

EnOcean – The World of Energy Harvesting Wireless Technology

Energy can be found everywhere – in the movement of doors and windows or machine components, the vibration of motors, changes in temperature or variances in luminance level. These energy sources, which usually remain unused, can be tapped into by means of energy harvesting to power electronic devices and transmit wireless signals. This principle is the basis of energy harvesting wireless technology from EnOcean.



What does “no batteries” mean?

Energy is within reach everywhere, it just needs to be harvested: this is the principle of energy harvesting. EnOcean uses this principle for its wireless modules, which get their power from the surrounding environment. Tiny energy converters power sensors and switches, enabling them to function without batteries or wires and therefore work maintenance-free. Replacing batteries means expenditure, both from a hardware and maintenance perspective. EnOcean’s self-powered technology means no batteries need to be replaced, ever. This is particularly true in systems consisting of several tens, hundreds or thousands of wireless nodes as you find in the field of smart home and building automation. Just think of a hotel, which has equipped each of its 400 rooms with four battery-powered sensors. Every two to three years, each one of these 1,600 batteries needs to be replaced – it is irrelevant if the devices are hard to access or hotel guests might be disturbed. Worse still is when batteries in a light switch or a remote control fail during guest usage. In commercial or industrial operation, a battery cost calculation must therefore be included to generate accurate lifetime costs covering maintenance efforts and proper hazardous materials disposal. Only Total Cost of Ownership (TCO) calculations reveal the true cost of battery-operated systems.

Energy harvesting solutions free building owners, facility managers or contractors from the burden of batteries. They combine the benefits of highly flexible wireless solutions with the same maintenance-free attributes as wired-in devices with a fast, consistent, and repeatable return on investment (ROI).

Which energy sources count?

There are three main sources of energy the EnOcean technology is using: motion, light and differences in temperature. In the process, an electro-dynamic energy converter uses kinetic motion, or a miniaturized solar module generates energy from available light in a room. Combining a Peltier element with a DC/DC converter taps into heat as an energy source. These small amounts of harvested energy are sufficient to transmit and receive wireless signals and enable operation of numerous maintenance-free sensor solutions. This includes battery-less switches, intelligent window handles, solar-powered temperature, humidity and light sensors, as well as self-powered occupancy sensors or even relay receivers.

➤ Energy from motion

The mechanical energy converter ECO 200 converts mechanical energy, the press of a switch for example, into electrical energy. It works similar like a dynamo and makes the energy immediately available. With an energy output of 120 μ Ws and an according wireless battery-less module, it is possible to transmit three radio telegrams per operation. The ECO 200 enables a typical completion of more than 300,000 switching cycles; under ideal conditions, more than a million switching cycles are possible.



➤ Energy from light

Miniaturized solar modules, not larger than 13 mm x 35 mm, can even use indoor light to supply electricity for ultra-low power wireless radio modules. If a measured value is transmitted every 15 minutes for example, 3.6 hours of charging in daytime and 200 Lux are adequate for an uninterrupted operation.



➤ Energy from temperature differences

Thermo generators, so-called Peltier elements, gain the energy. The ECT 310 DC/DC converter already starts to resonate upwards of 10 mV input voltage. On 20 mV (temperature difference about 2 K), a useful output voltage of more than 3 V is generated. At a temperature difference of only 7 K, approximately 100 μ W of energy is already produced.



What is the EnOcean platform?

It's not only energy harvesting that makes the wireless technology work. EnOcean offers its OEM customers a complete plug&play system of energy converters, energy management, wireless modules, software and development tools as well as an energy saving, very reliable radio protocol. All platform components are optimally matched to each other. Depending on the energy requirements, this complete package enables several wireless applications, which work without wires and batteries. In establishing this comprehensive platform, EnOcean has managed to keep the integration barriers extremely low. This enables easy integration processes, without the need for in-depth knowledge of battery-less technology.

Which radio protocols can EnOcean power?

Based on its know-how and comprehensive platform approach of optimally matched components, EnOcean can actually enable any ultra-low power radio to be operated by energy harvesting. Currently the EnOcean technology powers the international standard ISO/IEC 14543-3-1X (also known as EnOcean standard), which is optimized for ultra-low power wireless applications and energy harvesting. EnOcean was closely involved in the standard's ratification process at the International Electrotechnical Commission (IEC). The standard can be downloaded at www.iso.org.



In the meantime, associations and wireless players have started to specify ultra-low power sub-protocols of other existing wireless standards, e.g. for the 2.4 GHz ISM band (IEEE 802.15.4). These specifications are inspired by the characteristics of the EnOcean standard to allow the realization of ultra-low power applications in their particular established fields. Due to this development, EnOcean's energy harvesting wireless technology can also power radio communication in the worldwide open IEEE 802.15.4 standard.

Are these standards optimized for specific applications?

