Energy Harvesting Powered Wireless Sensors and Actuators

Smart SysTech
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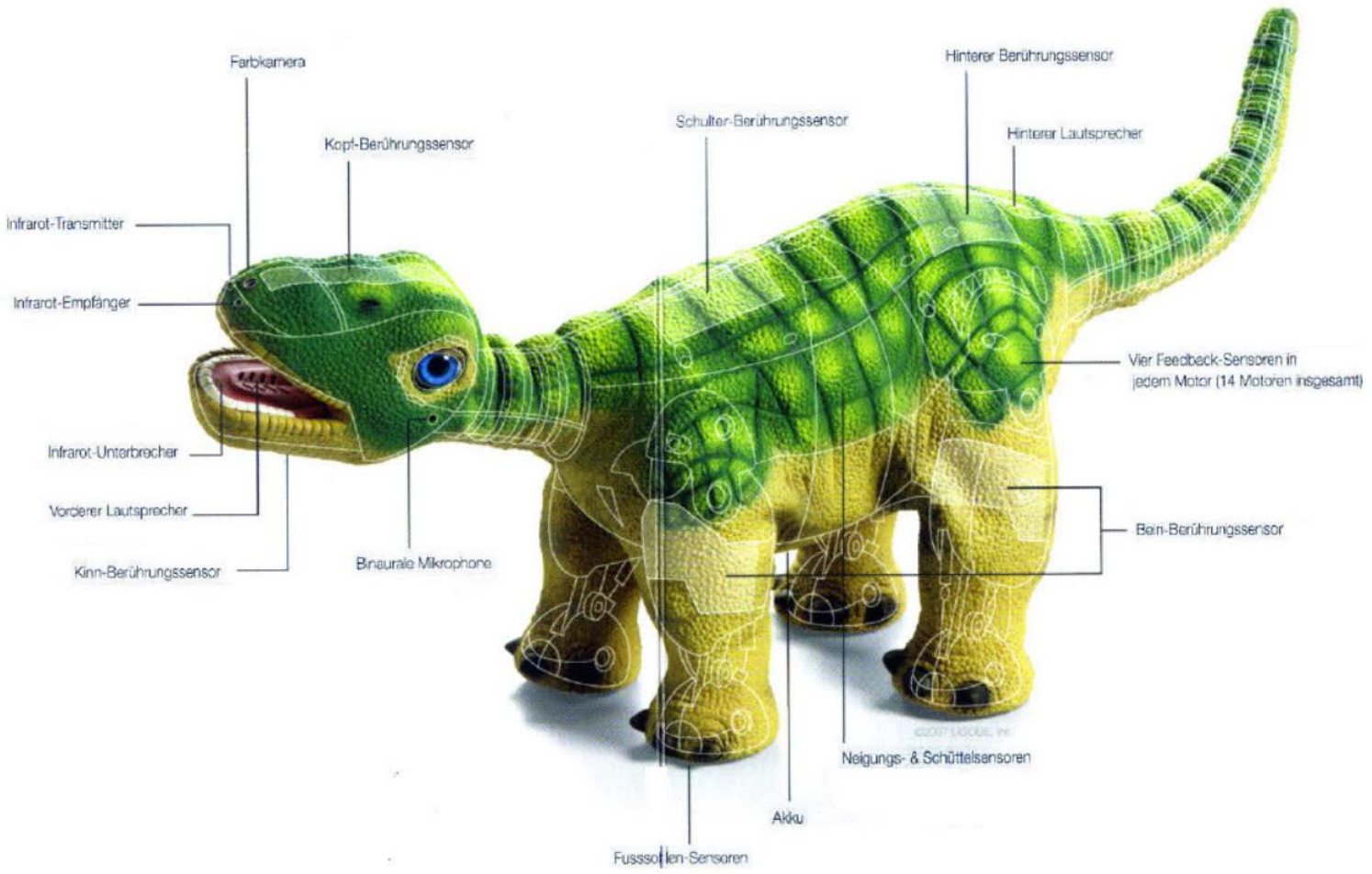
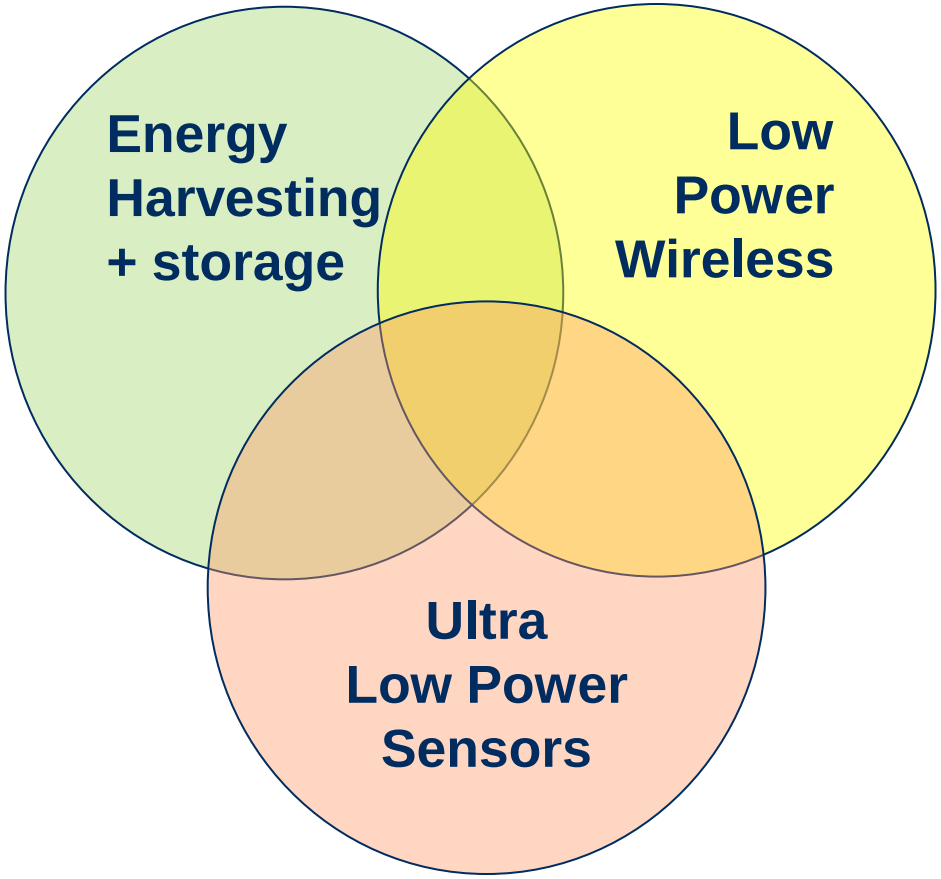
EnOcean GmbH

