A PRACTICAL GUIDE TO SMART MANUFACTURING

How to create value and boost productivity through the Industrial Internet of Things (IIoT).

What if your factory could talk back to you, predicting breakdowns before they happen, or alerting you when quality slips? This practical guide will introduce key Industrial Internet of Things (IoT) innovations that have ushered in a revolutionary era of smart manufacturing—boosting productivity, cutting costs, saving energy, and driving innovation in today's competitive global landscape.

01 Introduction

Industrial IoT: Manufacturing of the future.

The next wave of internet innovation—centered around connecting people, processes and things— is known as the **Internet of Things (IoT).** By connecting the physical world to the internet with sensors, IoT makes it possible to remotely monitor real-time sensor data—tracking anything from the parking availability in a busy metropolitan area, to the moisture level of agricultural land, to vital signs of cancers patient even after they have left the hospital. IoT ecosystems leverage incoming sensor data to automate or streamline key processes, drive the creation of user-facing apps (i.e. an app that tracks free parking spots), predict maintenance needs, and improve decision making.

Application Enablement

Analysis and visualization of data, decision making or enablement for 3rd party app development.

Data Storage

Database and services to process all the sensor data, store it and make it available to apps and devices.

Connectivity

Wireless communication gateways and protocols used to bring the data to the Internet.

Hardware

Sensors and devices that interact with the physical world.

4 core components of an IoT ecosystem: Sensors, embedded in anything from devices and vehicles to soil and human bodies, send and receive data via connectivity (WiFi, Cellular, LoRaWAN, etc.) to cloud storage. From there, the data can be easily manipulated and visualized in user-facing applications or dashboards.

In the coming decades, the IoT is expected to revolutionize major global industries including healthcare, agriculture, clean energy, urban planning, transportation, education, and manufacturing. This guide will focus on key Industrial IoT innovations driving smart manufacturing—which is expected to represent a $392 billion dollar global industry by 2020. So what is Industrial IoT, and how will it boost efficiency for a more productive future?

Industrial IoT

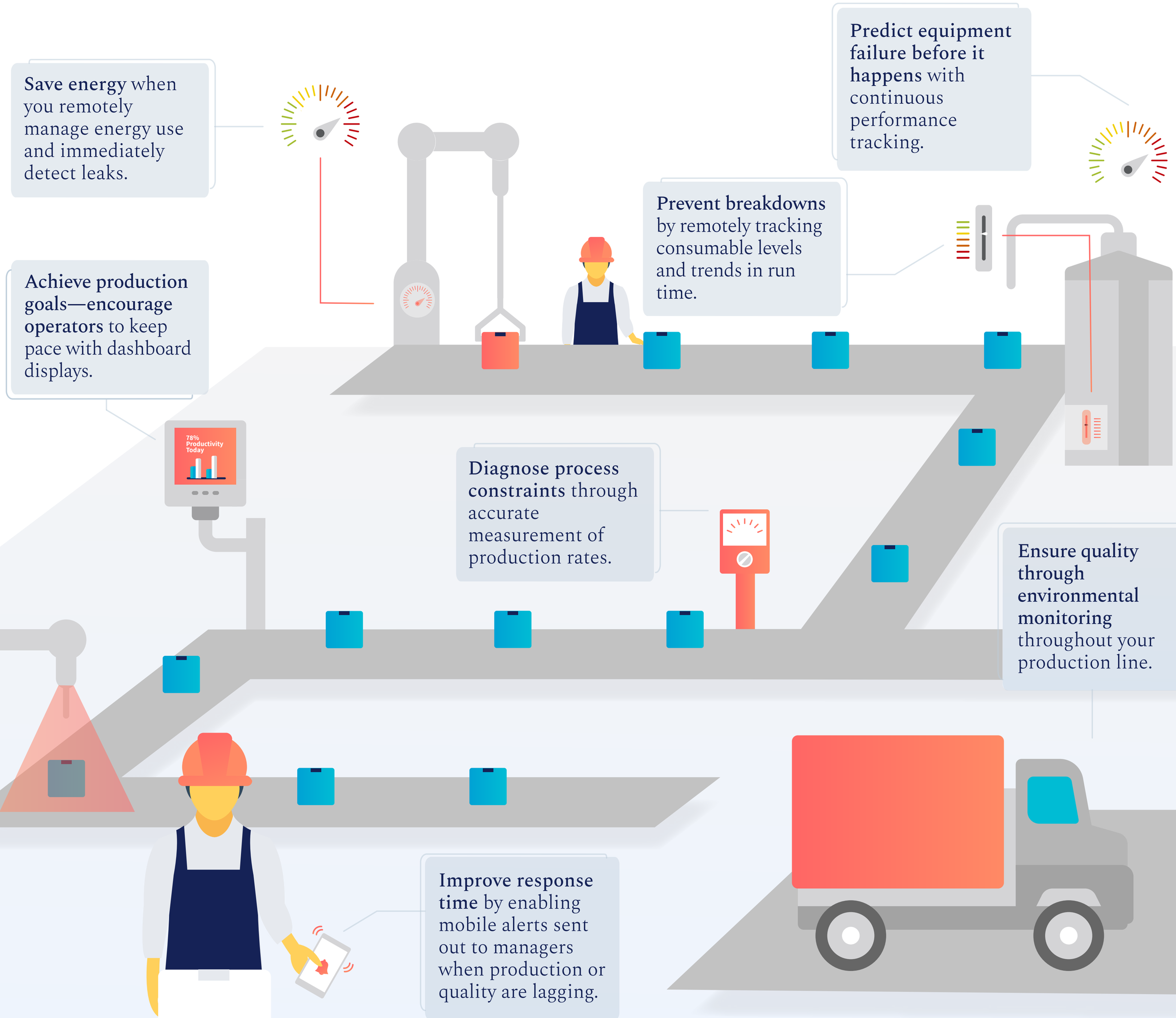
Manufacturing of the future.

