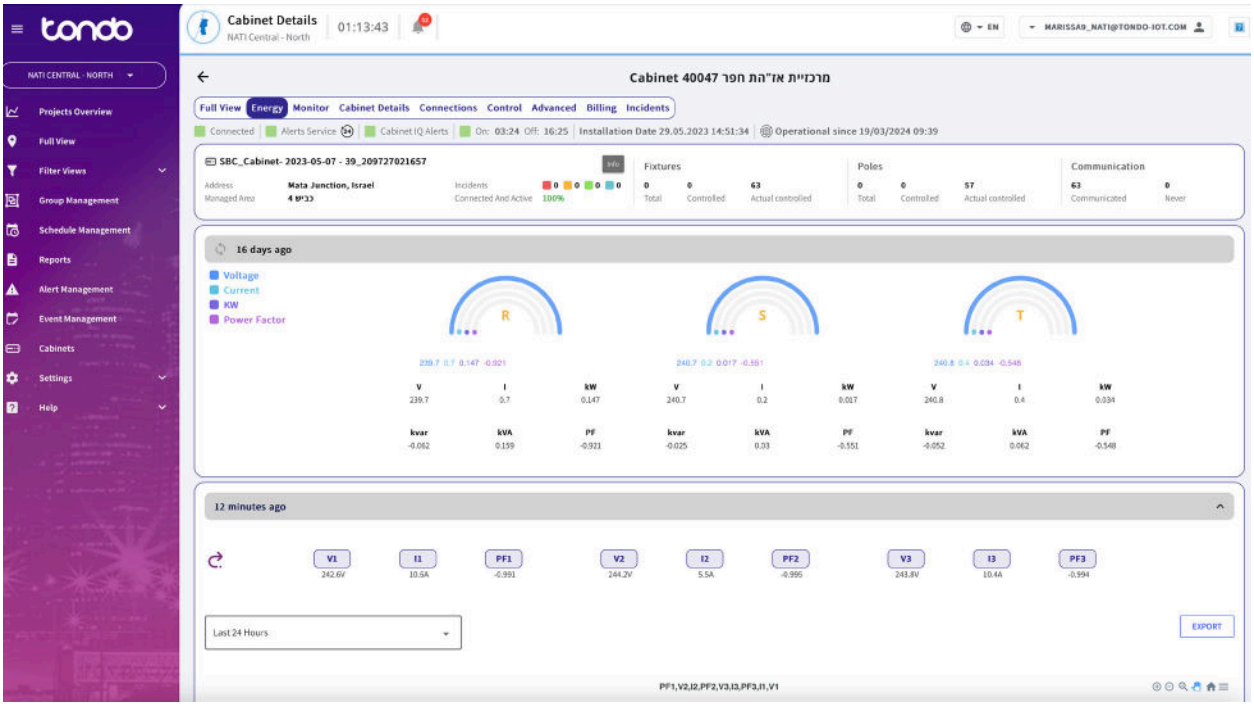


Figure 61: Cabinets - Cabinet Device Full (Map) View

9.9 Monitor Demands

Selecting the Monitor tab adjacent to the Energy tab displays the Demands, Harmonics, and Phasor views of the connected assets controlled by Cabinet IQ. The Demands View provides real-time power quality and demand measurements, which are critical for identifying operational issues in streetlight cabinets.

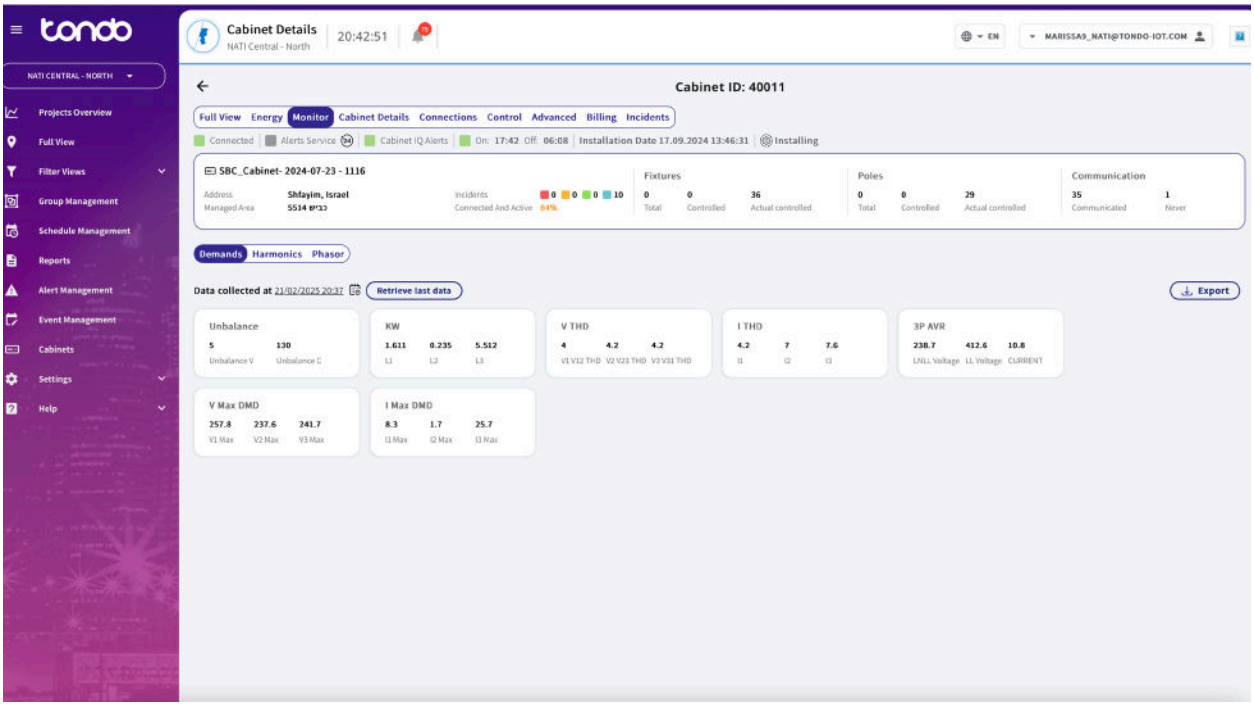


Figure 62: Cabinets - Monitor Demands

By continuously monitoring Demand, Tondo's Cabinet IQ can detect operational inefficiencies, prevent failures, and optimize streetlight and infrastructure energy use.