Sensors are the Eyes and Ears of Technical Systems



Source: pleoworld.com

A simple Idea : The Ocean of Energy Around US



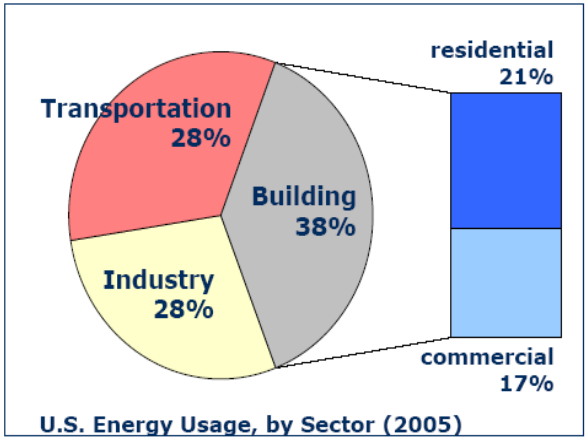
IEC/ISO Standard 14543-3-10

Wireless Sensing Technology saves resources

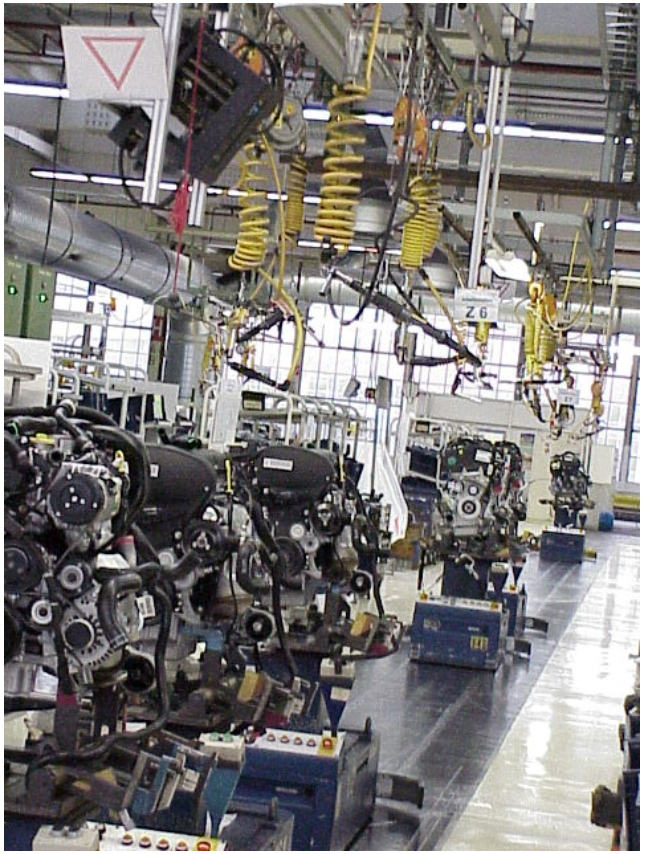
- Every 10 million wireless switches & sensors installed instead of wired devices can save :
  - 50,000 miles of cable
  - 3,000 tons copper / 11,500 tons of CO2
  - 7,100 tons PVC / 19,000 tons of CO2
  - Thousands of man years of installation time

Wireless Sensing Technology saves Energy

1. You can Save 30% Energy with Building Automation Systems

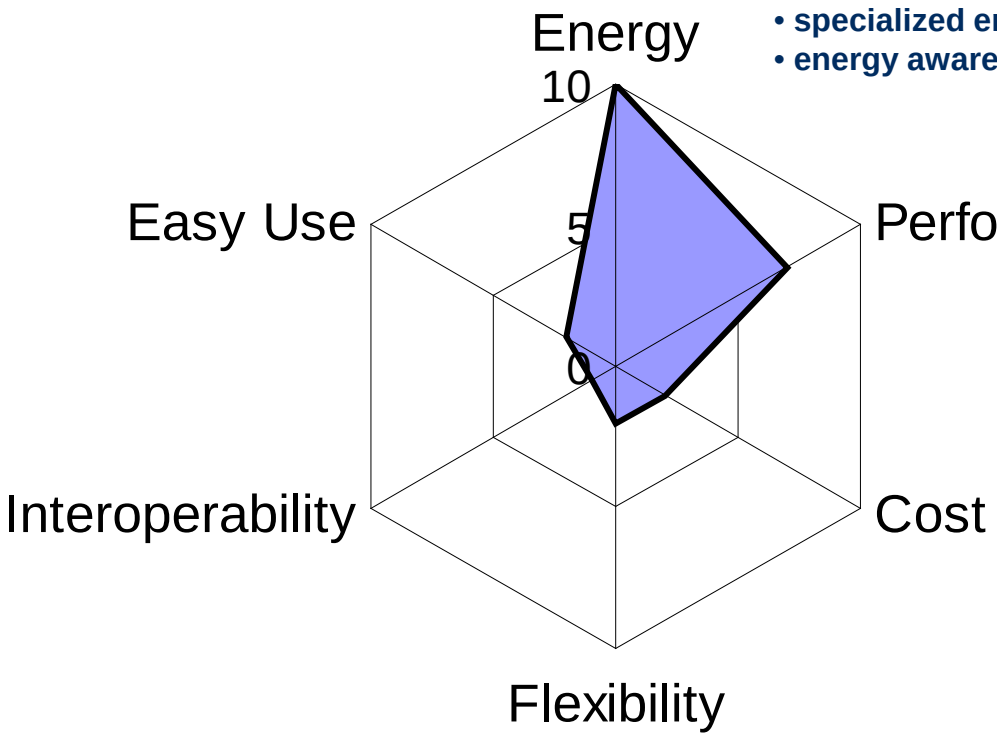


2. Energy Harvesting Sensors are ideal for Status Monitoring



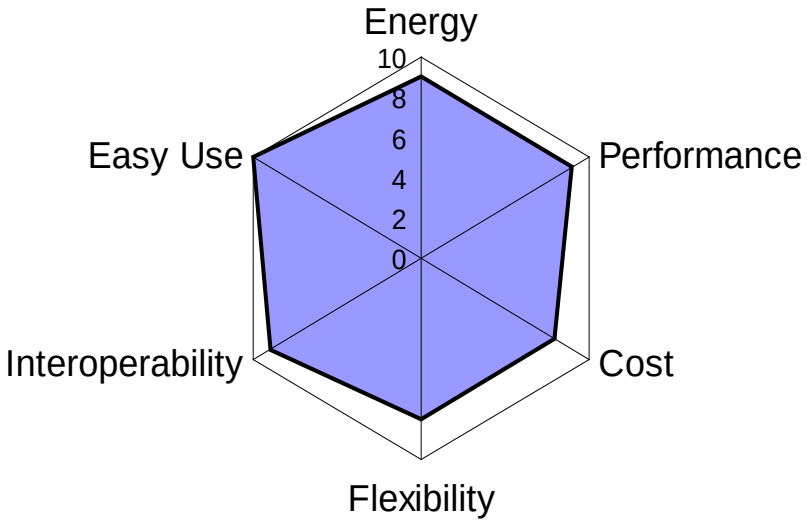
Typical Feasibility Study Optimization

- high efficiency conversion
- low loss energy storage components
- energy optimized radio protocol
- energy optimized sensors
- specialized energy management
- energy aware software design