The Internet of Industrial Things (IIoT) harnesses IoT technologies—sensors, actuators, connectivity, and cloud—for industrial purposes, giving manufacturers greater control over processes. Certain connected devices have been in use in the manufacturing world for the past few decades, which begs the question: what is IIoT really changing? With IIoT, it is now possible to connect virtually any asset involved in manufacturing processes (from raw materials to final products—both digital and nondigital) to the Internet.

In the factory and beyond, IIoT is helping industrial fields like manufacturing, oil & gas, water management, and transportation optimize processes, improve quality, and lower production costs. While this guide focuses primarily on IIoT in the context of smart factories, the systems discussed are broadly applicable to other industrial fields as well.

02 Inside
Smart factories

Smart factories use IIoT to remotely monitor—and often automate—certain core processes like maintenance, quality assurance, and raw material inspection. Here's a quick sketch of a few common IIoT use cases:



03 OEE:
Measuring factory efficiency

As the above infographic illustrates, IIoT has diverse applications across factory processes, targeting inefficiencies like machine malfunction, downtime, and energy waste.

A factory is only as efficient as it's weakest link. So how can factories measure efficiency—and identify which links must be optimized? Manufacturers and system integrators often use the metric OEE (Overall Equipment Effectiveness) to track the efficiency of industrial processes, encompassing machines, people, and materials. OEE takes into account 3 key performance indicators: the availability of resources (i.e. machine uptime), their performance (i.e. runtime), and the quality of their output.

OEE: Availability x Performance x Quality

The impact of a weak link: *Even if a factory is able to attain, for example, 100% performance and quality, if availability lags at 60% due to frequent breakdowns or operator changeover, overall OEE can never exceed 60%—the weakest of the 3 variable values.*

Inefficiencies in any one of these buckets can significantly impact OEE—and drive up costs. Here are some common weak links IIoT targets within each bucket:

Availability	Performance	Quality
· Breakdowns. · Operator delays and changeover (something as simple as an operator going to the toilet or receiving a call). · Lack of raw materials (due to defective batches, inefficient transit within the factory, etc).	· Reduced machine speed (i.e. a drop in units/hour produced). · Underperforming operators causing bottlenecks. · Minor stoppages (stoppages often go undetected when performance indicators are not alerting in real time).	· Rework (rejected sub assemblies or materials that need to be reworked to pass QA). · Defective raw materials received from suppliers. ·Returned products due to defects or failure post-purchase.

Even a modest IIoT project driving a 1% improvement to just one of these three areas could result in significant gains, heightening process efficiency, customer satisfaction, environmental efficiency, and product innovation. The following sections will explain these benefits in more detail, and provide practical information on how manufacturers can get the most out of IIoT.

In the field:

What could a 1% improvement in quality look like?

Take, for example, a plastic injection company with net sales of $150 million, and quality losses of over $29 million due to non-conforming product returns and rework. **With just a 1% increase in process yield due to quality improvements, direct savings could go up to $300,000 per year, which is more than enough to pay back the cost of the initiative.** Apart from the tangible savings, the IIoT project will likely add value in other ways by boosting quality and reducing environmental impact.

04 Drive process efficiency *with IIoT*

Breakdowns, slowdowns, and minor stoppages—caused by either equipment or operator failure— can severely limit both machine availability and performance. IIoT solves for these process inefficiencies by identifying, predicting, and preventing bottlenecks and maintenance needs in real-time.