9.10 Monitor Harmonics

Selecting the Harmonics button adjacent to the Demands button displays Harmonics detail. The Harmonics monitoring available from Cabinet IQ provides a detailed visualization of voltage and current harmonic distortions across different phases. This is critical for ensuring power quality, reducing equipment stress, and preventing failures caused by excessive harmonics.

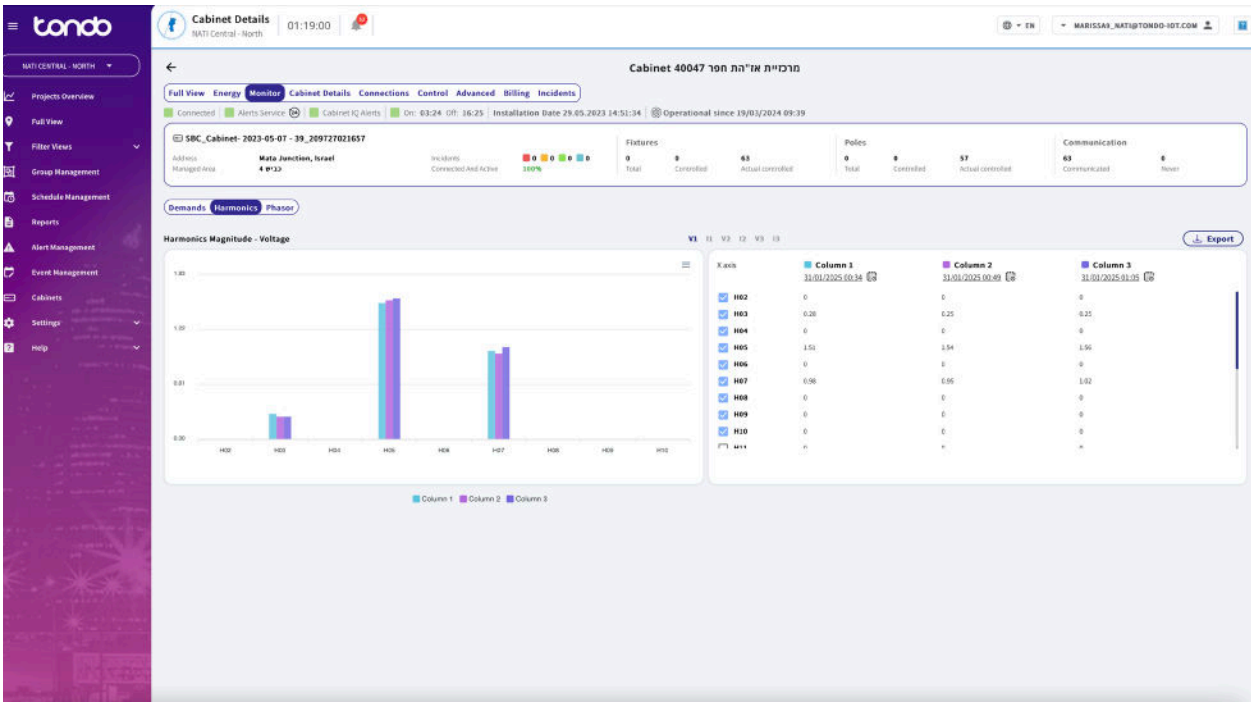


Figure 63: Cabinets - Monitor Harmonics

9.11 Monitor Phasor

The phasor monitoring screenshot from Cabinet IQ's Energy tab provides real-time insights into voltage and current phase angles, magnitudes, and frequency stability. This data is critical for identifying phase imbalances, transformer issues, and grid instability, helping ensure efficient and reliable streetlighting operations.

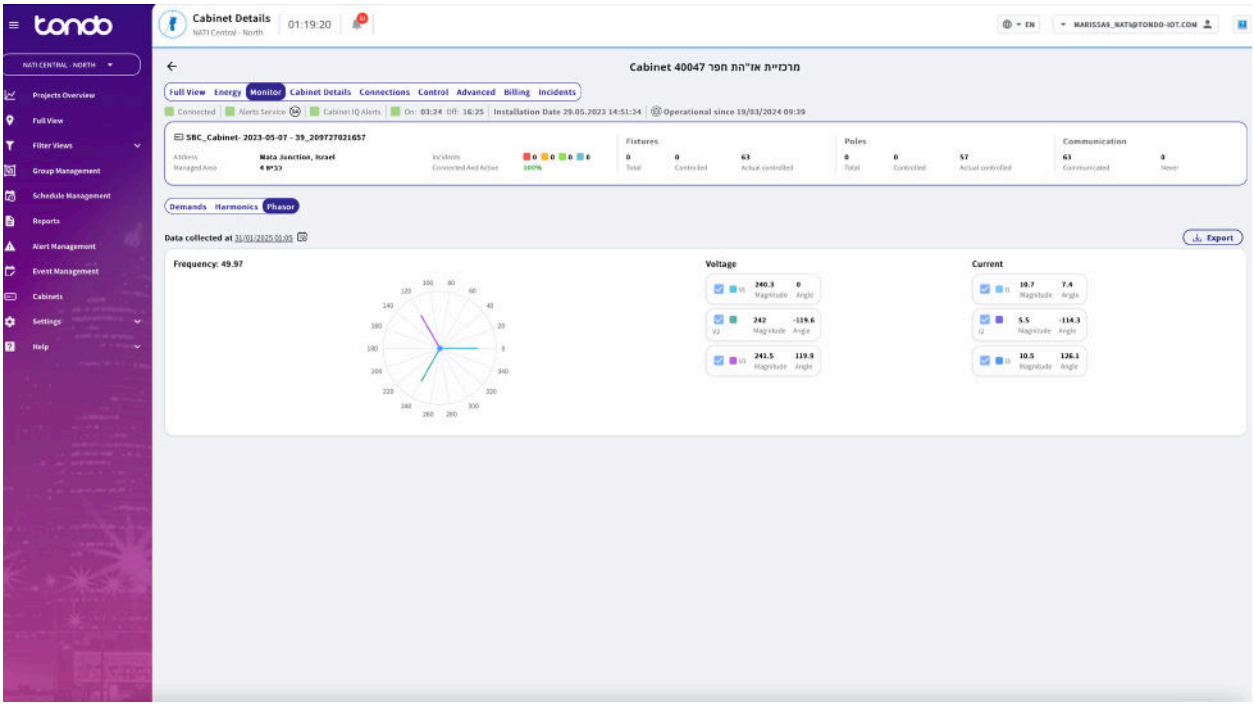


Figure 64: Cabinets - Monitor Phasor

Together, the Demand, Harmonics, and Phasor views within the Cabinet IQ Monitor tab can be used to address use-cases that include:

