Overcoming the Battery Obstacle to Ubiquitous Sensing — Finally

Why Self-Powered Sensors are the Game-Changer

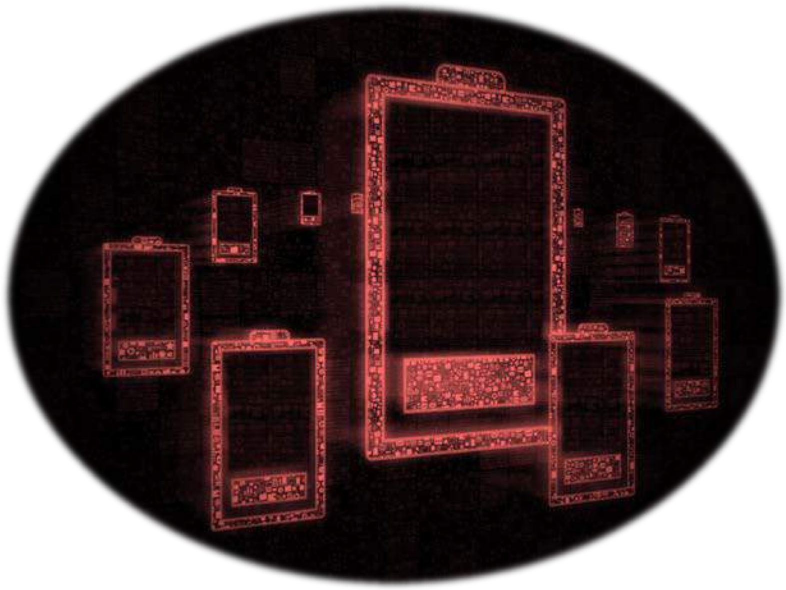
Introduction

Equipping objects with computing devices that lets them transmit data over the Internet has promised for years to revolutionize the way businesses operate and individuals live. And although the Internet of Things (IoT) is clearly affecting our personal lives—via smart phones, connected thermostats, wearable fitness trackers, and even water bottles that monitor our drinking habits—it has been slower to reach ubiquity than experts predicted, and far slower than expected to take hold among industrial businesses.

In 2012, IBM predicted 1 trillion connected devices by 2015.[1] The world didn't get close to that number. So in early 2017, Gartner forecast 50 billion devices by 2020.[2] But even Gartner's prediction might be optimistic, so Electronic Component News has since estimated 25 billion IoT devices by 2020.[3] And according to a Cisco study, 61% of IT and business decision-makers admitted they had "barely scratched the surface" of what IoT could do for their companies.[1]

If it has such game-changing potential, why have businesses been slower than anticipated to deploy IoT technology? One reason has been the fact that powering the IoT revolution could demand 25 billion, or 50 billion, or 1 trillion batteries. And that's no small problem.

This paper will explore how one major obstacle—the battery problem—has hindered adoption of the Industrial Internet of Things (IIoT) and deprived industrial firms of its significant benefits, such as pervasive sensing capabilities that can generate actionable intelligence never before accessible. We will then discuss a new technology that solves the battery problem entirely—self-powered wireless sensors—an innovation that can finally help businesses realize the *trillions* of dollars in value promised by the IIoT.



The Trillion-Battery Problem

Let's think through one of the implications of IBM's trillion-device forecast. That's a trillion batteries needed to keep those trillion IoT sensors collecting, analyzing, and sending data.

Now, let's talk battery life. A paper presented at the 2017 Kyoto Symposium on VLSI Circuits described new methods the industry is working on to extend battery life to 10 years for IoT devices. In fact, the paper's title is: "Reaching 10 Years of Battery Life for Industrial IoT Wireless Sensor Networks."[4]

Even if we assume the paper's authors are correct in their prediction, and the industry eventually achieves its goal of a 10-year lifespan for the average IoT battery, guess how many batteries would need to be replaced every day in a trillion-device world? The answer: 273,972,603. Even worse, if industry falls short of that goal and delivers only a two-year battery lifespan, that means every person on the planet (all 7.4 billion) is changing a battery every five days.

In a best-case scenario, powering 1 trillion IoT devices would require replacing 274 million batteries every day. And that's assuming those batteries all reach their full 10-year life expectancies. Clearly, this is not a feasible plan.

Can We Replace the First 137 Million Batteries Before Lunch?

Of course, you might be thinking, this trillion-device estimate lacks context. It doesn't tell you much about what the battery problem would mean specifically for your manufacturing plant or industrial facility. So let's put this in real-world terms that reflect how you might actually leverage IoT in your own business.