EnOcean recommends the ISO/IEC 14543-3-1X standard for reliable, sustainable integrated building automation for an intelligent control of interconnected building areas requiring high system availability. Therefore, the EnOcean radio protocol is specifically designed to support ultra-low power devices and energy harvesting applications in building and home automation. For optimal RF effectiveness, the radio protocol uses sub 1 GHz frequency bands. RF reliability is assured because wireless signals are less than one millisecond in duration and are transmitted at a data rate of 125 kilobits per second. Although transmitted power is up to 10 mW, the wireless transmission used here only has an energy requirement of 50 μ Ws for a single telegram. That is about the same as the power needed to lift a weight of 1 gram by 5 millimeters. The short telegram is randomly repeated twice in the space of about 40 milliseconds to prevent transmission errors.



Energy harvesting applications using the IEEE 802.15.4 standard meet more specific market demands, e.g. for consumer LED lighting control or other control solutions in areas where channel availability and grade of service is not the major customer request.

What is the range of wireless signals powered by energy harvesting?

Devices, which operate in the sub 1 GHz ISM frequency band, offer robustness of transmission through walls, minimal interferences and a communication up to 100 feet (30 meters) in buildings and 1000 feet (300 meters) in the free field. Detailed information on range planning in the sub 1 GHz band can be found in the [EnOcean Range Planning Guide](#). These range characteristics makes the EnOcean standard highly suitable for integrated building control.

At the same time, using sub 1 GHz bands minimizes electric smog, because the electromagnetic fields emitted by the radio switches are extremely low. In addition, the battery-less sensors are in a sleeping mode most of the time and only transmit wireless telegrams (status updates, measured values, control commands) when activated or in a pre-defined time cycle and over a very short time. More details on the radio emissions of the EnOcean standard can be found in the report from the independent [ECOLOG institute](#).

The short activation cycles also apply to 2.4 GHz energy harvesting applications so that wireless signals are sent only when needed. This reduces electric smog in this higher band as well. Usually, the range at 2.4 GHz is about 30 feet (10 meters) in a building and 300 feet (100 meters) in the free field. Therefore, it is more suitable for single-room solutions, where a high penetration through walls is not required.

Can I use EnOcean worldwide?

Yes, the EnOcean ISO/IEC standard uses different license-free frequency bands in the sub 1 GHz range to meet the specifics and legal regulations of countries around the world. EnOcean solutions are available in the following frequencies, making them suitable for a worldwide use: 868 MHz for Europe and China, 902 MHz for North America and Canada and 928 MHz for Japan. In addition, there are battery-less solutions using the worldwide opened 2.4 GHz frequency band.

What about data integrity and security?



EnOcean modules transmit data packets at random intervals to ensure that the probability of collision and interference is extremely small. As a result, a range of switches and sensors using the sub 1 GHz frequency band can be operated in close proximity to each other. Besides this, each EnOcean standard module comes with a unique 32-bit identification number (ID), which cannot be changed or copied and therefore protects against duplication.

This authentication method offers field-proven secure and reliable communication in building automation. For applications requesting additional data security, e.g. in smart home systems, EnOcean protects battery-less wireless communication in sub 1 GHz with enhanced security measures to prevent replay or eavesdropping attacks and forging of messages. These features include a maximum 24-bit rolling code (RC) incremented with each telegram and state-of-the-art encryption using the AES algorithm with a 128-bit key.

How can I start with EnOcean technology?

➤ Modules and accessories

EnOcean offers all components of the energy harvesting wireless platform. First of all, the energy converters, being the ECO 200 electro-mechanical harvester, the ECS 300 miniaturized solar cells and the ECT 310 DC/DC converter for thermo-electric applications. These go hand in hand with a comprehensive wireless module portfolio which includes plug&play sensor modules, programmable modules, transceiver modules, a ready-for-integration switch module as well as components for industrial switches. Some module variants include advanced security functionalities ex works. The products come along with software, firmware and source codes for EnOcean modules. With EnOcean Link, the company offers a middleware, which provides a universal interface for wireless communication and automatically interprets information from EnOcean telegrams. A detailed overview of all EnOcean products can be found at www.enocean.com/products.

The [EnOcean Product Finder](#) helps you to find the right products for your application.

➤ Development platform

EnOcean has set up a cost-effective and customized development platform for engineers to allow a fast integration of energy harvesting wireless technology into applications. The concept is based on the developer kit covering the entire product range, from energy harvesting and wireless modules to ready-made product solutions. Due to the modular concept, OEMs benefit from a higher flexibility in product development meeting their specific, product-related requirements and assure them a competitive edge.

➤ Fastest time-to-market: OEM white label finished products

In addition to the module portfolio and the development kits, EnOcean offers a first base line of white label finished products. This supports OEM customers in bringing EnOcean-based product portfolios to the market quickly and cost-effectively. OEMs benefit from significantly shorter development timelines, reduced investment, and reduced distraction, as they work to capitalize on quickly evolving market opportunities for energy harvesting wireless applications. Instead of developing the products on their own, manufacturers simply private label the needed products. The white label offering includes self-powered occupancy sensors, a window contact, light switches, a key card switch as well as solutions for HVAC and lighting control.

Where can I buy EnOcean products?

EnOcean works together with a worldwide network of value-added distribution partners. They offer the EnOcean portfolio in all available frequencies and offer application support and technical expertise. To find your appropriate distribution partner, please look at www.enocean.com/en/products/distributor/.