- Streetlight Wire Theft Detection
- Phase Overload & Transformer Stress
- Grid Instability or Equipment Failure
- Early Streetlight Controller or LED Driver Failure Detection
- Over-voltage & Equipment Damage Risk
- Circuit Failure or Tampering
- Transformer Efficiency Monitoring & Power Factor Correction
- Streetlight Operational Compliance Deviation
- Cabinet or Panel Overdraw

- Battery Backup Failure Alert for UPS Systems
- Equipment Stress & Power Quality Degradation
- Gradual Increase in Harmonics Over Time
- Non-Linear Load Identification
- Phase-Level Distortion Mismatch
- Power Distribution Issues
- Transformer or Capacitor Bank Issues
- Unbalanced Feeder Circuits
- Grid Instability or Generation Issues

With Cabinet IQ's advanced energy analytics and Tondo Cloud's AI-based insights, operations teams will gain greater control over their lighting infrastructure with less effort, and costs.

9.12 Cabinet Details

The Cabinet Details view shows collected asset information for the Cabinet IQ. As with the Edge IQ, custom asset fields may be added to collect any other information related to Cabinet IQ deployments and their environments.

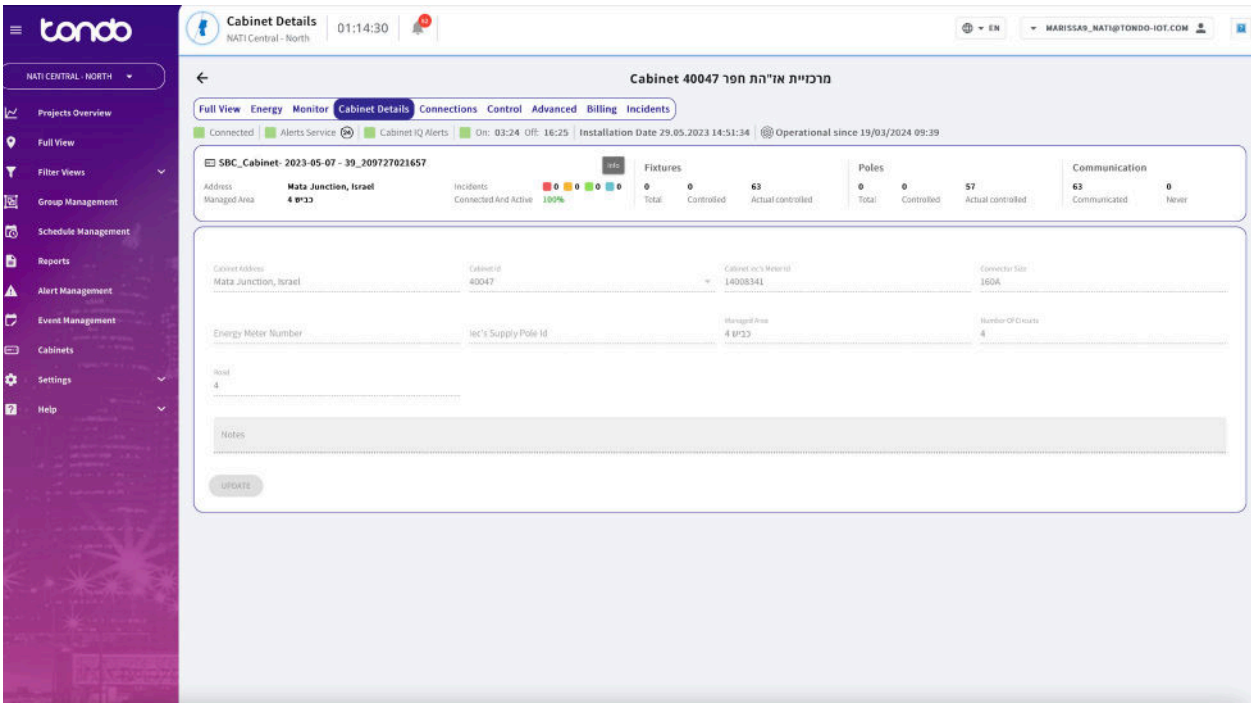


Figure 65: Cabinets - Cabinet Details

9.13 Connections

The Connections view of Cabinet IQ displays any meters, sensors, or other devices connected to Cabinet IQ. New connections may be added for devices and sensors connected to the I/O ports and relays and controlled by Cabinet IQ.