Imagine you were to deploy 10,000 Industrial IoT devices across your facilities—sensors strategically placed to transmit real-time data about the health and performance of your machines and equipment, to monitor temperature and air quality in various sectors, to check for toxins that might have leaked, to relay the status of your steam system, HVAC systems, and other vital infrastructure.

If we assume an optimistic notion of a 5-year average life in those 10,000 batteries, your team would be replacing roughly 2,000 batteries each year, or about 5 every day (think of the household smoke detector problem, but on steroids). And depending on the types of devices we're talking about, the batteries themselves could cost anywhere from a few dollars to several hundred dollars each to replace. Perhaps even more concerning, though, is this point from ECN Magazine: "The cost of getting to a remote sensor to change a battery is often much higher than the cost of the battery itself."[3]

All of this helps explain why, according to a 2017 report cited by the Institution of Mechanical Engineers, "Batteries must be eliminated for the Internet of Things to flourish."[5]

Batteries Cannot Sustain the IoT

Required Battery Replacements per Day

Battery Lifetime (Years)	Number of Assets Monitored: 10 B	20 B	50 B	100 B	1 T
1	27 M	55 M	137 M	274 M	2,740 M
2	14 M	27 M	68 M	137 M	1,370 M
3	9 M	18 M	46 M	91 M	913 M
5	5 M	11 M	27 M	55 M	548 M
10	3 M	5 M	14 M	27 M	274 M

We cannot do ***this***

1 B+

or even a "best case"

274 M

times in a ***single day***

5 Reasons Batteries Restrict Cost-Effective IIoT Deployments

In a recent report on the drawbacks of batteries in electronic products, IDTechEx argues that continuing to deploy billions of battery-powered sensors—many of which will be cost-prohibitive to replace when they die—could eventually undermine 80% of IoT's potential value over time.[6]

Let's examine five reasons batteries can create problems for a business deploying an Industrial IoT sensor network.

1 Battery-powered sensors require manual maintenance

The most obvious issue, as the IDTechEx report noted, is that all batteries eventually need to be replaced. As we pointed out earlier, the cost of accessing and replacing dead batteries—because such processes must still be done manually—is often much greater in resources and man-hours than the cost of the new battery itself.

This need for frequent manual effort immediately defeats the core value of connected sensors. Indeed, one of the primary reasons manufacturers and industrial-plant operators turn to IoT sensors in the first place is that the automated data coming from those devices can eliminate the need for physical inspections of equipment, machinery, pipes, or other assets.

If all of those sensors themselves need to be manually checked on a regular basis to ensure that their batteries are functioning and/or to ultimately replace those batteries, then the organization has in effect traded one time-consuming manual maintenance schedule for another.

Instead of enjoying the benefits of your new data streams

You'll spend precious time replacing batteries

2 Batteries' finite lifespans can lead to gaps in mission-critical data

The inevitablility of a dead battery can have consequences beyond the marginal labor and capital resources required to inspect and replace batteries.

Unless the team overseeing a plant's IoT sensors discovers a dead battery immediately and is able to quickly get out to the sensor and replace it, the plant will permanently lose whatever data the sensor would have been collecting and transmitting in the interim. To make matters worse, as a Clemson University paper points out: "Batteries wear out quickly in wireless sensor networks, even when carefully managed."[7]

Because some of an industrial plant's sensors record and stream data that are mission-critical for safety and compliance, dying batteries can create significant hazards for the business.

3 To conserve battery life, sensors are often configured to transmit data less frequently

Ideally, an IoT device at an industrial plant—say, a sensor positioned near the facility's chemical operations to continuously monitor the atmosphere for toxic leaks—should be transmitting its data extremely frequently. Updates several times a minute are ideal.

But every data transmission consumes power. So, to extend battery life, many IoT sensors are unfortunately configured to transmit data far less frequently than would be ideal—sometimes in batches as infrequently as once every 24 hours.

This can give a plant's operators an inaccurate picture of the data a sensor is capturing. With updates only once a day, for example, a manufacturing plant's team might get an erroneous picture about the environmental quality of a given facility or the condition of a given asset.

Over time these inaccuracies, as well as the potential for false positives and false negatives, can increase exponentially, rendering the sensor's data increasingly misleading and failing to deliver on the IoT's promise of "real-time" awareness.