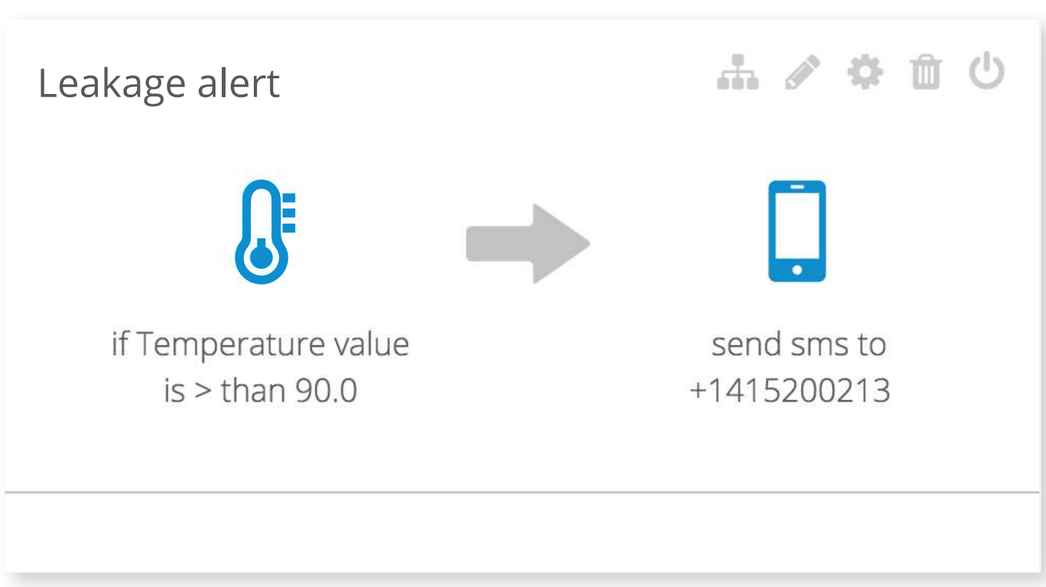
Corrective Maintenance

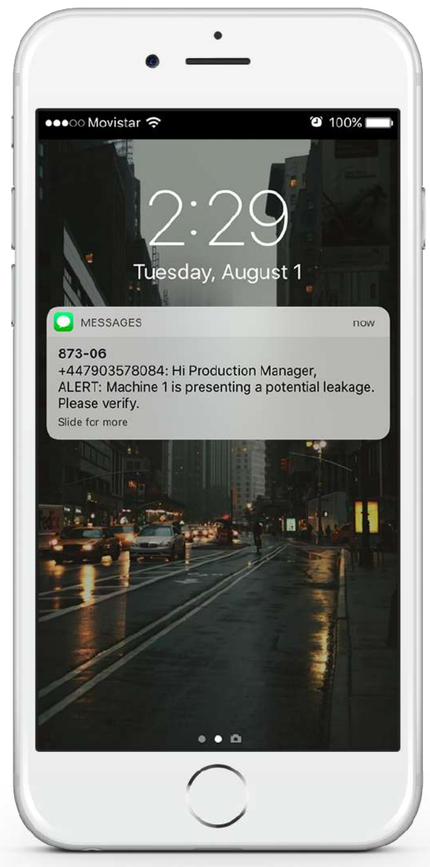
Many manufacturers only become aware of critical breakdowns at the end of a day, when the number of units produced falls short of quota. In contrast, IIoT-powered dashboards and alerts immediately notify manufactures of breakdowns and emergencies (through something as simple as a text message), so corrective actions can be performed immediately. IIoT also helps factories better understand what went wrong through detailed downtime analysis and failure reports focused on key machines, components, or process constraints. Improved downtime analysis drives more informed decision making, and helps manufacturers reduce MTBF (mean time between failures) and MTTR (mean time to repair).

In the field:
Simple corrective maintenance alerts

What does a corrective maintenance alert look like?

A production manager, for example, can trigger an SMS notification through the Ubidots platform when a specific machine or production line is failing. **Setting up a corrective maintenance alert can be as simple as creating a baseline metric** (for example: optimal energy consumption of X machine = Y value)—and triggering an alert when values deviate from your baseline.





Preventive *Maintenance*

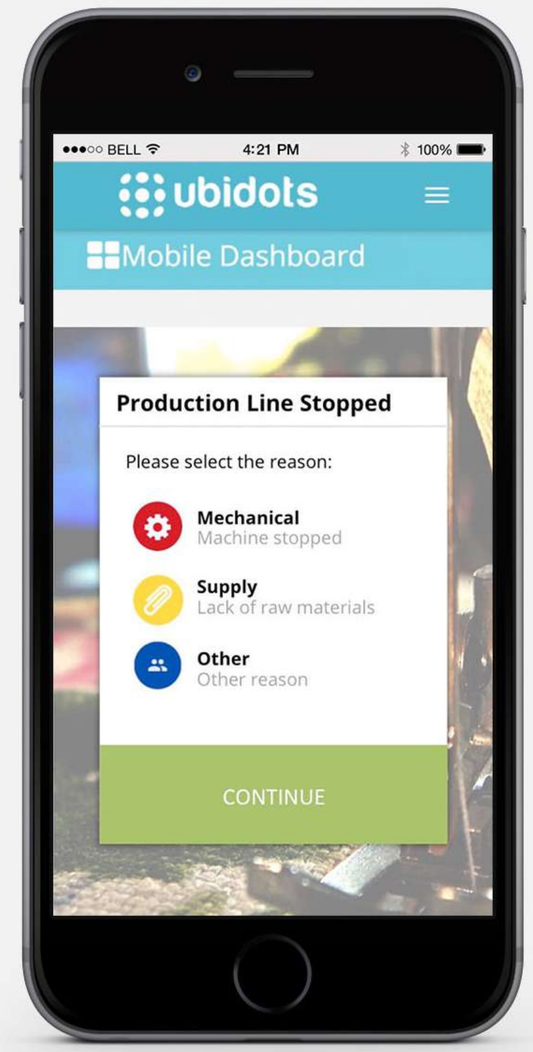
Many common causes of equipment slowdowns or breakdowns are avoidable (i.e. running out of lubricant, or failing to replace a worn-out part in time.) But when producing thousands of units across many complex subassemblies, it can be challenging to track which machines require what fluid or service, and at what time.