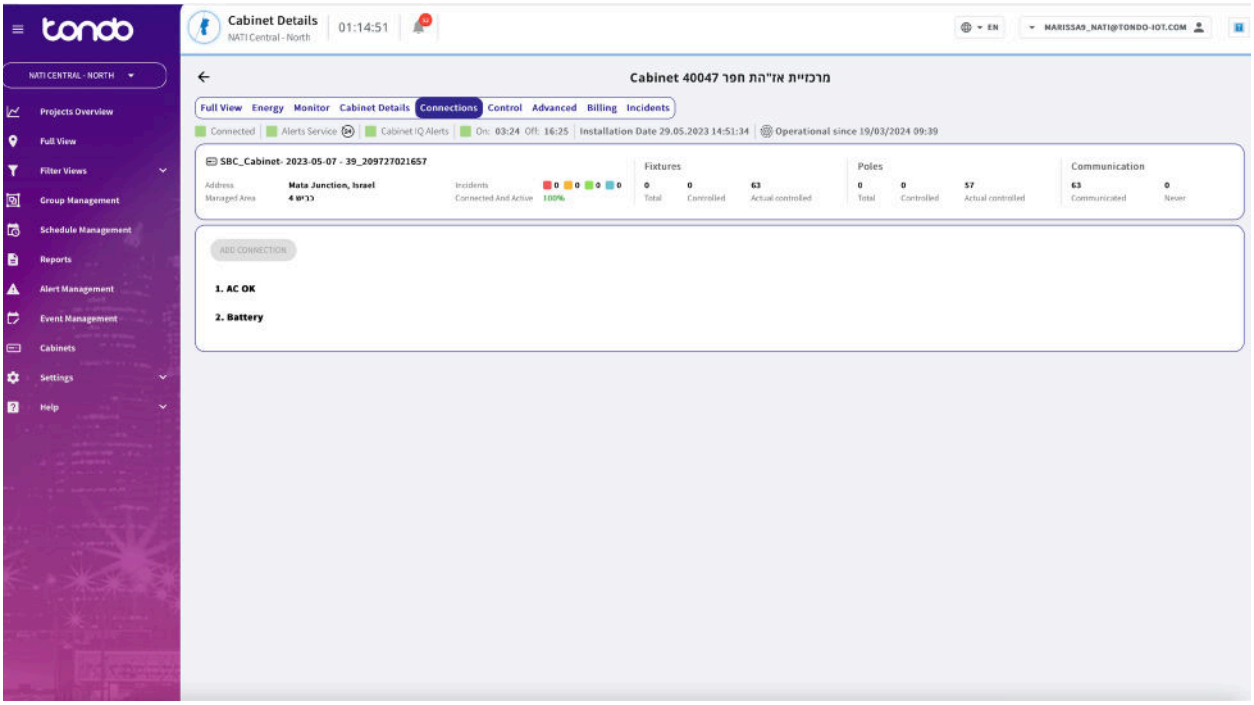


Figure 66: Cabinets - Cabinet Connections

9.14 Control

The Control view of Cabinet IQ displays the current status of control Connections.

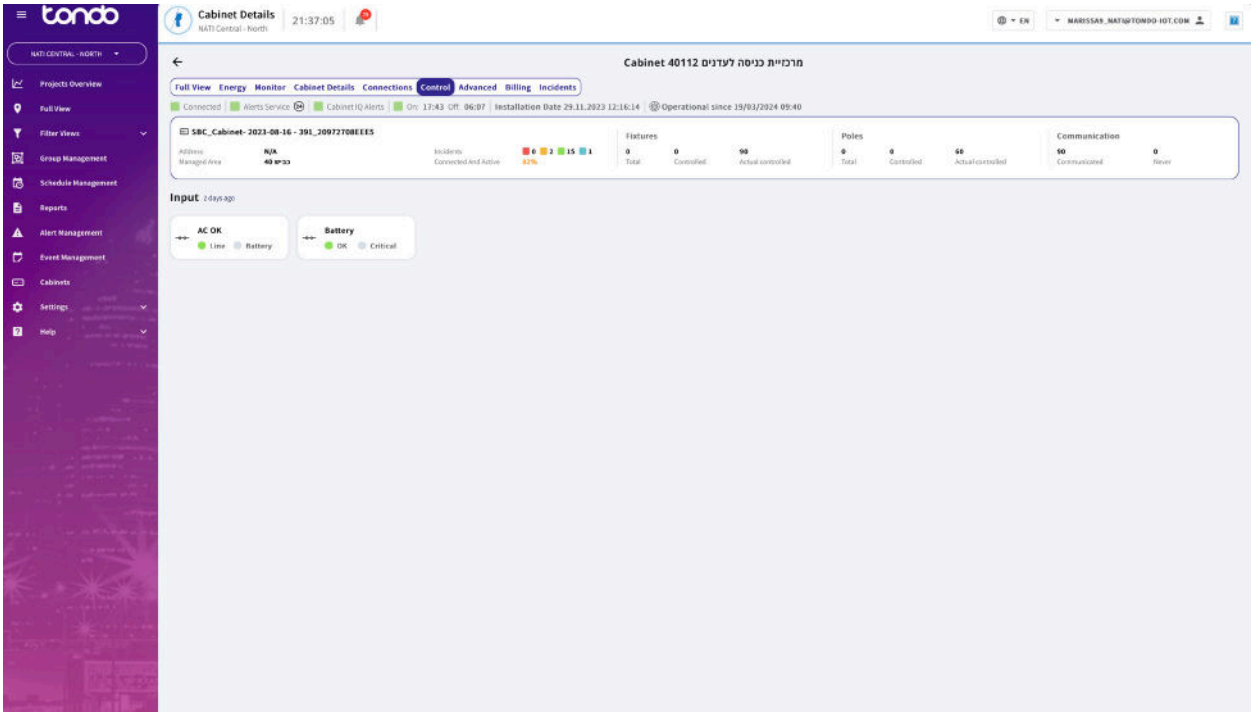


Figure 67: Cabinets - Control

Each Connection represents a relay or I/O connection to Cabinet IQ. Selecting a Connection provides details about the Connection's settings that control its behavior, including the AC power to the Cabinet as shown below.

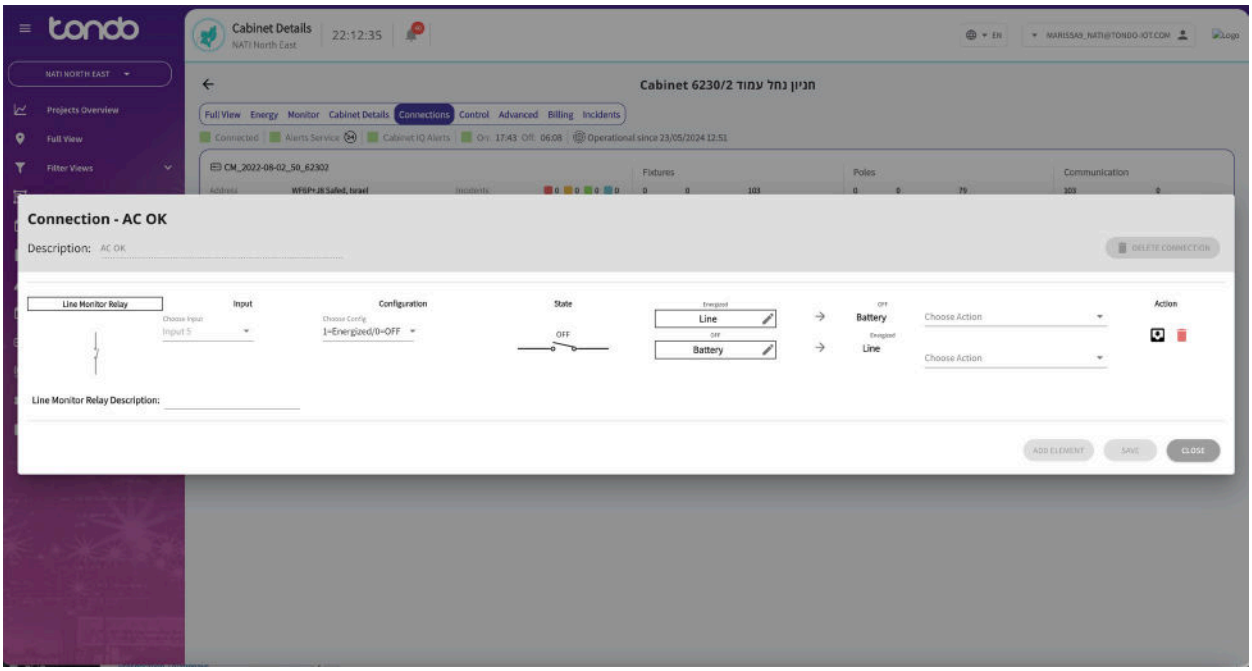


Figure 68: Cabinets - Cabinet Connections - AC Detail

Each Cabinet IQ has a 48-hour UPS to support operations in case of electrical service failure. Below you can see the connection status detail of that UPS.