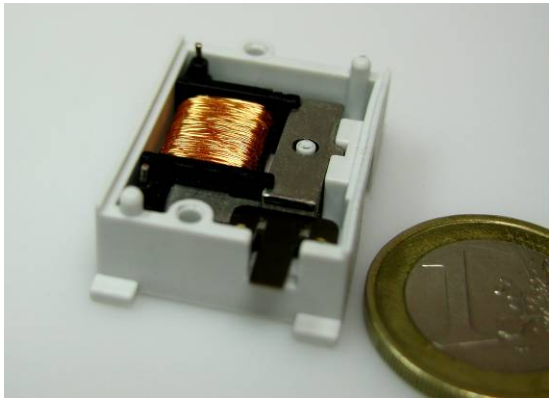
- maintenance free function
- worst case scenario ability
- High Radio Range
- High Radio reliability
- Real Time data transmission

System Approach – Key to Market

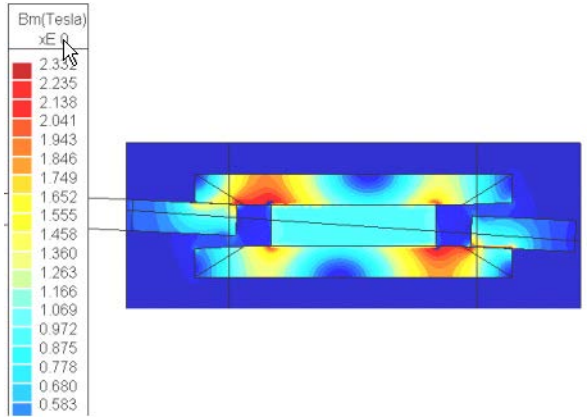


- Generic Development Platform using Standardized Radio
- „Construction Kit“, Containing all innovative Parts
- Software API for maximum flexibility
- Low Cost reliable energy converters
- Developer tools and product design support
- Installers: planning tools, debugging tools, teaching

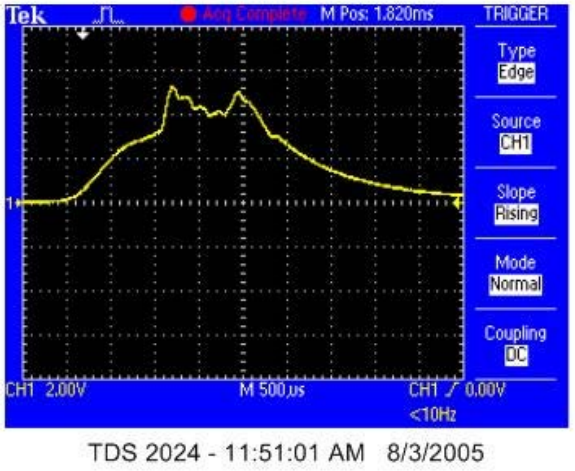
Mechanical Energy (1):Linear Movement



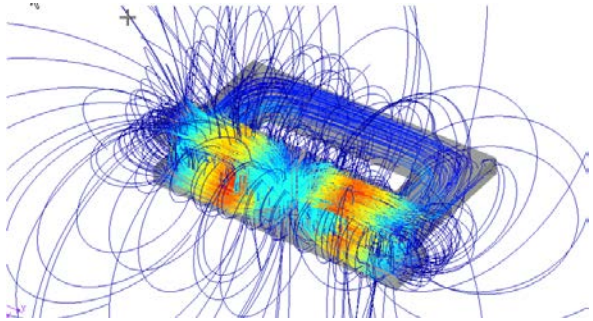
- **EnOcean ECO 100 converter module**



FEM-Simulation magnetic flux density within iron core



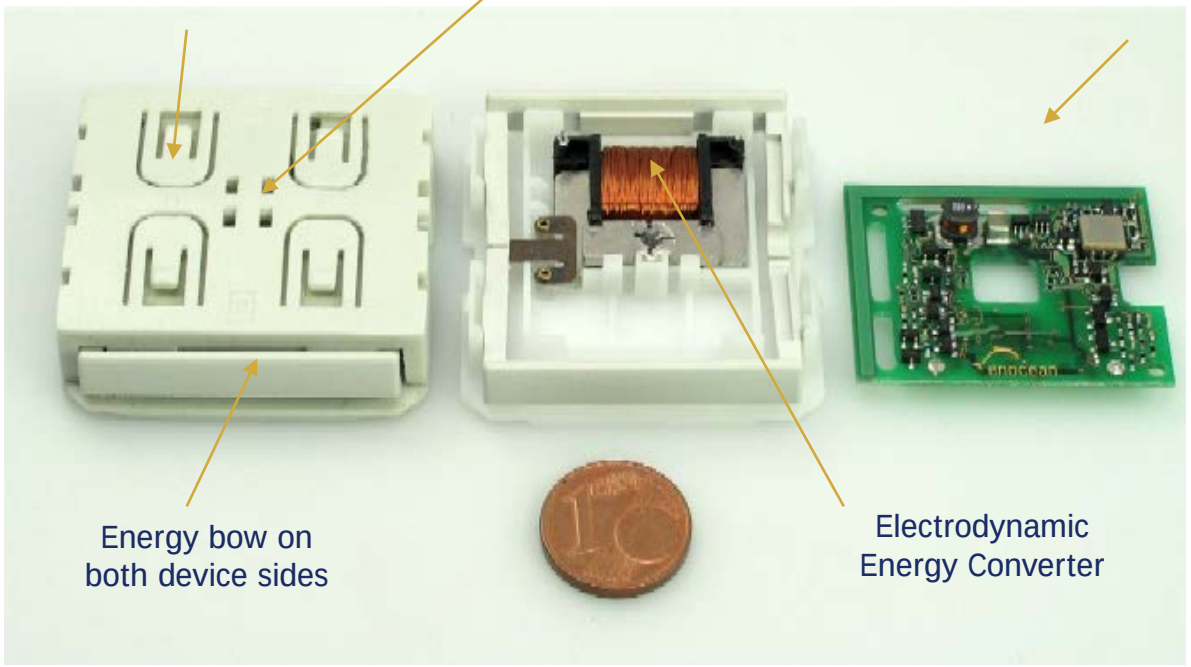
EnOcean ECO 100 voltage response



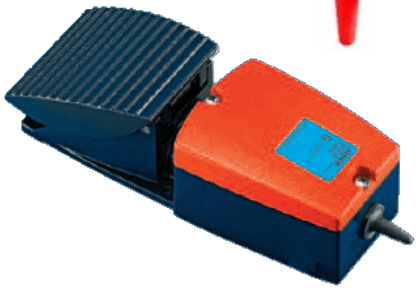
FEM-Simulation of external magnetical field

Mechanical Energy – Linear Movement and Button Push (2)