Smart manufacturing simplifies this kind of ongoing, preventative maintenance through remote tracking of consumables, wear-and-tear, and more. Sensors attached to specific equipment components allow manufacturers to track levels of vital consumables like lubricants or refrigerants, as well as their temperature, viscosity and other variables. This makes it easy for maintenance teams to schedule—or even automate—consumible servicing. The same is true for the servicing or replacing of parts and other routine tasks. Through detailed tracking of machine running times and component wear and tear, manufacturers can optimize preventive maintenance programs and keep their equipment in good condition.

Predictive *Maintenance*

Predictive maintenance takes preventive maintenance a step further, enabling machines to predict potential breakdowns or remaining useful life. Before IIoT,
the only real predictive maintenance strategy to help manufacturers stay ahead of unexpected breakdowns and downtime was the regular examination of equipment, which can be time consuming and imprecise. A routine vibration analysis, for example, may only capture the point-in-time at which the machine was inspected, and could miss important aberrations or warning signs of declining performance.

IIoT predictive maintenance strategies make it possible to continuously monitor performance through vibration analysis, thermography, ultrasound, and electric power behavior over time—reducing the need for costly ongoing inspections and searching for possible problems.



With recent advances in sensor technologies and machine learning, predictive maintenance data is more precise than ever. Equipment self-diagnostics can predict, for example, remaining useful life of an asset or part based on previous stress tests. This allows manufacturers to plan better and fix or replace critical parts before they can compromise OEE.

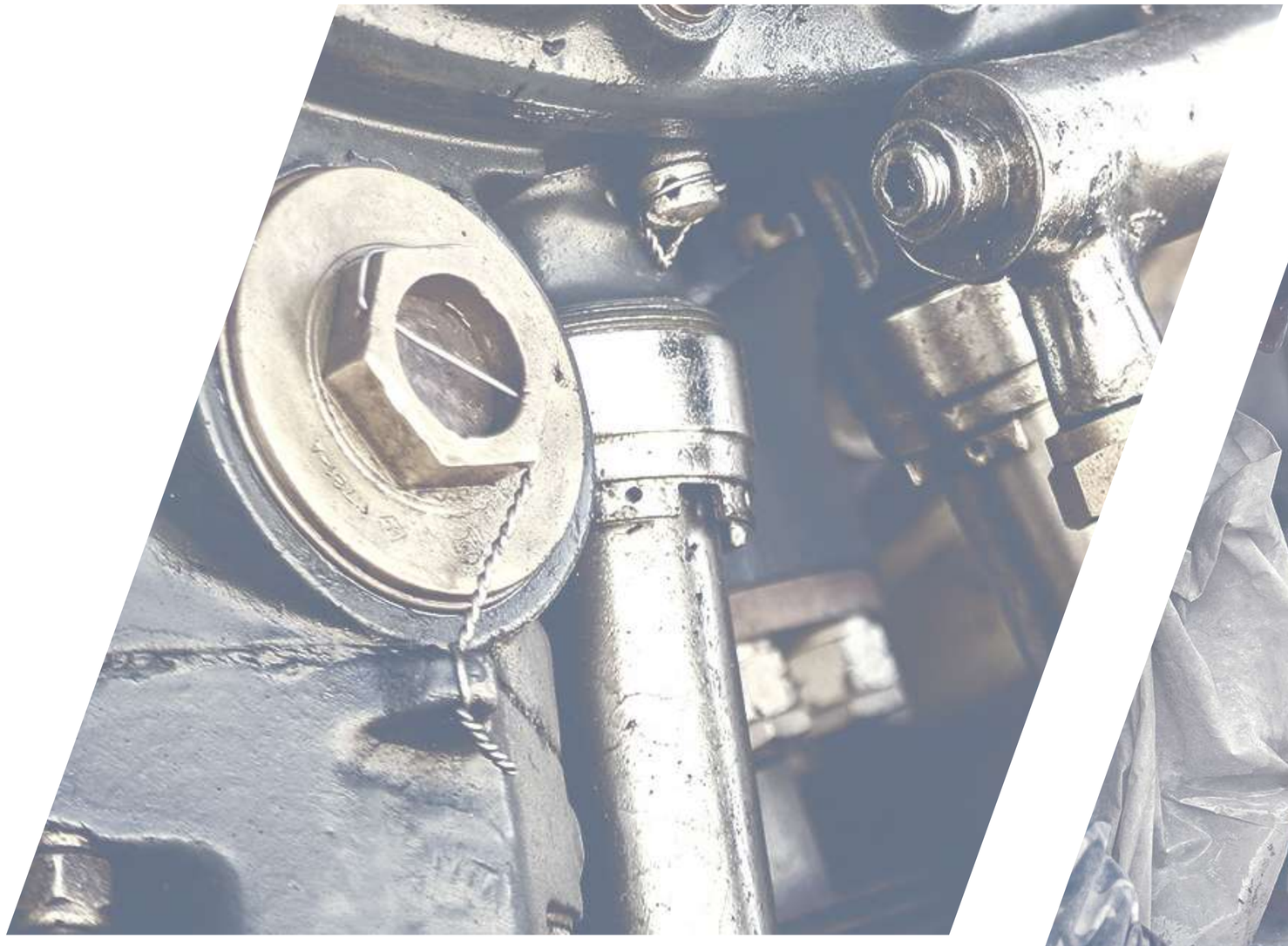
Operator
Productivity

Even if you reduce inefficiencies in equipment maintenance processes, uptime is still be limited by operator productivity—which can be even more challenging to measure and optimize. When scaling production to thousands of units, underperforming operators can represent a remarkable bottleneck to overall performance. But in the absence of reliable and timely data, it can be challenging to identify performance problems. Team leaders and operators are often unaware of real production speeds, minor stoppages, and other key production metrics.