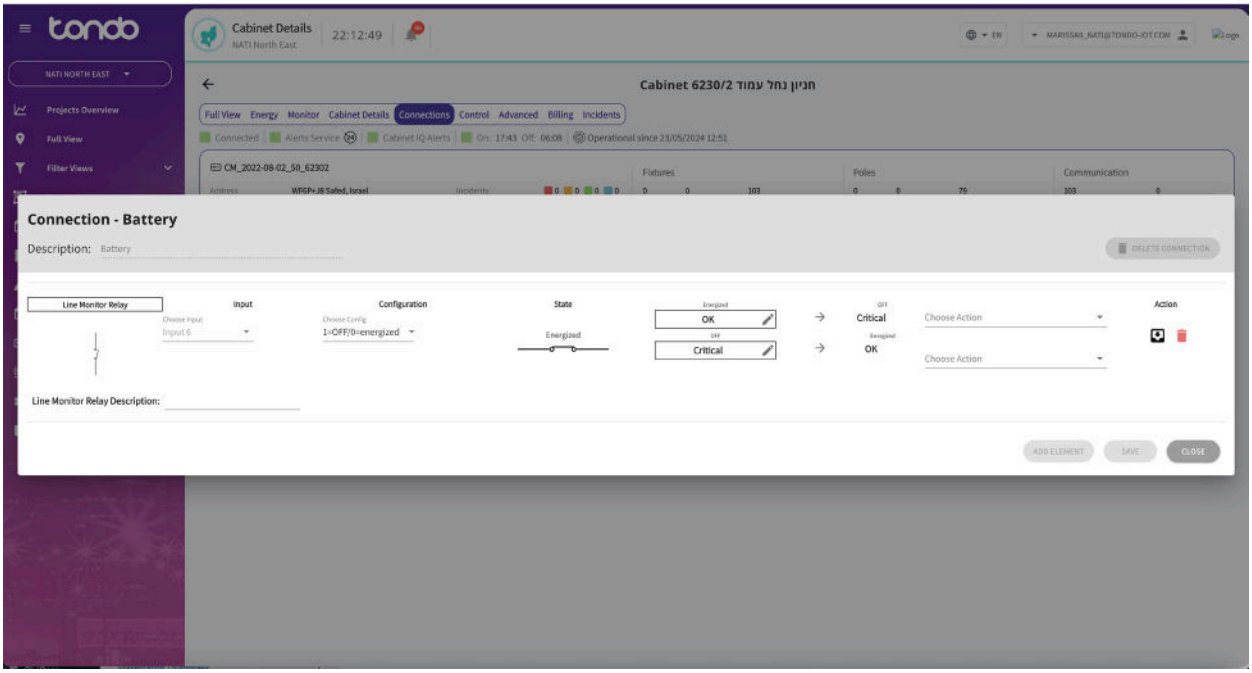


Figure 69: Cabinets - Cabinet Connections - Battery Detail

9.15 Advanced

The Advanced view of Cabinet IQ displays information typically used by Tondo Support and is generally not used by Tondo customers outside of a support call.

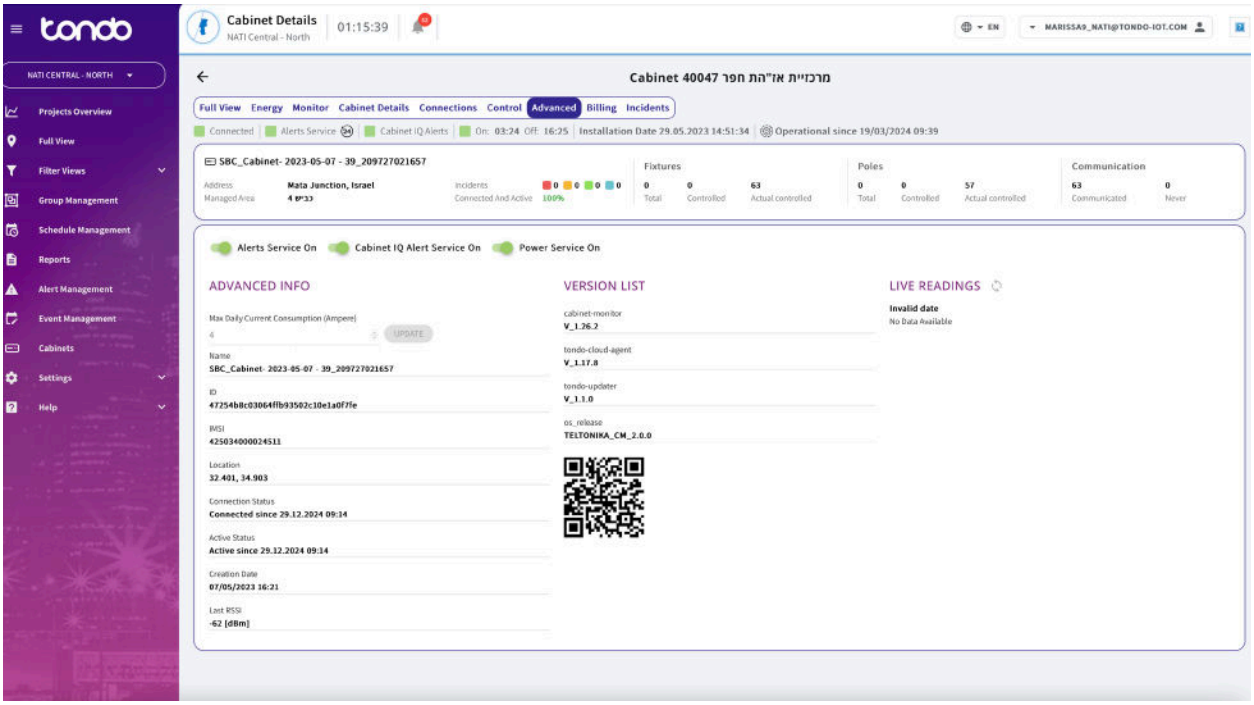


Figure 70: Cabinets - Advanced Information

9.16 Billing

The Billing view of Cabinet IQ displays energy consumption and Time-of-Use / Tariff energy consumption for any given period. This information is ANSI C12.1 Accuracy Class 0.5 billing- and revenue-grade accurate, ideal for reconciliation of energy billing and can be exported to CSV format for import into Excel and other software applications supporting the CSV format.