What is the difference between EnOcean and the EnOcean Alliance?



EnOcean, the company, is the inventor and provider of the energy harvesting wireless technology. The company offers its technical platform to manufacturers (OEMs) to enable them developing their system ideas for buildings, industry and the Internet of Things. EnOcean is a Promoter member of the EnOcean Alliance.

The EnOcean Alliance is an international consortium of nearly 400 companies worldwide, which develop and promote solutions based on the EnOcean energy harvesting wireless standard in the sub 1 GHz band. The organization's main objective is to make the most effective use of intelligent control and automation to improve a building's carbon footprint while increasing comfort and safety.

The Alliance ensures the interoperability of devices and solutions by defining standardized application profiles (EnOcean Equipment Profiles). This ensures the interoperability of the devices, meaning that products from different Alliance members can seamlessly work together in a system. In addition, the organization offers its members a platform of vital exchange and partnership. Today, the EnOcean Alliance is one of the fastest growing technical Alliances and has the largest wireless installation base in several hundreds of thousands buildings worldwide.

What is the unique point about EnOcean technology?

EnOcean energy harvesting wireless solutions overcome a high obstacle: How to network an increasingly large number of individual wireless nodes or sensors that can communicate with long-range wireless networks? Here, power cables or batteries can prove to be a drawback, both at installation and ongoing maintenance. Battery-less devices have access to ever-present power sources, making them maintenance-free and highly flexible to install, even in retrofit projects.

Due to its special properties, energy harvesting wireless technology is an attractive solution for the flexible and maintenance-free collection and transmission of all types of data. Energy harvesting turns self-powered sensors into important assistants that help us performing the tasks of our modern lives.

Benefits of energy harvesting wireless solutions

- **Reduced planning and installation costs, no wires needed**
- **Maintenance-free for > 20 years, no battery replacement needed**
- **Equivalent functionality as wired devices**
- **Flexible positioning and updating**
- **Reliable, long range communication**
- **No hazardous waste disposal**
- **Worldwide use of battery-less technology**

Which are the core markets for battery-less applications?

➤ Building automation and smart homes



Energy harvesting wireless applications are very well established in the building automation and smart home sector. The self-powered sensors and switches bridge the “last meters” in a communication system, delivering the needed data from many different points for intelligent HVAC, lighting or shutter control to reduce energy consumption and increase comfort and security. Solutions range from window contacts and temperature, brightness and humidity sensors to presence detectors, CO₂ metering devices and even thermal-powered heating radiator valves or complete smart home systems.

Today, more than 1,500 products for home and building automation based on the EnOcean standard are offered by members of the EnOcean Alliance. The [EnOcean Alliance Solution Finder](#) helps you to find the ideal wireless building solution. In addition, these devices can easily be connected to other protocols such as WiFi, Ethernet/IP, KNX, BACnet, LON or DALI via gateways, enabling an integrated system interconnecting all building areas for a highly optimized intelligent control.

➤ Machine-to-Machine

Due to its unique characteristic of combining wireless, battery-less and maintenance-free operation, energy harvesting wireless technology is rapidly becoming the established standard for the last leg communication level in M2M applications. The vigilant sensors can warn against danger, monitoring liquid and gas leaks, for example, or can be used in early warning systems for avalanches. In addition, agricultural monitoring is a M2M application with a highly promising future. In this case, long range self-powered wireless sensors are placed over large areas to provide early warnings or to monitor farm animals and plants in order to react very quickly to changing conditions. Sensors monitor the degree of humidity or soil nutrients for an optimal supply of water and care for plants. Similar sensors can monitor parameters related to structural health of buildings, bridges, tunnels, dams or drilling platforms. This includes integrity, position, and vibrations and acting as an early warning system. The energy harvesting wireless technology also enables wireless bus stop buttons and facilitates continuous, maintenance-free monitoring of logistics processes and cold chains.

➤ Internet of Things (IoT)/consumer

EnOcean has also conquered the IoT consumer market with a self-powered switch module that operates in the 2.4 GHz range. Users can thus control their LED light systems at home with the kinetic energy from pressing a button. The energy harvesting light switch is practical, especially when no smart phone is at hand or if it would be inconvenient to start the app only to switch on the lights.

The intelligence to make use of the data can and will be implemented anywhere, but the systems that collect the initial information need to be reliable and perpetual so that you can “install and forget” this. This is where energy harvesting wireless sensors come in: the Things in the Internet of Things.

What is the future of energy harvesting wireless technology?

Energy harvesting wireless is just starting to unfold its potential. The rapid improvement of components and system design setup will open up new applications in every aspect of life. In smart city concepts, for example, the self-powered sensors could supply information for flexible parking space and traffic data management as well as the data for demand-driven street lighting.

As energy harvesting wireless technology advances, possibilities are emerging for using self-powered, maintenance-free wireless modules for numerous applications where wired or battery-powered systems would be too elaborate in their technology and by no means cost-effective. Powering sensors is inevitable for collecting data and the digitalization of our world independently from location and time.