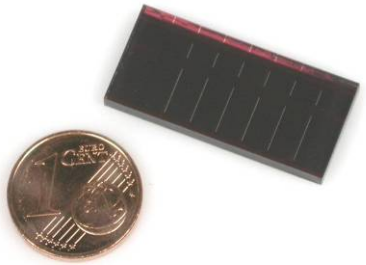
"Plug & Play" Light Switch Module

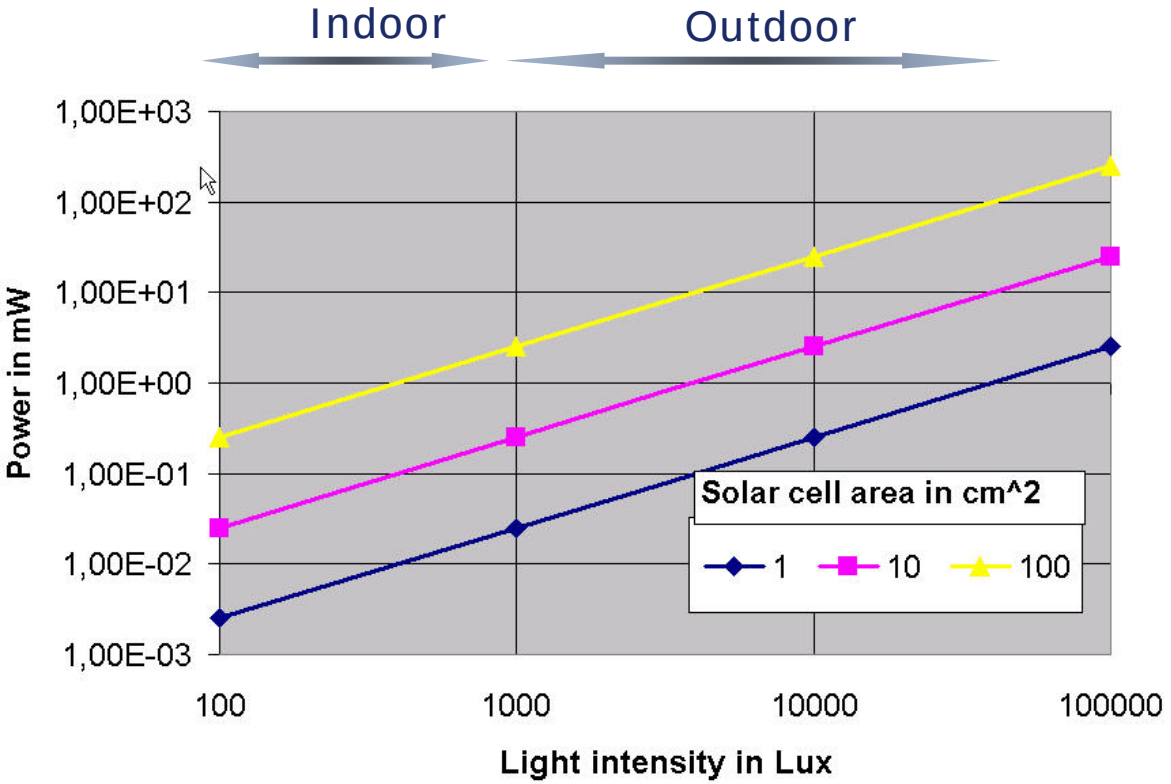


Module Based Switch Product Examples



Light Energy Power Levels





Power, attainable from Low Cost Thin Film Solar Cells

Energy Need Optimization

Concepts:

Very short working Periods of all components

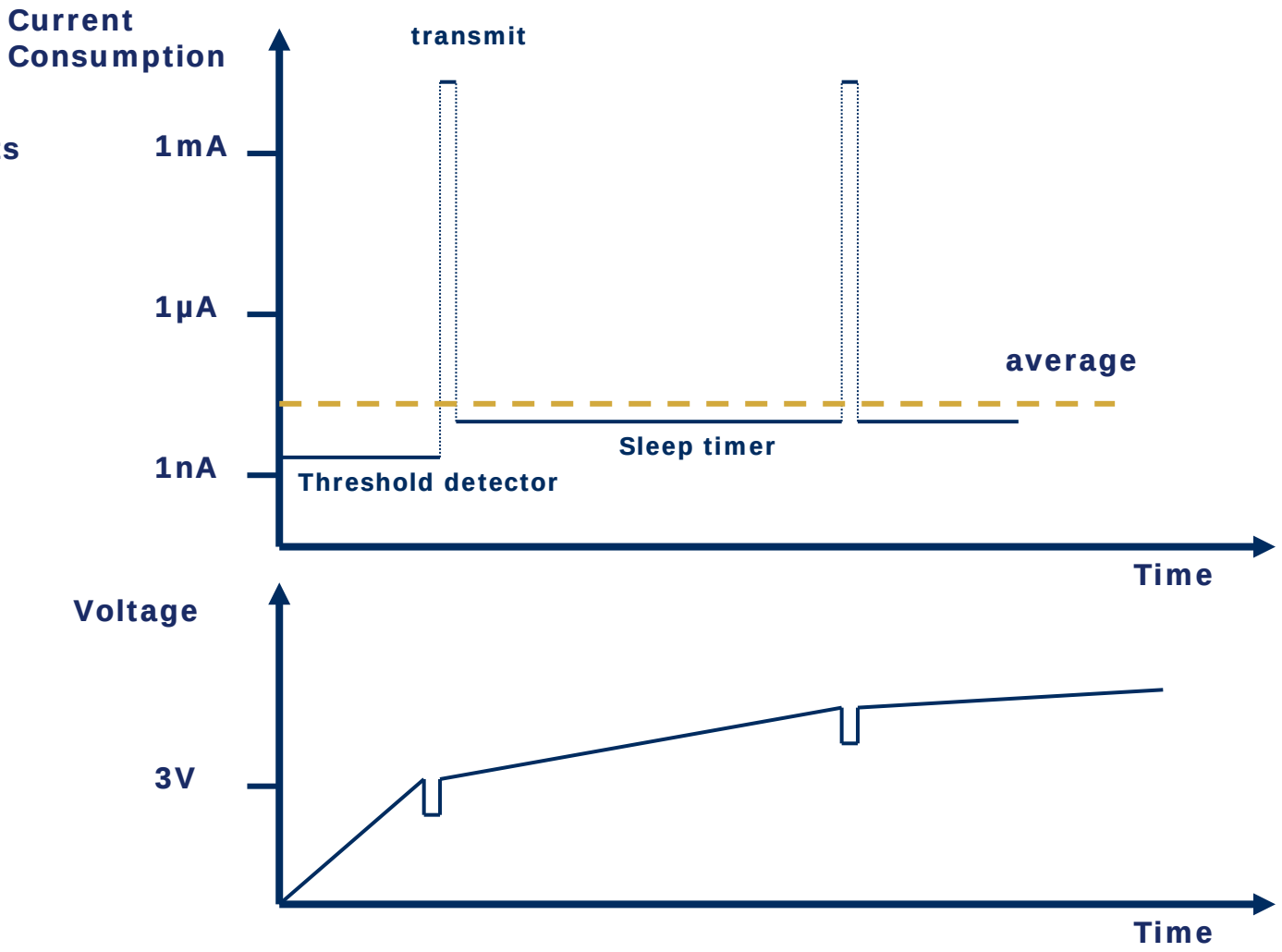
Extreme optimization of Timers and other permanent working components

EnOcean:

< 1 ms Operation for sensing, signal evaluation and transmission

Timer 20 nA

Theshold detection ca. 4 nA (STM 110)



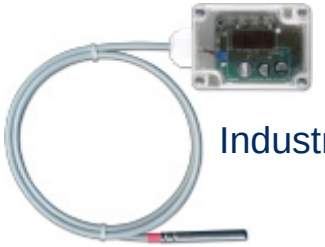
Modular Approach for Market Optimization

Solar Powered
Sensor Module STM 110

Outdoor Temp.
Sensor

Duct Temp. Sensor

Room control panels



Industrial Temp. Sensor

Industrial Fridge
Sensor Sensor

gas sensor (CO,
CO2)

Window Contact

Industrial Temp.
Sensor

Light
Sensor

PIR Presence Detection

Outdoor Thermal Energy Example: Can we drive long range radio?