4 A battery's physical dimensions can limit sensor functionality

As an article in Electronic Specifier magazine explains, batteries are often the largest part of an IoT sensor system, leaving engineers limited choices of which batteries to add to their sensors.[8]

Moreover, as the Clemson University paper explains, the size, weight, and dimensions of the battery often limit the usefulness of the sensor. This is because those physical characteristics of the battery can restrict both the types of applications a sensor can perform and which other components the battery can coexist with on the sensor's board, as well as where it can be deployed (with embedded locations, of course, off limits due to required battery changes).

5 Batteries can create safety risks and cause environmental harm

Finally, as the US National Institutes of Health (NIH) reports, the lithium batteries commonly used in IoT sensors "may contribute substantially to environmental pollution and adverse human health impacts, due to potentially toxic materials."[9]

You can see why this might be the most concerning aspect of the continued deployment of battery-powered IoT devices around the world—particularly if these devices are rolled out in the coming years by the billions or tens of billions as predicted.

The NIH report explains that lithium batteries pose health risks to humans due to the leaching of cobalt, copper, and other substances, and they can harm the environment through leaching such substances as thallium and nickel.

Source: *US National Institutes of Health report, "Potential Environmental and Human Impacts of Rechargeable Lithium Batteries in Electronic Waste"*

As you can see from the graph above, lithium batteries have shown far higher concentrations of all of these metals than the government's minimum threshold required for classifying a substance as hazardous waste.

A Final Reason Not to Want Batteries in Your IIoT Sensors

Another important concern cited in the Clemson University paper is that, unlike other areas of technology, batteries have historically shown slow rates of performance improvement over time.

The paper points out that Moore's Law (the observation that semiconductor performance doubles roughly every 18 months) does not apply to the chemical and manufacturing processes used in the production and research of battery technology.

For example, after batteries received their most recent "upgrade"—the move to lithium, the lightest substance available for production—performance improvements to batteries have been at most a few percent a year, not nearly enough to keep pace with the advances in computing power in general, or the increasing demands of IoT devices in particular.

A Different But Related Problem with Most IIoT Solutions

The battery problem also serves as a helpful jumping-off point here for us to explore a related weakness inherent in most Industrial IoT networks: the lack of cohesion among the various components in many IoT devices.

For an IoT network to work optimally, the entire ecosystem—wireless sensors, data capture and analytics tools, software—should be unified, designed at the system level to work as a unit.

Unfortunately, many IoT sensors are built with a component-level focus—pulling together disparate parts, made by different manufacturers and built with different specs and applications in mind. This lack of system-level unification in IoT design falls short for two reasons:

1 Not all components will necessarily work together to prolong battery life

Yep, we're back to the battery problem, although this subset of the problem involves a unique set of challenges.

With existing commercially available parts, the combined energy needed to power all of a sensor's operations—data sensing, processing, memory, wireless communication—necessitates a battery, particularly if this sensor is built using disparate components from different sources.

Some manufacturers are developing components for wireless IoT sensors billed as "ultra-low-power," and that's great. But when an end-user pulls together a set of disparate components, we're back to the battery problem.

The microcontroller might be built for low power consumption, but what if the radio, or temperature sensor, or clock chip isn't? Ultimately, despite the burdensome integration effort, today's available technology simply does not allow an end-user to build a useful, fully integrated sensor network that leaves the battery behind.

2 A sensor built on disparate components could lead to a suboptimal system

Another weakness in sensors built from disparate components is that these sensors often can't effectively respond to the inevitable challenges an IoT network will face.

Imagine, for example, that within some of your wireless sensors the data processing capability is becoming overloaded. If your system is comprised of disparate, standalone hardware and software components that don't communicate seamlessly with each other, you might have difficulty solving that problem—and you might not even be alerted that the issue exists. The data processing tools will simply continue working as hard as they can to meet the demand, until they fail, and none of the other parts of your system will come to help.

Now imagine that your entire IoT network was built as a unified ecosystem—with all pieces designed to work together, from data acquisition to processing to analysis to transmission.

In this type of cohesive environment, you can much more easily modulate and adjust your system to meet your changing needs. If some of your processors are becoming overloaded, the system can transfer some of the data-processing workload to less-taxed areas of the system.

The Two-Pronged Solution to IIoT: Batteryless Sensors, System-Level Design

Due in large part to the two related weaknesses we've discussed here—the need for batteries to power every IoT sensor, and the fact that most IoT networks aren't built as cohesive systems—the current approaches to Industrial IoT simply will not allow the technology to scale cost-effectively, and will in fact create many ongoing challenges and costly setbacks over time.

What the industry needs, then, is a two-pronged solution to make IoT feasible for manufacturing and other industrial facilities.