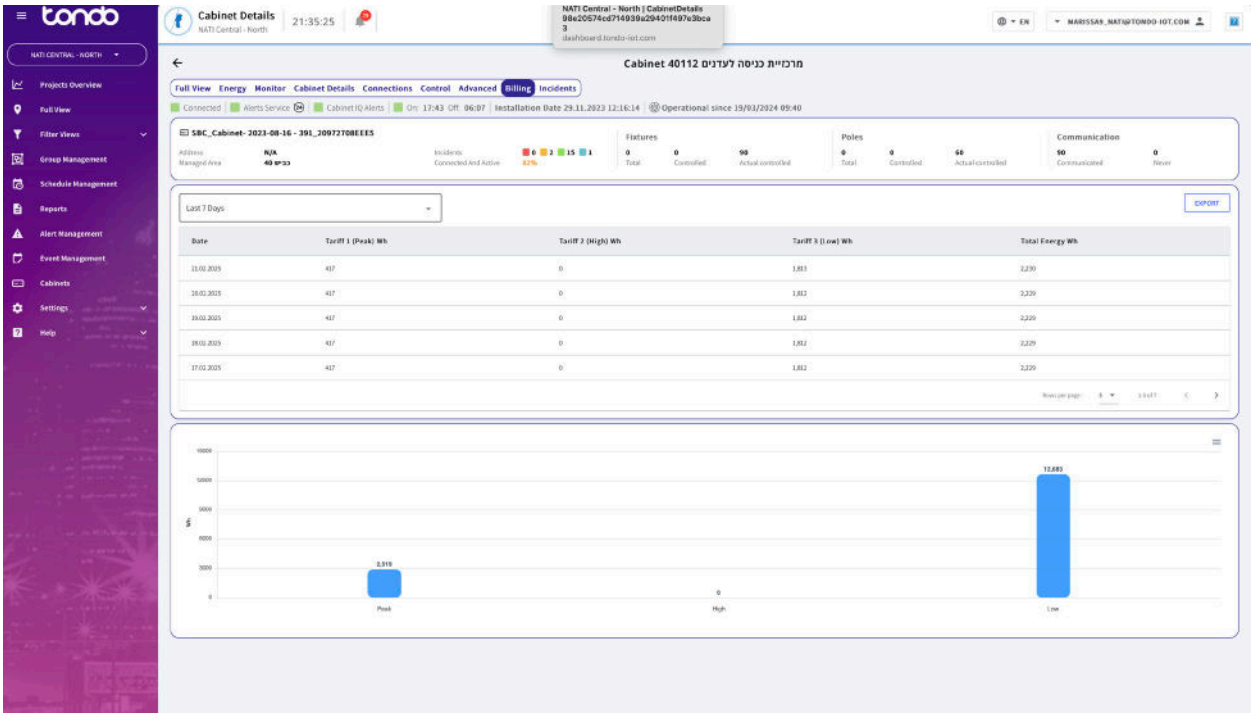


Figure 71: Cabinets - Billing

9.17 Incidents

The Incidents view of Cabinet IQ displays a list of anomalies detected by Cloud IQ and enables users to easily examine details of specific events and relevant data, as well as tagging each incident as “closed” as each is reviewed.

As with other Alert and Event data in Tondo’s Cloud IQ, integration with customers’ existing operations & maintenance management systems can automate the sending of critical issues to trouble-ticket systems for additional follow-up.

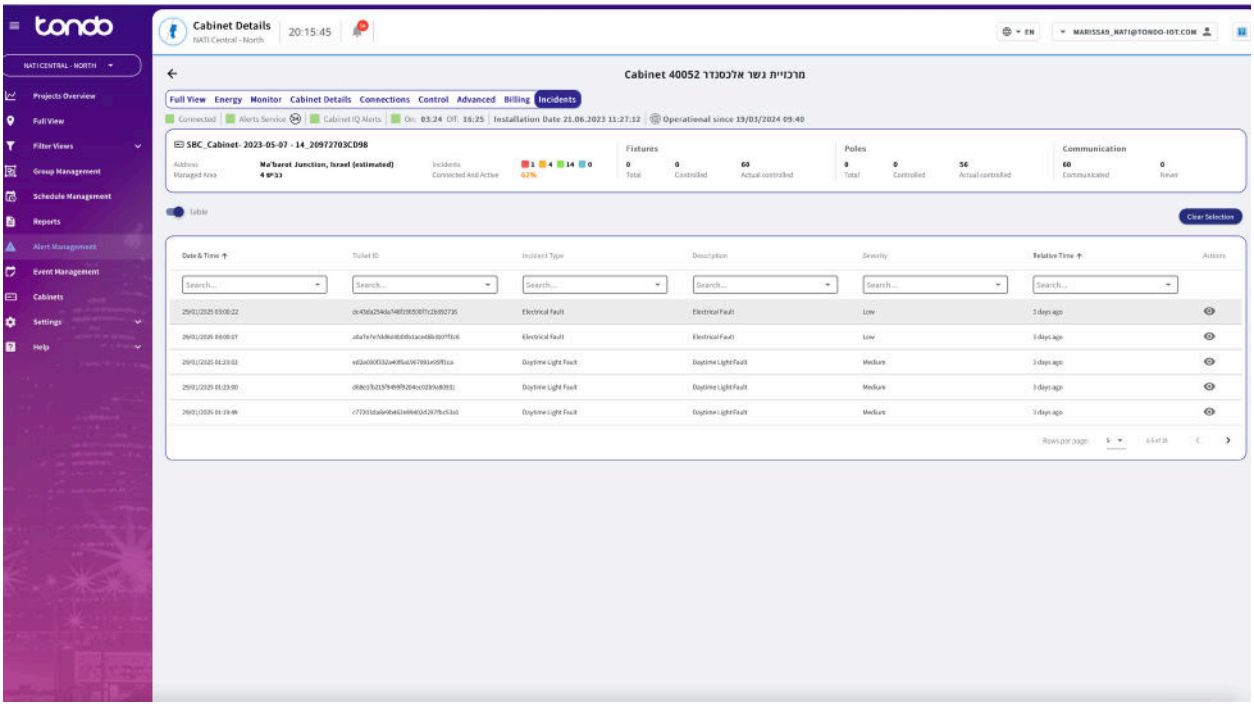


Figure 72: Cabinets - Incidents

10. Connecting Sensors and Controls

10.1 Connecting Sensors via Edge IQ Controllers

Tondo's Edge IQ controllers use wireless Bluetooth 5 LE/Mesh or on NEMA controllers, a direct-wire 24V Logic Signal Interface (LSI) connection is available for sensor and control connectivity. Zhaga socket controllers use DALI D4i for sensor connectivity.