Cooling down one drop of water by 1 degree contains enough energy for

25.000 EnOcean

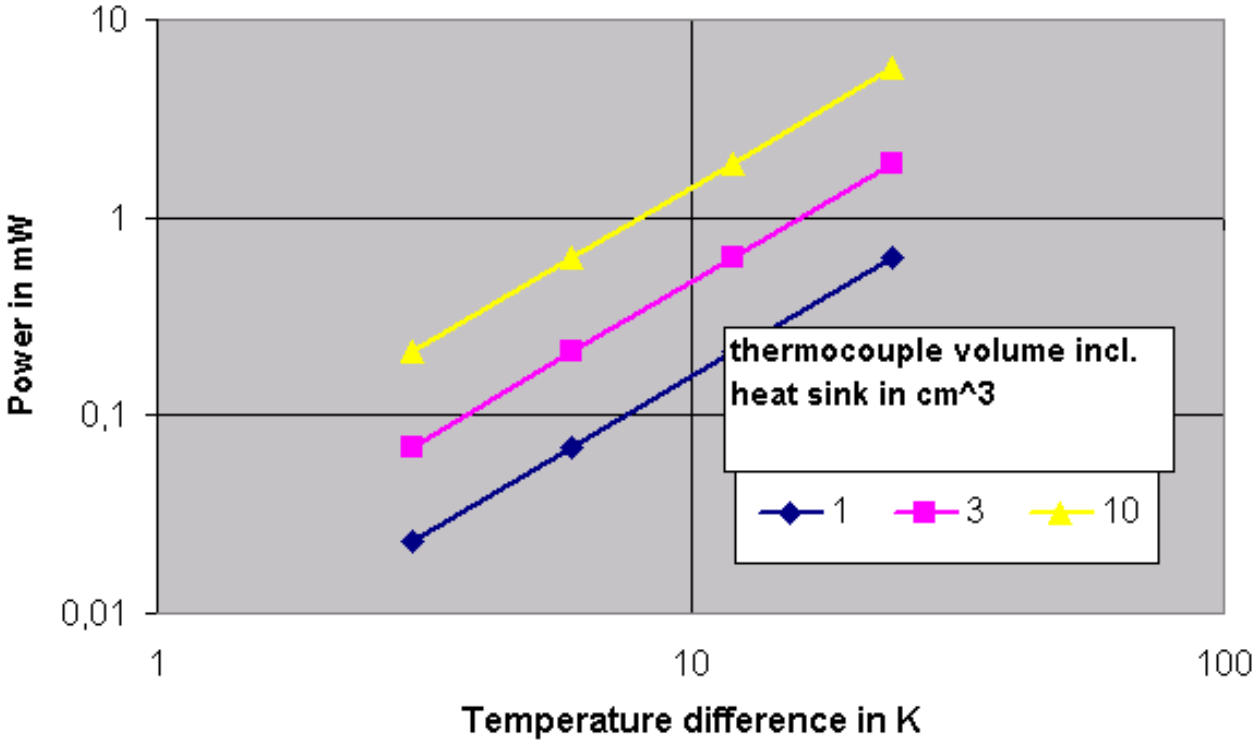
Radio telegrams at

125 kBit/s

or for

250 radio telegrams

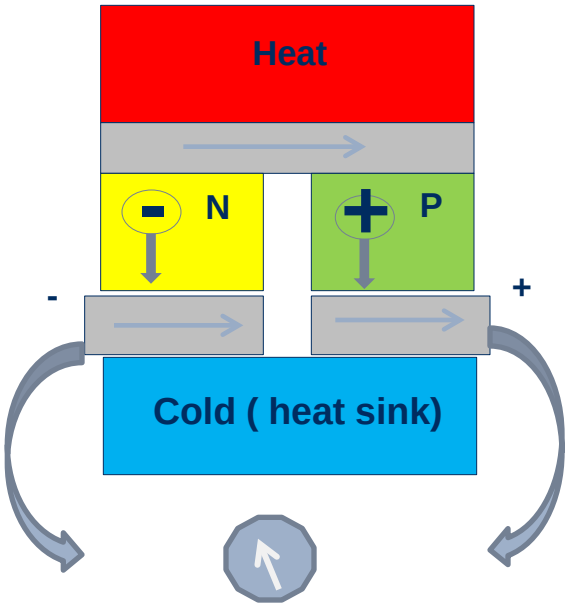
At 1,2 Kbit/s



Attainable power from thermoelectric converters depending on size and temperature difference.

For Outdoor applications a new challenge shows up: converting slow temperature changes in time into spatial gradients.

Harvesting Heat differentials



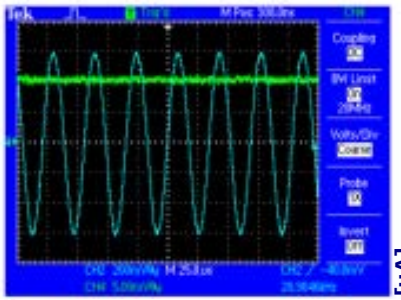
A heat source will drive electrons in the n-type element toward the cooler region, creating a current through the circuit.
Holes in the p-type element will then flow in the direction of the current. The current can then be used to power a load.

