WHITE PAPER
2024

TCO Comparison of Battery-Powered vs. OPV-Powered **IoT Sensors**

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Executive Summary

The deployment of Internet of Things (IoT) solutions has revolutionized industries by providing real-time data, and has increased automation and improved decision-making processes. However, IoT deployments often include thousands of battery-powered sensors that require periodic replacement, raising concerns about the Total Cost of Ownership (TCO) over the long term. This White Paper, "TCO Comparison of Battery-Powered versus Organic Photovoltaic (OPV)-Powered IoT Sensors", delves into the critical issue of TCO for companies that rely on IoT solutions with battery-powered sensors. While these sensors offer flexibility and cost-effectiveness in the short term, their maintenance and battery-replacement costs can accumulate significantly over time.

Key Highlights

- **Comparing Sensor Solutions:** We provide a comparison between battery-powered IoT sensors and OPV-powered IoT sensors on a number of critical factors. These are power source, TCO, environmental impact, reliability, scalability, and application flexibility.
- **Implications for TCO:** We delve into the key factors that play a significant role in determining the TCO for IoT solutions over a 10-year period.
- **TCO Calculation Methodology**: We present a TCO analysis over a 10-year period, incorporating various cost factors such as sensor costs, battery replacements, maintenance, and energy consumption.
- **Real-World Case Study:** To illustrate the practical application of a TCO analysis and the impact of sensor choice, we provide a detailed case study of an actual IoT sensor deployment by a large corporate global enterprise with hundreds of offices worldwide.

This white paper serves as a valuable resource for decision makers and professionals seeking to evaluate the true cost of battery powered IoT sensor deployments and make informed choices between available sensor solutions. By taking a holistic view of TCO and comparing sensor options, organizations can optimize their IoT strategies and maximize the long-term benefits of their IoT investments.

SECTION 01

Comparing Battery-Powered IoT Sensors to OPV-Powered IoT Sensors

1. Power source

Battery-Powered Sensors:

- Depend on disposable or rechargeable batteries.
- Require periodic battery replacement every 3 to 4 years.
- Power availability is limited by battery life.

OPV-Powered Sensors:

- Use OPV technology to harvest energy from indoor ambient light.
- Do not rely on disposable batteries, offering a sustainable and maintenance-free power source.

2. Total Cost of Ownership

Battery-Powered Sensors:

- Initial deployment cost is typically lower due to inexpensive batteries.
- TCO over a 10-year period can be significantly higher when factoring in battery replacement, labor, and disposal costs.
- Maintenance and replacement costs can fluctuate based on the number of sensors and battery types used.

OPV-Powered Sensors:

- Higher upfront cost for OPV-powered sensors.
- Reduced TCO over the long term (10 years), as battery replacement is not required.
- Stable and predictable maintenance costs.

3. Environmental Impact

Battery-Powered Sensors:

- Generate electronic waste (e-waste) when batteries are replaced.
- Potential environmental impact during battery disposal arises from the disposal of materials like lithium.

OPV-Powered Sensors:

- Environmentally friendly, as they do not contribute to e-waste.
- Sustainable power source, reducing the overall carbon footprint.
- Align with green and eco-conscious initiatives and regulations.

4. Lifespan and Reliability

Battery-Powered Sensors:

- Limited lifespan determined by battery life.
- Risk of sensor downtime when batteries fail.
- Reliability can vary based on battery quality.

OPV-Powered Sensors:

- Extended lifespan as OPV technology is durable and resilient.
- Consistent operation with minimal downtime.
- Enhanced reliability, particularly in remote or inaccessible locations.

5. Scalability

Battery-Powered Sensors:

- *L*arge scale deployment of battery-powered sensors spread over many locations will not be viable due to the associated maintenance costs for battery-replacements.
- Frequent battery replacement can be a logistical challenge for deployments of sensors at moving assets like containers.

OPV-Powered Sensors:

- *S*calable without the constraints of battery replacements.
- Suitable for large-scale deployments with reduced maintenance requirements.