IIoT solves for this by making it possible to share incoming data (from unit counters or flow meters, for example) with workers through factory dashboards, and help teams stay on target with metrics like production rate or units produced per shift. **Managers can stay on top of their team's progress and be alerted of any bottlenecks through mobile alerts, improving response time and problem solving.**

05 Boost quality
with smart factory QA strategies

In addition to smoothing out "weak links" in factory processes, IIoT helps manufacturers optimize "weak links" in production quality—from raw material supply to the final product. IIoT empowers manufacturers to monitor and optimize critical quality variables, improving customer satisfaction while minimizing scrap and rework.



Streamline QA
to save time and money

Quality begins with raw materials. IIoT takes incoming batch quality inspection to the next level, by making it possible to remotely inspect materials before they ship via sensor technology installed on the supplier side. Dashboard visualizations of incoming data from suppliers support proactive problem solving and prevent costly hiccups in the supply chain.

After materials arrive on the shop floor, IIoT QA systems continuously monitor quality as products move through the assembly line. For example, in a semi-automatic home appliances assembly line, in-line quality inspection devices measuring RPM, voltage and current provide a real-time picture of quality levels across specific subassemblies. Dashboards and alerts further aid manufacturers in identifying machines and operators that negatively impact quality metrics.

With embedded sensors (built into products themselves), it is possible to perform advanced Statistical Process Control (SPS) analysis, monitoring both quantitative and qualitative data (e.g. dimension, temperature, pressure, color) to ensure variables are behaving within spec limits. In addition to alerting quality teams of any issues, process analyses adds long term value by tracking trends over time and building detailed records of in-factory quality standards.

Reduce product returns
and increase customer satisfaction

When products underperform or break down, customer complaints can spread like wildfire over social media and damage brands of any size. IIoT can help companies get ahead of malfunctions and negative mentions by tracking quality of final products—even after they've left the shop floor.

Cloud-based monitoring of QA variables allows traceability of quality in outgoing batches throughout shipping, handling and storage, and can even be used to predict product failure once products are in the hands of customers. A dairy manufacturer, for instance, could set up temperature alerts for perishables such as milk and yogurt throughout the shipping and storage process, preventing product loss or unsatisfied customers.

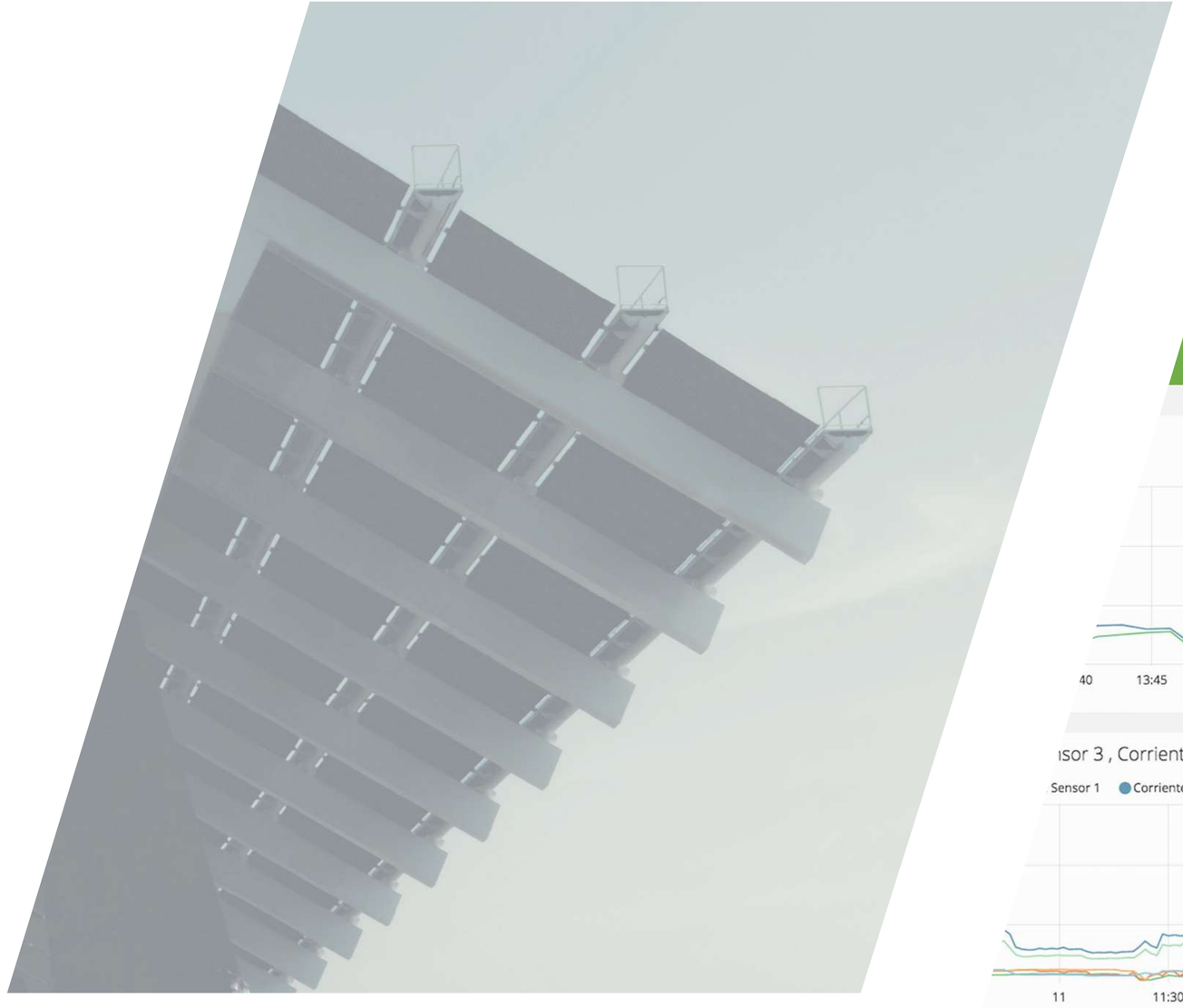
Embedded sensors allow permanent monitoring of failure-prone product features, detecting pitfalls before customers do and preventing bad customer experiences, complaints or negative social media mentions. Incoming data from products in the wild can indicate if customers are improperly using the product (overuse, poor storage conditions, short circuits, etc), providing valuable data that can be used for evaluating warranty requests or strengthening customer support.