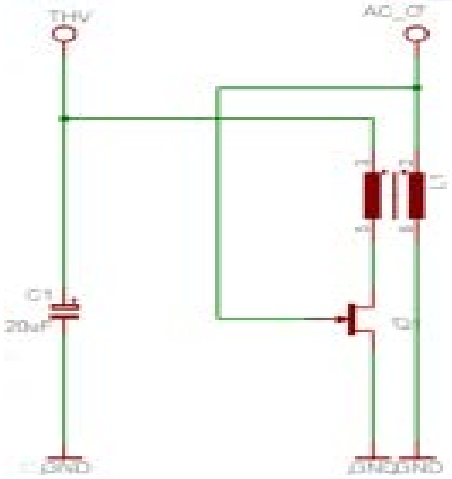
PELTIER / SEEBECK effect

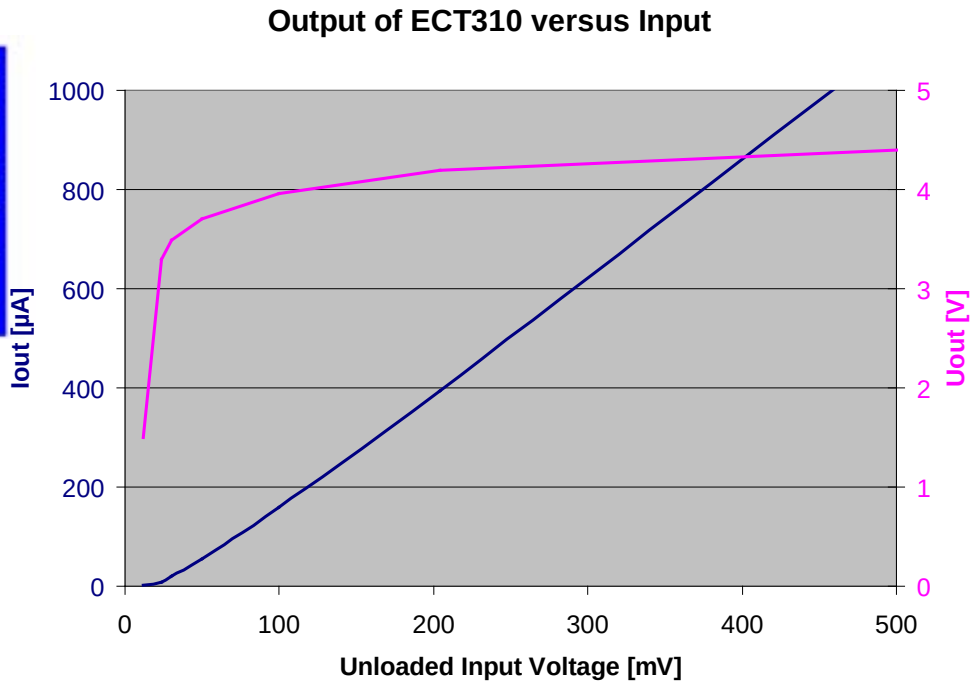
- A thermoelectric device creates a voltage when there is a different temperature on 2 junctions of 2 metals, a property discovered by Seebeck in 1821.
  - Conversely when a voltage is applied, it creates a temperature difference (known as the Peltier effect).
- There are a number of low cost Peltier elements available and these can be used ‘in reverse’ as generators for small wireless monitors.
  - Standard thermoelectric modules manufactured today consist of P- and N-doped bismuth-telluride semiconductors sandwiched between two metallized ceramic plates

ECT310 Working Principle

New converter concept – Highly optimized blocking oscillator for very low voltages