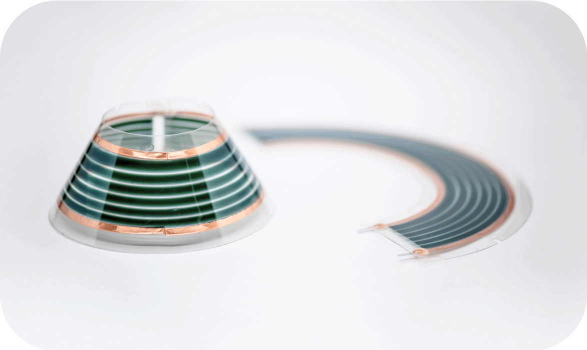
6. Application Flexibility

Battery-Powered Sensors:

- *S*uitable for applications where replacing batteries is feasible and cost-effective.
- May be preferred for short-term or temporary deployments.

OPV-Powered Sensors:

- *I*deal for long-term and remote applications where continuous, maintenance-free operation is essential. Low maintenance will favor OPV-based sensors and enable the notion of Connect and Forget!
- Well-suited for IoT deployments in challenging environments, such as smart meters in cellars, smoke detectors at ceilings or sensors at industrial machinery.



Key take-aways OPV versus batteries in IoT sensors

The choice between battery-powered IoT sensors and OPV-powered IoT sensors depends on specific project-requirements and objectives. While battery-powered sensors may come at a lower one-time costs, they come with on going maintenance and environmental considerations which could be substantial when considered for the entire life time of a solution.

OPV-powered sensors provide a sustainable and reliable power source, reducing long- term TCO and minimizing environmental impact. Organizations should assess their IoT needs, budget, and sustainability goals when selecting the most suitable sensor solution.

In Section II the key cost drivers will be reviewed impacting the Total cost of Ownership of typical IoT solutions. In this context also the direct and indirect impact of batteries powering sensors will be reviewed.

In Section III an analysis of the Total Cost of Ownership will be presented for a real-live case of a smart building solution at a large (non-disclosed) enterprise client. The TCO comparison between 2 scenarios will be done between battery-powered devices versus OPV powered sensors.

SECTION 02

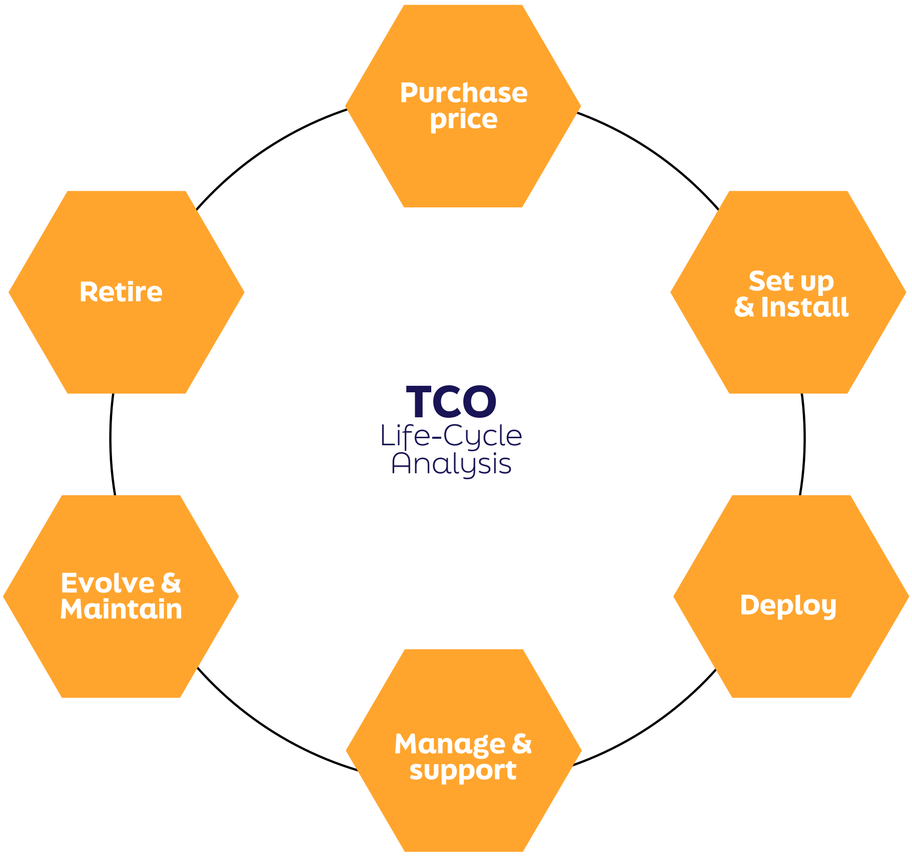
Cost Drivers for TCO

TCO for IoT sensor deployments is influenced by a myriad of factors, both direct and indirect. In this section, we delve into the key factors that play a significant role in determining the TCO over a 10-year period. Understanding these factors is essential for organizations seeking to take informed decisions about their IoT deployments.