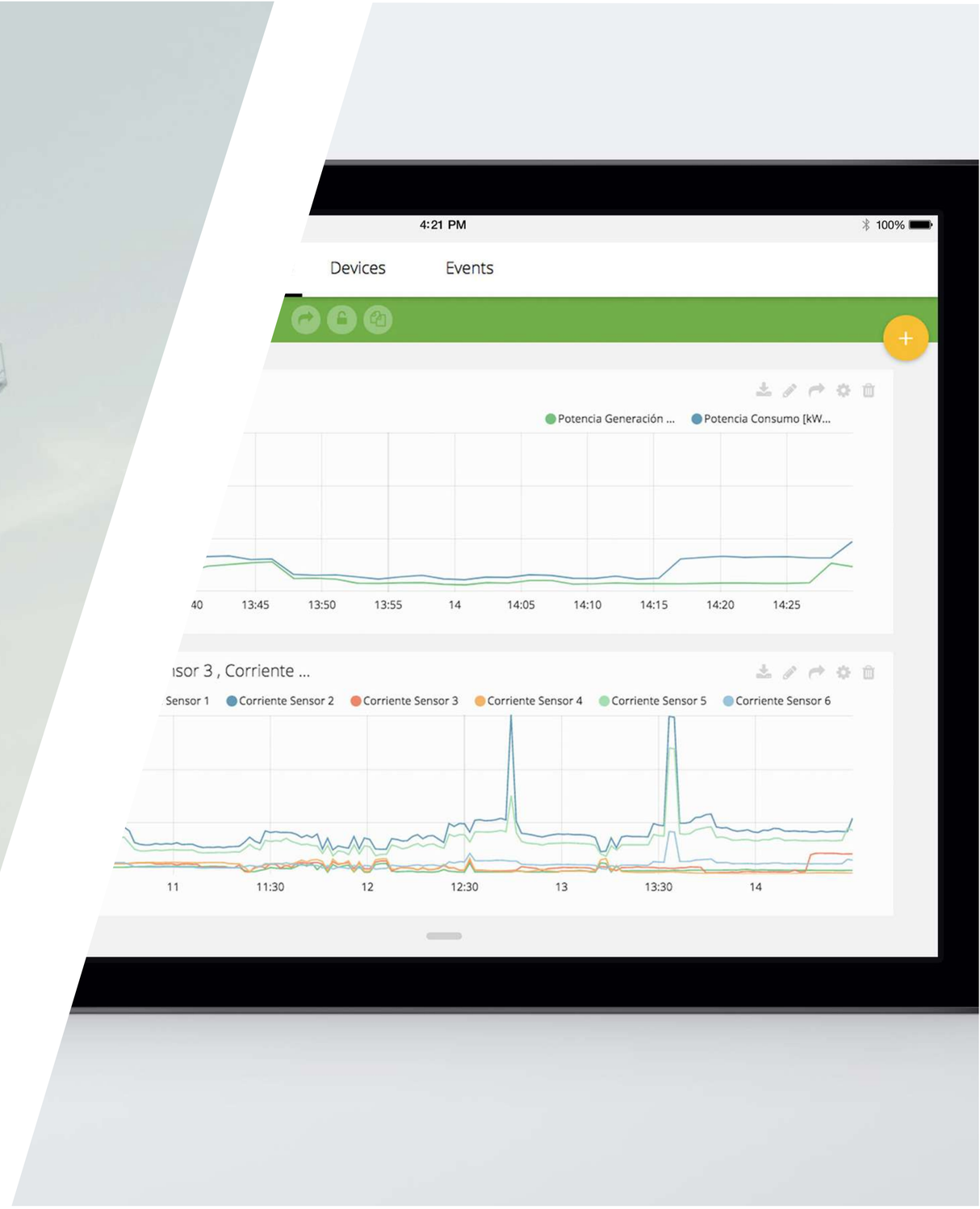
In the field:
Embedded sensing in cranes
How embedded sensors can improve quality?