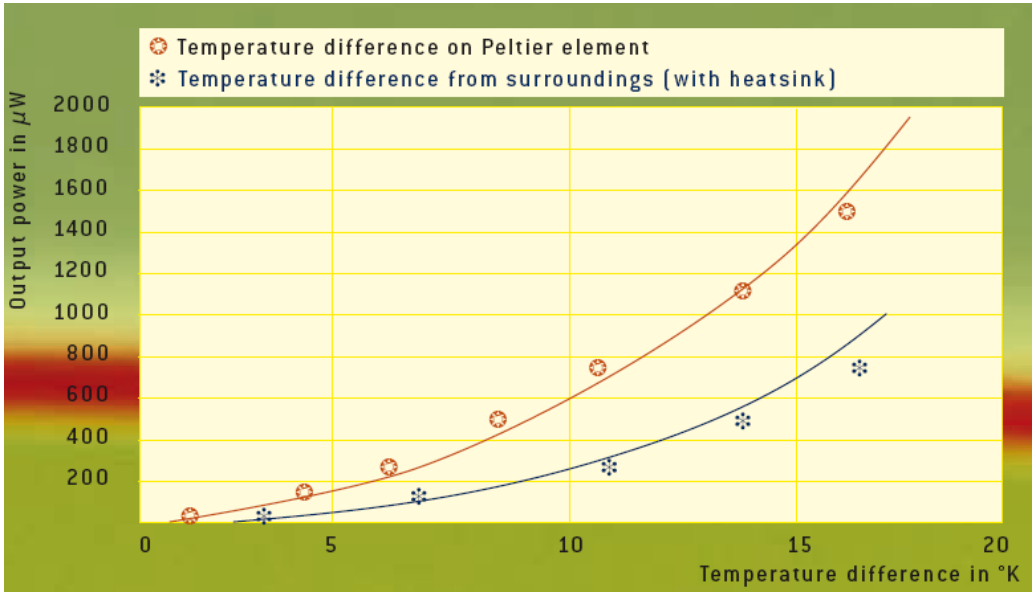




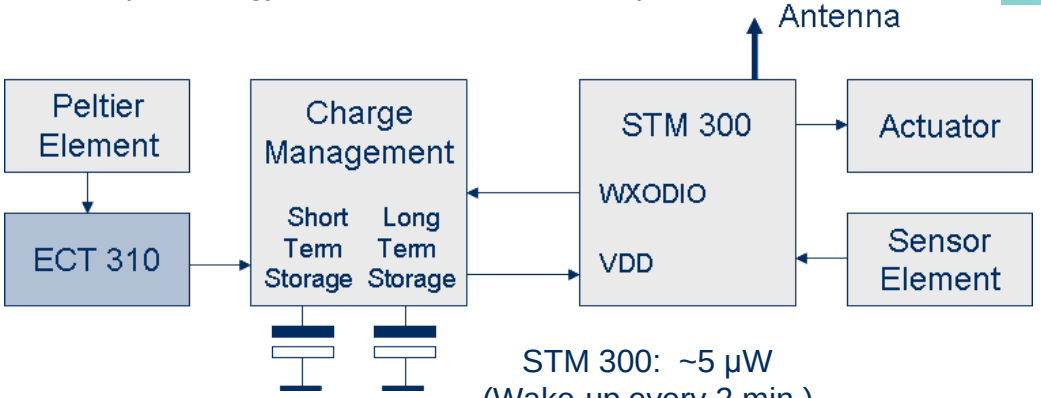


Input voltage larger than 20 mV is converted to an output voltage ≥ 3 Volt

Thermo-powered Wireless Actuator



~100 µW energy available at 7 Kelvin temperature difference

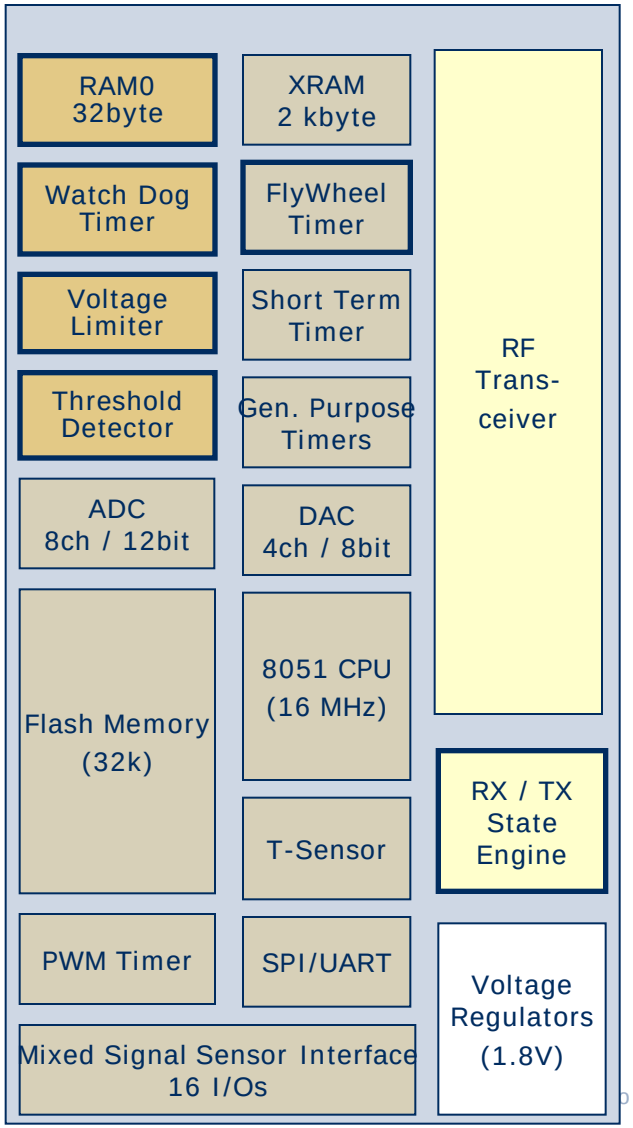


STM 300: ~5 µW
(Wake-up every 2 min.)

Actuator Application

Enough energy is available to power some intermittently powered actuators !

Electronics for 3rd Generation Devices: Dolphin Single Chip Solution

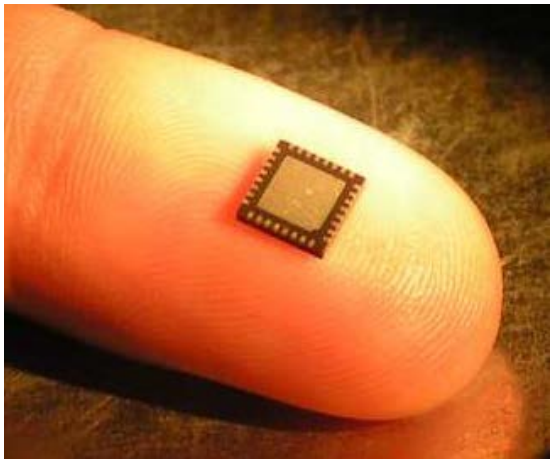


Energy Scavenger

Sensor(s)

XTAL

Antenna

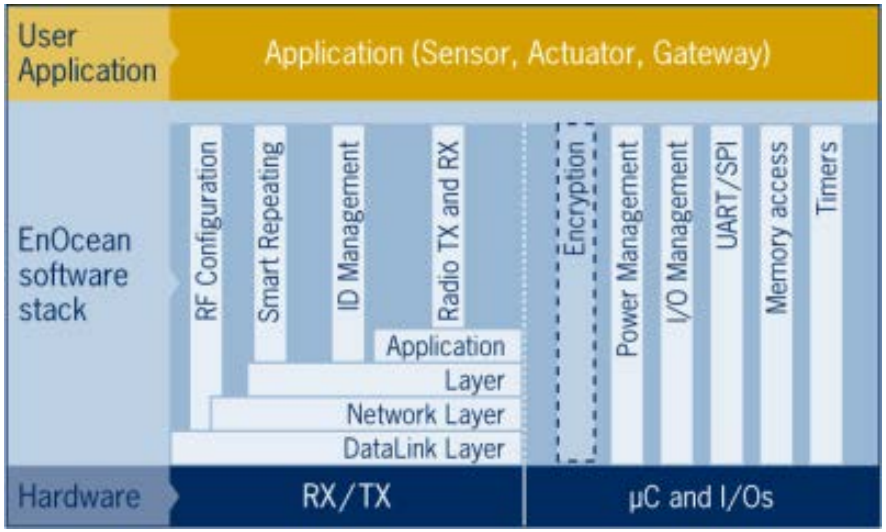


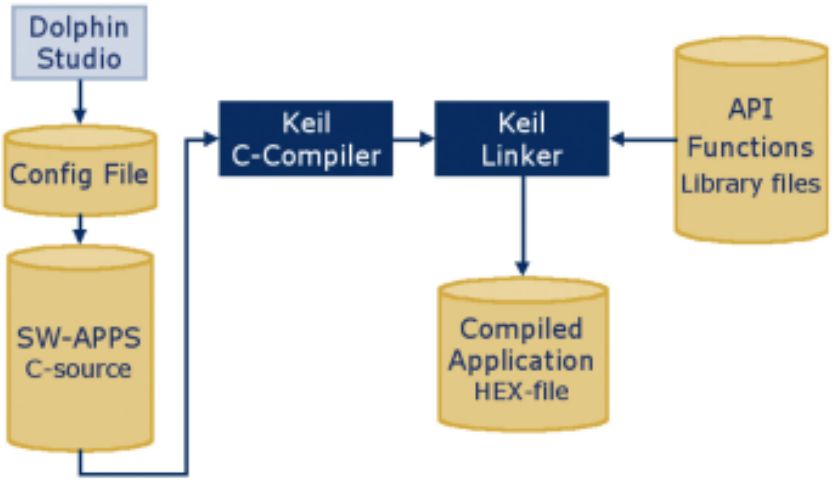
Superior Low Energy Need

- **OFF Mode** **~20nA**
- **Deep Sleep Timer Mode** **~200nA**
- **Flywheel Sleep Mode** **~500nA**
- **Short Term Sleep Mode** **~15µA**
- **Standby Mode** **~1.3mA**
- **CPU Mode** **~4mA**
- **TX (868MHz, 10dBm)** **~25mA**
- **RX (868MHz)** **~28mA**

- **Fast operation mode changes**
- **Only a few additional components needed**

EnOcean Dolphin Software API





- Operating system with API
- Easily programmed using "C"
- Source code samples (switching, dimming, etc.)
- Comprehensive software libraries (wireless communication, energy management, etc)

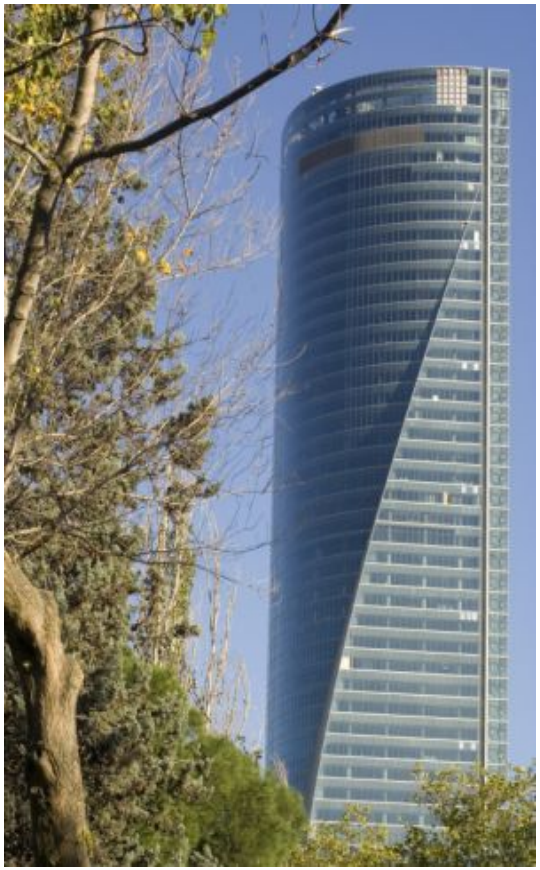
EnOcean Radio Protocol – an International Standard