1. Sensor Costs

- The upfront cost of IoT sensors is a crucial component of TCO. The price per sensor unit may vary based on factors such as sensor type, technology, and features.
- Organizations should consider sensor costs when calculating TCO, especially for large-scale deployments with numerous sensors.

Total cost of ownership (TCO) model



2. Battery Replacement Costs

- For battery-powered sensors, one of the most substantial ongoing expenses is battery replacement. Batteries typically have a finite lifespan, necessitating periodic replacements.
- Factors affecting battery replacement costs include the type of batteries used, the frequency of replacement, and labor costs associated with the replacement process.
- The costs of manual labor to travel to and locate the relevant sensors, demount the sensor, and replace batteries and administer the task is a cost that is oftentimes forgotten, but can be considerable.

3. Maintenance and Support Costs

- Maintenance and support play a critical role in TCO. These costs encompass regular sensor upkeep, troubleshooting, and technical support.
- Organizations must account for ongoing maintenance and support expenses, particularly when dealing with a large number of sensors.

4. Data Transmission Costs

- Data transmission is a fundamental aspect of IoT deployments. The method and frequency of data transmission can impact TCO. The wireless protocol used by most IoT devices is LPWAN (like LoRaWAN®, NB-IoT, mioty), well suited to be sourced by energy harvesting.
- Costs may include data transfer fees, cellular connectivity charges, or expenses associated with using communication protocols.

5. Installation and Deployment Costs

- The initial installation and deployment phase involves labor, equipment, and infrastructure costs. These upfront expenses contribute to the overall TCO.
- Complex installations or remote deployments may have higher associated costs.

6. Energy Consumption Costs

- Energy consumption is a significant factor in battery-powered sensors. The power required for sensor operation directly affects battery life and, consequently, TCO. LPWAN wireless protocols can enable a sensor lifetime of multiple years.
- Needless to say, less energy-efficient sensors will lead to lower operational costs over time.

7. Scalability Considerations

- Scalability is essential when evaluating TCO. As IoT deployments expand, organizations must anticipate the costs associated with adding new sensors, regularly replacing batteries, and other maintenance costs. Customers need to implement smooth processes for shipping, onboarding and configuring sensors across multiple sites around the globe in order to minimize operational costs.
- Organisations tend to forget to include operation costs (OPEX) for maintaining the IoT solution during the lifetime of the deployment. Replacing batteries of thousands of sensors in different locations will kill many business cases for large IoT deployments.
- Needless to say, the scalability of the IoT solution will influence TCO positively or negatively in a substantial way (see section III).

8. Environmental Impact

- Environmental considerations encompass not only the environmental impact of sensor disposal (in the case of batteries) but also the overall sustainability of the IoT solution.
- In large IoT deployments, of say 100,000+ sensors, this could result in more than 1M batteries wasted during the lifetime of such IoT solutions. If OPV energy-harvesting would have been deployed instead of battery-powered sensors, this would have eliminated the waste of batteries.
- Choosing eco-friendly options aligns with corporate sustainability goals and reduces long-term environmental costs.

9. Lifespan and Reliability

- The lifespan and reliability of sensors significantly affect TCO. Longer-lasting sensors with high reliability can reduce replacement and maintenance costs, which requires also to eliminate batteries in the product-design, in order to avoid battery replacement and device failure due to battery leakage.
- Downtime of sensors or other devices due to drained batteries can result in operational disruptions and increased expenses, hence next-generation product-design needs to consider including energy harvesting.

10. Application Specific Factors

- The specific application and use case may influence the TCO significantly.
- Battery-powered devices only perform as long as batteries are not dead, which is an uncertainty factor for the large volume of mission-critical use cases where reliability and accuracy of data is key, e.g. trackers and temperature loggers in the pharmaceutical, chemical and food industry.
- The value of missing data due to sensors that have gone out of power has not been included in this TCO analysis, as they depend very much on the use case. However, each customer should include this based on their specific use case.