First, we need sensors that won't ever require batteries.

For the reasons we've explored in this paper, batteries are often the limiting factor in how much and how cost-effectively an IoT infrastructure can scale. True ubiquitous sensing will require devices that generate power through some means other than a built-in battery.

So consider the game-changing nature of being able to ramp up deployment of IoT sensors everywhere without the need to add, monitor, or replace a single battery.

- 50 billion IoT devices worldwide: 0 batteries needed
- 1 trillion IoT devices worldwide: 0 batteries needed
- **Most importantly, your facility's 10,000 IoT devices: 0 batteries needed**

The solution: self-powered sensors that can run indefinitely by harvesting energy from their immediate environment.

Second, we need an end-to-end IoT solution that works as a unified ecosystem.

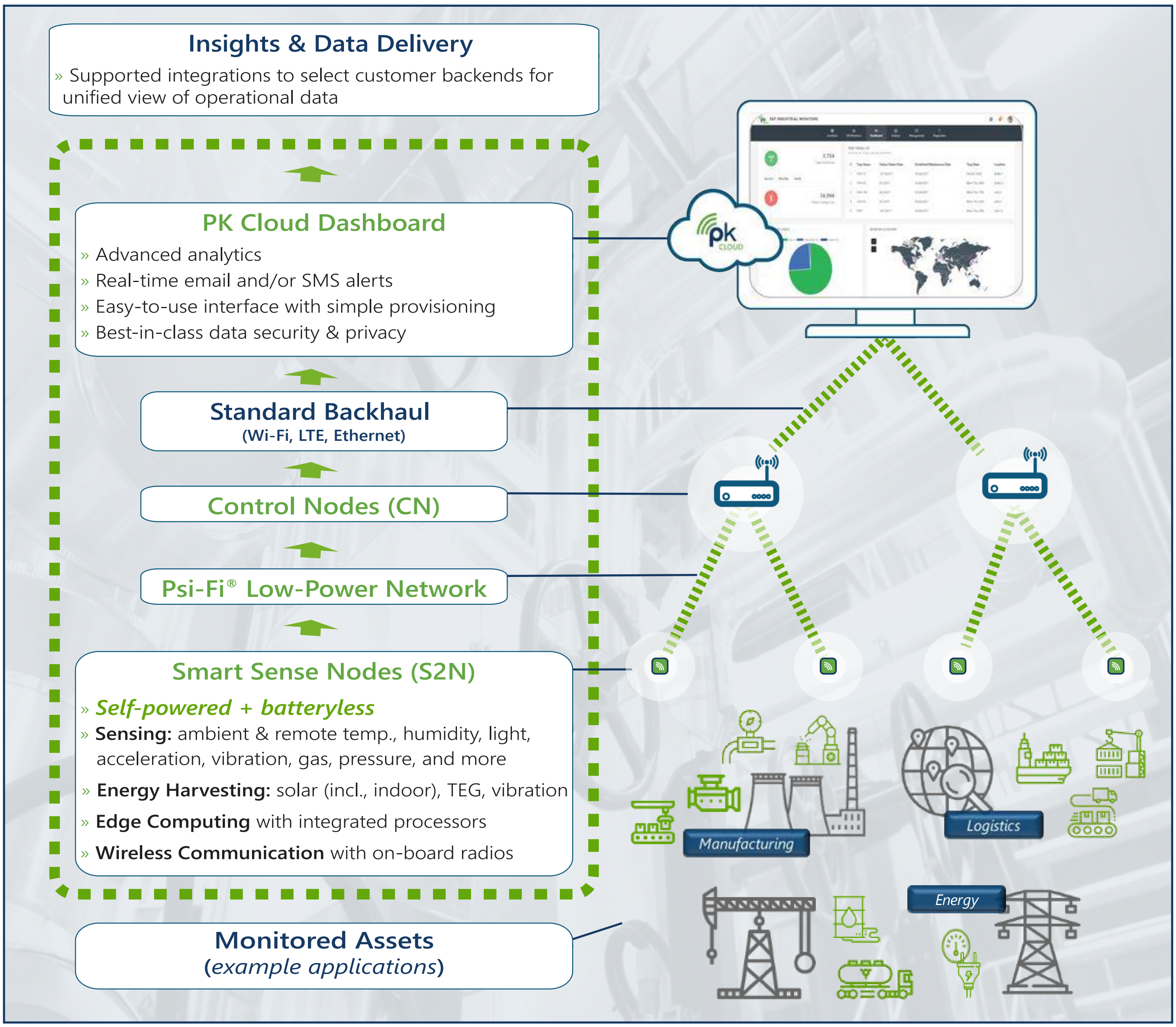
Once we have solved the battery problem, the next goal is to migrate away from the industry-standard approach of cobbling together an IoT infrastructure from a series of disparate pieces of hardware and software—and instead look for a unified, end-to-end system.