Whether connected via Bluetooth or LSI direct-wired connections, Edge IQ utilizes the DALI D4i protocol to facilitate communications with connected sensors or controls. Connecting sensors via Edge IQ controllers is ideal for on-pole and on-fixture "Smart City" use-cases that do not require significant bandwidth, or where luminaires are equipped with a DALI D4i sensor socket through the luminaire driver.

For each type of sensor and scenario, Tondo will have created custom Event triggers, Alerts, and Incidents generated by Tondo's AI.

A socket pin diagram for Edge IQ can be viewed in the section, "Edge IQ NEMA Socket Connection" on page 20.

10.2 Connecting Sensors with Cabinet IQ

The Cabinet IQ system is designed to provide energy monitoring, automation, and infrastructure control using its built-in digital inputs (DI), relay outputs (RO), and communication interfaces.

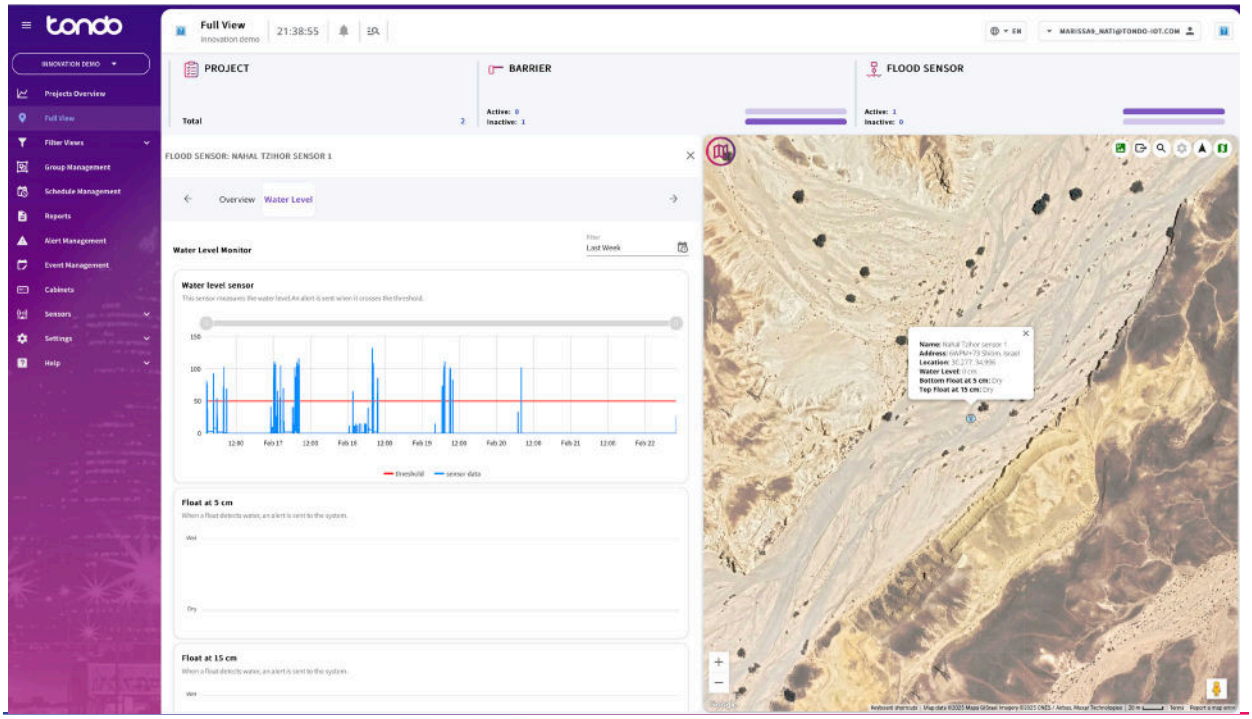


Figure 73: Sensors & Controls - Flood Sensor

While the standard configuration of Cabinet IQ is pre-configured for energy monitoring and power control, additional unused I/O capabilities can be leveraged for custom sensor integration and expanded functionality.

10.2.1 Understanding Cabinet IQ's I/O and Relay Capabilities

The standard configuration of Cabinet IQ includes six digital inputs (DI) and one relay output (RO) on the energy meter module. However, some of these I/O connections remain unused by default, allowing for additional sensors and automation devices to be connected.

Unused I/O in the Standard Configuration

- **Digital Inputs IN1, IN2, and IN3**: Used for Cabinet IQ system monitoring.
- **Digital Inputs IN4, IN5, and IN6:** Available for additional digital sensor connections.
- **Relay Output (RO):** Can be used for automated control actions, such as activating alarms, resetting power circuits, or triggering external systems.

These inputs and outputs provide opportunities to expand Cabinet IQ's capabilities for custom monitoring and automation applications.

10.2.2 Connecting Additional Sensors to Cabinet IQ

Digital Inputs (DI) – Monitoring External Sensors

Cabinet IQ supports dry-contact digital sensors that can be connected to its unused digital inputs (IN4, IN5, IN6) for event-triggered monitoring and automation. Connection is simple:

- Connect the sensor output to an available digital input (IN4, IN5, or IN6).
- Connect the sensor ground/common to COM.

Tondo's Cabinet IQ can optionally be configured with:

- Seven additional digital inputs (no relay outputs)
- Eleven digital inputs and four relay outputs

For each type of sensor and scenario, Tondo will have created custom Event triggers, Alerts, and Incidents generated by Tondo's AI.

Glossary of Terms

A

Adaptive Roadway Lighting – A lighting system that automatically adjusts brightness based on pedestrian or cyclist traffic levels adjacent to the roadway to match roadway lighting standards and optimize energy consumption and visibility.