Embedded sensors can improve quality across diverse industries and products—large and small. An industrial crane company, for example, uses Ubidots business-grade platform to track use and maintenence needs of their cranes once in the hands of end customers—enhancing maintenance services and customer satisfaction.

06 Green your factory
with energy saving IIoT solutions and enviromental monitoring

The raising and volatile price of energy, combined with tightening government environmental regulation, is increasingly driving factories to explore smarter and more environmentally-friendly energy usage. IIoT makes this easy with innovative new ways to manage consumption and cut energy costs—which may account for up to 20% of total operating costs according to McKinsey & Company (2012). .





Smart energy
management

IIoT can help energy managers detect shortages or leaks in production and other processes, and ensure that energy is used only when needed. Through detailed sensor data on heating, ventilation, air conditioning, refrigeration, lighting, and more, manufacturers can remotely monitor and automate energy use (for example, by automatically triggering air conditioning only when warehouse temperatures rise above a certain pre-set threshold.)

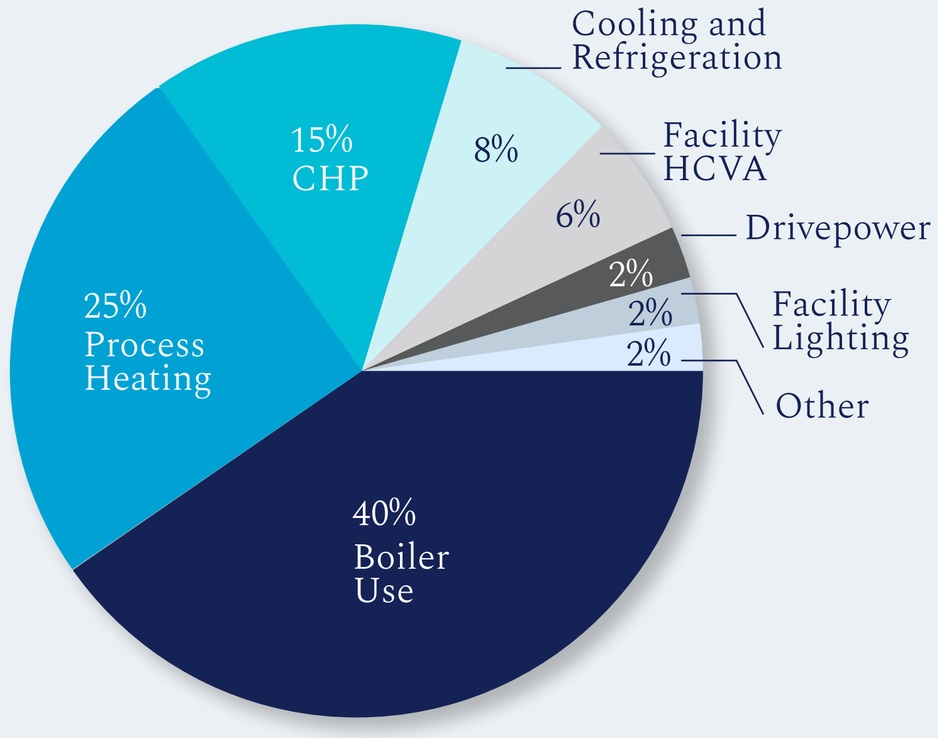
Sensor data also empowers manufacturers to track key metrics such as actual energy consumption across different periods of time or across machines—and set up custom alerts when energy consumption varies from baseline. For example, a manager could receive a triggered SMS or email as soon as a leak is detected, or when a machine's energy consumption is above average.

By implementing even a very basic version of the IIoT energy management approach described above, factories can cut costs by 5-15% with little investment required. More robust energy management programs can save companies around 30% on energy spending—with high performers saving a striking 50-70%.

On average, manufacturing facilities use 95.1 kWh of electricity and 536,500 Btu of natural gas per square foot annually.

Take a 100,000 sq2 as an example; this would mean nearly $1M / year on energy bill.

5% of savings could mean $250k in a five year span.



Environmental
Monitoring

Energy consumption is just one piece of a factory's environmental profile. Other important environmental factors impacting production and environmental impact include air quality, water quality, ozone levels, and temperature—inside the factory walls and beyond.

Through IIoT-powered environmental monitoring, manufacturers can track air quality metrics (i.e. carbon dioxide and smog) and water quality (i.e. pollutants) to improve workplace safety and reduce environmental impact. This data is valuable not only in terms of internal problem solving and progress tracking, but also supports manufacturers in demonstrating compliance with government regulations through real-time or historical data on emissions of carbon dioxide or other pollutants.