The solution: an out-of-the-box IoT platform that works as a seamless unit—from hardware to software, from data acquisition through data analysis.

Fortunately, This Two-Pronged Solution Now Exists

PsiKick ESP® Insights-as-a-Service Platform

PsiKick has developed just such a solution for the Industrial IoT revolution: an end-to-end system that pulls together all of the necessary components for a robust and ubiquitous sensing solution—built around wireless IoT sensors that are entirely self-powered.



Solving the Two Key Obstacles to Industrial IoT—
So Your Company Can Start Realizing the Full Value of Pervasive Sensing Today

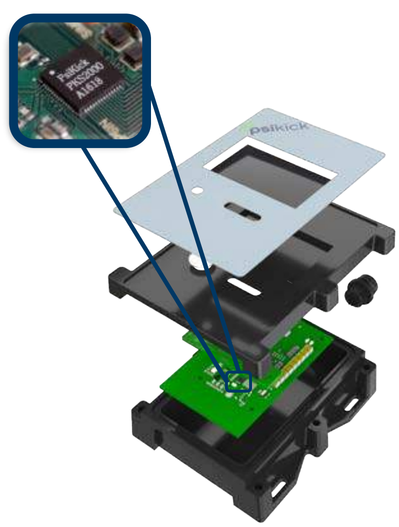
1. Batteryless, self-powered sensors

Developed with patented core semiconductor and wireless networking technology that enables them to operate off low levels of ambiently harvested energy, PsiKick's sensors can generate enough power to enable their ultra-low-power operations indefinitely. In other words, our sensors operate continuously and will never need a battery.

PsiKick's systems harvest energy from a number of environmental sources—including low-level indoor solar (and, of course, outdoor solar), the thermoelectric effect (capturing ambient energy generated wherever there is a temperature gradient), as well as through the vibration of piezoelectric materials (such as certain crystals and ceramics) and even from radio waves traveling through the environment. More importantly, unlike other "low-power," but single-purpose electronic components that utilize energy harvesting, PsiKick develops complete sensor devices. This means that each device, or "Smart Sense Node," is able to not only collect an array of data using multiple sensors, but also process, analyze, and transmit that data wirelessly—all on the same batteryless power budget.

You can think of PsiKick's self-powered systems as "forever sensors," because you can deploy them throughout your facilities and then never have to worry about physically inspecting them for maintenance or a battery-level check.

PsiKick 1st Generation
Smart Sense Node,
built upon custom-designed
ultra-low-power chips



2. A fully integrated, ultra-low-power ecosystem

As we've discussed in this paper, the second obstacle holding businesses back from deriving the full value of pervasive sensing is that most of these sensor systems are built at the component level—not the system level—which means they cannot function optimally or cost-effectively for a number of reasons.

First, there's the power problem. Some components in a sensor might be designed for low-power needs, while others are not. This leads to issues such as sensors that transmit less data, or less frequently, in an effort to conserve and prolong battery life.

A second problem with sensors built on disparate parts, from different sources, communicating with software systems developed by still other manufacturers, is that they simply aren't designed to work as a cohesive system where all of the component parts work seamlessly together. This can lead to missed opportunities and insights that can come only from a system that works as an integrated whole instead of a series of cobbled-together parts.

PsiKick's systems solve these problems as well. We've created the industry's first and only integrated, full-stack pervasive-sensing platform where the entire environment—physical sensor, data capture and processing functionality, wireless communication, analytics and reporting software platform—was designed to operate as a true ecosystem.

To learn how PsiKick's batteryless systems can deliver value for your operations, reach out to* sales@psikick.com *today.

About PsiKick

PsiKick, Inc., is a venture-backed startup pioneering wireless, batteryless IoT systems for industrial environments. Leveraging groundbreaking technology developed at the University of Virginia and the University of Michigan, PsiKick approaches self-powered systems from multiple angles, combining energy harvesting nodes with overhauled wireless communication and ultra-low power radios. PsiKick's investors include New Enterprise Associates, Osage University Partners and the Michigan Investment in New Technology Start-Ups Fund (MINTS). The Company is based in Santa Clara, CA, with design centers in Charlottesville, VA and Ann Arbor, MI. For more information, visit www.psikick.com.

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