Alert – A real-time, actionable notification indicating a problem, such as over-voltage, lamp failure, or abnormal power consumption.

ANSI - The American National Standards Institute

ANSI C12.1 – A standard for billing-grade energy metering, ensuring Tondo's metering accuracy aligns with industry requirements.

ANSI C136.41 – A standard defining the electrical and mechanical interface for streetlighting control receptacles, ensuring compatibility between smart controllers and luminaires.

ANSI C12.20 – A stricter standard for energy metering, ensuring Class 0.2 or Class 0.5 accuracy, making it suitable for revenue-grade metering in smart lighting applications.

ANSI C136.10 – Defines the physical and electrical interface for twist-lock photocontrol receptacles, ensuring compatibility between smart controllers and luminaires.

ANSI C136.50 – A standard that defines methods for measuring energy consumption in network lighting control (NLC) devices for outdoor lighting. It establishes metering accuracy requirements

ANSI C137.1 – A standard defining DALI communication for indoor and outdoor lighting, ensuring interoperability between different manufacturers' control devices.

ANSI C137.4 – Defines the security and networking requirements for IoT-enabled lighting systems, including encryption, authentication, and cybersecurity best practices.

ANSI/IES RP-8-22 – A recommended lighting practice for roadways and outdoor spaces, guiding adaptive lighting strategies to improve safety and energy efficiency.

B

Bluetooth 5.3 – The latest version of Bluetooth Low Energy (BLE) used in Tondo's Edge IQ controllers for short-range communication and device commissioning.

C

CAT-M1 – A low-power wide-area (LPWA) cellular technology optimized for IoT applications, providing long-range communication with better power efficiency than traditional LTE, and requires specific support for CAT-M1 on 4G cellular networks.

CAT1.bis – A variation of LTE Cat-1 designed for lower-cost IoT connectivity on existing , providing a balance between performance and energy efficiency. Unlike CAT-M1, CAT1.bis operates on existing 4G cellular networks.

D

DALI-2 (Digital Addressable Lighting Interface) – An open-standard lighting control protocol that allows individual luminaires to be digitally controlled, monitored, and adjusted for precise dimming and energy optimization.

DALI D4i – An extension of DALI-2 that enables luminaires to store operational and energy data, allowing for advanced metering, diagnostics, and smart city integrations.

E

Event – A logged occurrence that provides system insights, such as power fluctuations or maintenance activities, which may not require immediate action.

H

Hall Effect Sensor – A sensor in Cabinet IQ that measures electrical current (I1, I2, I3) using magnetic field detection, ensuring accurate energy monitoring. Also known as a Current Transformer sensor or CT sensor.

Hardware Security Module (HSM) – A tamper-resistant hardware device that securely stores cryptographic keys and performs encryption, authentication, and certificate management.

Harmonics - Integer multiples of the fundamental frequency in an AC power system, which can cause distortions in voltage and current waveforms. Excessive harmonics can lead to power quality issues, such as overheating, reduced efficiency, and equipment failures

I

Incident – An Event that triggers an actionable Alertin Tondo's system that encompasses multiple alerts or events, such as a cabinet failure or large-scale network outage.

Internet of Things (IoT) – A network of connected devices that collect and exchange data, enabling smart city applications like adaptive streetlighting and traffic monitoring.

K

kVAR (Kilovolt-Ampere Reactive) – A measure of reactive power, indicating energy that oscillates between the source and the load but is not converted into useful work.

kW (Kilowatt) – A unit of power measurement representing 1,000 watts, commonly used to measure electricity consumption.

kWh (Kilowatt-hour) – A unit of energy measurement, representing the amount of energy used over time (e.g., a 1kW device running for 1 hour = 1 kWh).

L

Load Shedding – Turning off non-essential circuits when power demand is too high, preventing overloads and blackouts

LTE (Long-Term Evolution) – A wireless communication standard for high-speed data transmission, used for IoT and smart city applications.

M

Mesh Networking – A decentralized network architecture where multiple interconnected devices (nodes) relay data between each other, enabling resilient, self-healing communication. In smart lighting, mesh networks ensure that streetlights remain connected even if some nodes fail or lose signal.

MFA (Multi-Factor Authentication) – A security method requiring users to verify their identity using multiple credentials, such as a password and a mobile authentication code.

N

NB-IoT (Narrowband IoT) – A cellular IoT technology optimized for deep coverage, low bandwidth, and minimal power consumption, ideal for applications like smart lighting and metering.

P

Phasor – Used in electrical power analysis to describe the magnitude and phase angle of voltage and current signals in AC power systems. Phasor analysis helps ensure balanced power distribution and detection of abnormalities such as phase imbalances or harmonic distortions

Power Factor (PF) – A ratio that indicates how efficiently electrical power is being converted into useful work. A power factor close to 1.0 is ideal, while lower values indicate inefficiency.

R

RBAC (Role-Based Access Control) – A security framework that restricts system access based on user roles, ensuring that only authorized personnel can modify or control lighting networks.

Reactive Power – The portion of electricity that does not perform useful work but is required to maintain voltage stability in an AC system.

Relay - an electrically operated switch that allows low-power control signals to activate or deactivate higher-power electrical circuits.

S

Secure Boot – A cryptographic process that ensures only trusted, signed firmware can run on a device, preventing unauthorized code execution.

Secure Data Logging - Permanent recording of energy usage ensuring historical tracking for audits and maintenance

T

TLS (Transport Layer Security) – An encryption protocol that secures data communication between Tondo Edge IQ controllers and Cloud IQ.

Time-of-Use (TOU) Billing – A pricing model where electricity rates fluctuate based on demand, encouraging energy use during off-peak hours to reduce costs.

Z

0-10V Dimming – A method for controlling light output where a voltage signal between 0V (off) and 10V (maximum brightness) determines the light intensity.

For more information, contact Tondo at support@tondo-iot.com

RF Exposure Information and Statement

This equipment complies with FCC and IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance of 20 cm between the radiator and your body. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

15.19

This device complies with part 15 of the FCC rules and RSS-247 of Industry Canada. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

15.21

NOTE: Unauthorized modifications could void the user’s authority to operate the equipment.

15.105

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.

- Increase the separation between the equipment and receiver.

-Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

-Consult the dealer or an experienced radio/TV technician for help

- This device and its antenna(s) must not be co-located or operating in conjunction with any other antenna or transmitter.