For many manufacturers, environmental monitoring proves beneficial for both the planet and the business, reducing waste and improving quality. Tracking environmental conditions (i.e. ozone and temperature) throughout the storage and packing process of food products, for example, reduces needless waste due to unstable conditions.

In the field:
Environmental monitoring for cold chain vaccines

How can enviromental monitoring increase quality?

In the medical supply industry, environmental monitoring is used to track temperature, humidity, and other conditions to control quality of life-saving supplies. For example, one of the Ubidots' healthcare clients uses IoT-powered tracking and analysis to make sure vital cold-chain vaccines and medications are stored in appropriate conditions.

07 Drive innovation and improve customer satisfaction
through product lifecycle management

Products, like people, have a lifecycle: from inception, through early development, to peak productivity across different locations and contexts, and finally to disposal. IIoT connects manufacturers more closely to their products at each phase in the lifecycle, allowing for advanced product lifecycle management (PLM). The previous sections have addressed how IIoT improves lifecycle management within the context of the factory through improved maintenance, quality assurance, and environmental monitoring. But what about the phases of a product's lifecycle before and after its time on the shop floor? IIoT can add tremendous value to the very early phases of the product lifecycle (product research and development).

Accelerate research and development

with real-time usage data.

Manufacturers can spend months or years developing a product—and then launch it in the wild, with very limited visibility into how it performs in the hands of real users. This can makes ongoing research and development quite slow and difficult, as designers and engineers must conduct focus groups or interviews to understand how users interact with products.

With digital products (i.e. software, mobile applications), web analytics make it easy to extract detailed data on product use, giving companies valuable visibility into customer behaviors and needs. For physical products, it has been difficult or impossible to extract this kind of product usage data—until recently. With IIoT embedded sensors, it is now possible to track the same core metrics that drive software research and development, including:

- **Product usage periodicity**
- **Ease of use**
- **Customer's location (country, region, city, zip code, etc)**
- **Used vs. ignored features (i.e behavioral heatmaps)**

By adding sensors to different components of products, companies can easily detect when products are being used, how long, what features are more popular, and so on, and use this data to drive product innovation. Product designers and engineers benefit from more comprehensive consumption insights, attained at a much lower cost than time-consuming user research methods like focus groups.

Embedded sensors also facilitate simple and accurate product reliability testing. Sensor-based useful-life trials can capture massive amounts of continuous data that, up until recently, was unknown or acquired manually. In addition, manufacturers can easily analyze reliability data across different locations to better understand the impact that temperature, moisture, altitude, and other environmental conditions have on machines and other processes.

Increase customer satisfaction
maintenance support and inventory tracking

Beyond helping companies respond to customer needs in the long-term through product innovation, embedded sensing is a powerful tool for meeting customers immediate needs through ongoing maintenance support and inventory tracking.

As described above, IIoT enables manufacturers to predict and stay ahead of the maintenance needs of equipment in the factory. The same can be true for end products in the hands of customers. Manufacturers can add great value to their products by providing customers with ongoing support and tools for managing maintenance. This could be as simple as a courtesy call to the customer when a part needs to be replaced, or something more advanced, like a mobile app for customers to track relevant maintenance variables.

IIoT also helps companies add greater value to products and services through inventory tracking—making it seamless for customers to monitor existing inventory, and even automate restocking to ensure continuous supply where needed.

In the field:
Intensive care gas supply inventory monitoring

How can IIoT increase customer loyalty and sales?

Cryogas, an emergency gas supplier for Intensive Care Unit (ICU) patients, uses an Ubidots-powered inventory monitoring system to ensure that hospitals never run out of vital gas inventory. By remotely tracking remaining gas levels in the ICU through real-time pressure measurements, Cryogas can alert the customer of possible shortages and facilitate timely restock. Through this fairly simple IIoT system, the gas manufacturer has been able to boost both customer loyalty and sales, since they are able to guarantee their client gas availability with no backup suppliers

Responsible
Disposal

The final stage of product lifecycle management—disposal—is becoming increasingly important given mounting evidence of the environmental and health hazards posed by improper disposal of electronics, plastics, and more. IIoT can help manufacturers track disposal and partner with customers to recommend how and when it is appropriate to dispose or recycle a product.

08 Conclusion

Machines can talk, IIoT gives manufacturers the tools to listen.

IIoT helps factories optimize maintenance programs, improve quality processes, reduce energy use, drive innovation, and more. Each of these factors contribute to overall efficiency, or OEE, and even a modest IIoT affecting just one area can move the needle a great deal (for example, consider what just a 1% reduction in rework or a 5% reduction in energy consumption could mean in terms of cost savings). All of these innovations taken together are building smarter, more cost-effective, and greener future for manufacturing.

How will your factory harness the next wave of manufacturing innovation?

Learn about Ubidots' toolkit for bringing your IIoT initiative to life—from prototype to product. Ubidots' business-grade platform makes it easy to connect your assets to our cloud, so you can monitor, visualize and act on incoming data.

Learn more at Ubidots.com

ubidots