SECTION 03

TCO Comparison of Battery-Powered versus OPV

In the following section of this white paper, a cost comparison is shown for a real-world Enterprise site-deployment of a Smart Building solution based on battery-powered and OPV-powered wireless sensors. The use case has been added as an example to calculate the real costs for an enterprise user (B2B), providing insights, calculations, and real-world examples to help organizations comprehensively assess and manage their TCO for IoT sensor deployments. The use case focuses on room and desk occupancy sensors deployed in each room and under every desk of the building. This allows to monitor in real-time the usage of scarce resources, i.e. work desks in offices and meeting rooms. The sensors are based on the LoRaWAN® wireless protocol, which is one of the lowest power consuming wireless technologies, hence used in ample IoT solutions.

Following specifics have been the basis of the TCO analysis:

- The sensors deployed are using batteries: 3.6V ½ AA Li-SOCl2, 1200mAh.
- Batteries are specified to last 16 months, hence assumed to be in need to be replaced each year.
- Time to open the device with a screwdriver and replace batteries has been assumed to be 3 minutes.
- The price of such a lithium battery is assumed to be EUR 5.00.
- Total hourly FTE costs to execute this operational task is EUR 75.00 per hour.

The Total Cost of Ownership has been calculated in such a way that labor costs have been included in scenario 1 (battery-powered), which would not be required in scenario 2 (OPV-powered). The specific activities for maintaining the battery-based sensors over the lifetime of 10 years can impose a huge cost to an organisation. The following tasks have been included in the TCO analysis. The Total Cost of Ownership has been calculated in such a way that labor costs have been included in scenario 1 (battery-powered), which would not be required in scenario 2 (OPV-powered). The specific activities for maintaining the battery-based sensors over the lifetime of 10 years can impose a huge cost to an organisation. The following tasks have been included in the TCO analysis:

- Organizing logistics for having sensors available on site to be serviced (e.g. pallets or containers).
- Travel time of staff to go on site to do the job of replacing batteries.
- De-mounting the sensors and putting back on e.g. walls or desks.
- Recycling the batteries in a proper way.

In our use case, the Enterprise has deployed an IoT solution in 25 locations, with 1,000 sensors deployed at each location. The TCO for this Enterprise for the two scenarios is shown below.

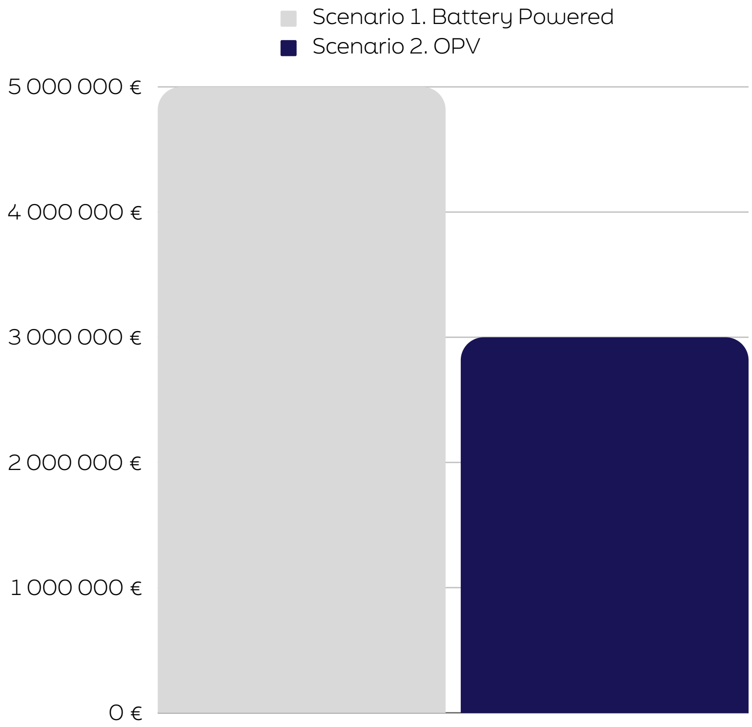
Results of TCO Analysis

Comparing the two scenarios shows that scenario 2 (OPV-powered) will benefit from a TCO reduction of 41% compared to scenario 1, i.e. the classical deployment of battery-powered IoT sensors.

Our calculation shows that this client's TCO over a period of 10 years would be:

- **Scenario 1:** Battery-powered sensors: TCO equals €5 Mio.
- **Scenario 2:** OPV-powered sensors: TCO equals €3 Mio.

TCO comparison
Battery powered vs. OPV for a smart building IoT solution



This equals a saving of €2M for this particular case, which clearly advocates for the Organic Photovoltaic energy harvesting solution from a cost (TCO) standpoint.