The standard offers physical layer, data link layer and network layer

The EnOcean Alliance standardizes the application level (interoperability)

Important addition to the wireless standards landscape (e.g. IEEE 802.11, IEEE 802.15.1, IEEE 802.15.4)

Installation Examples: Office Towers



- 4200 Wireless & Battery-less Light Switches
- Occupancy Sensors
- Daylight Sensors

- **Savings**

  40 % Lighting Energy Costs

  31 Kilometers of Cable

  80 % cost of retrofitting

Torre Espacio, Madrid, Spain

TECHNOLOGY INSIDE – EnOcean GmbH
Provider of Modules & EH Components to OEMs

EnOcean Commercial Building – CASE STUDIES

The Squaire – Frankfurt

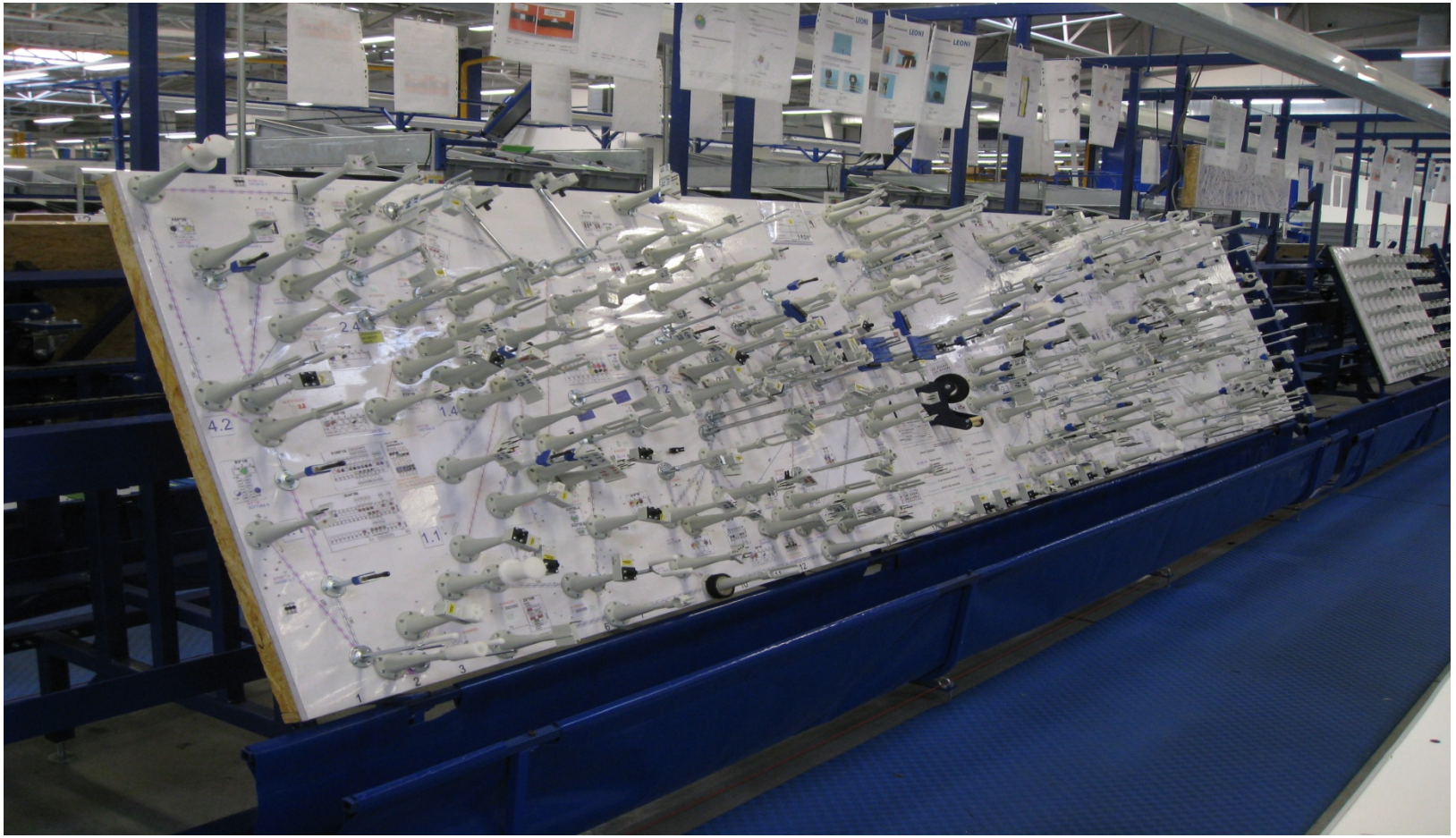
Unit	Type	Pieces
EnOcean-Terminal	750-642	1838
EnOcean- Switch	PTM 200	12000
EnOcean- Roomsensor	SR07	6000

Tower 185 Frankfurt

Torre Espacio & Torre Cristallo – Madrid

ONE-SHOP SH SOLUTION – TELEFUNKEN

Industrial Applications 3



- **Cable Tree Radio Sensors for Automotive**
- **Status: Products**

ONE-SHOP SH SOLUTION – Eltako ELECTRONICS

Green. Smart. Wireless. enocean®

Eltako Smart Home –
die preiswerten Schritte zur Gebäudeautomation

Die ganze Freiheit

Smart Home-Zentrale

Ergänzungspakete

Licht-Controller
2 x FLC61NP-230V, 1 x FT4F-wg

Lichtdimmer-Controller
2 x FUD61NPN-230V, 1 x FT4F-wg

Beschattungs-Controller
2 x FSB61NP-230V, 1 x FT4F-wg

Energie-Controller
1 x FWZ61-16A, 1 x FEA55D-wg

Heizungs-Controller I und II
1 x FKS, 1 x FTR55H-wg oder 2 x FKS

Software-Upgrade
FVS-Smart Home auf FVS-Home

Product cataloque with around 1000 ordering positions

Eltako Smart Home ist der Eltako-Gebäudefunk mit den revolutionären leitungs- und batterielosen ***enocean***®-Funksensoren in Eltako-Funktastern und mit innovativen Eltako-Funk-Schaltgeräten.

Eltako Smart Home ist keine Insellösung wie viele zuvor angebotenen Smart Home-Systeme. Alle Komponenten sind Originalteile aus dem erfolgreichen Eltako-Funk. Sie kommunizieren in dem Eltako-Gebäudefunk mit Telegrammen, welche von der EnOcean-Alliance weltweit standardisiert werden. Die Sendemodule und Funkchips fertigt EnOcean, München.

www.eltako.com

150+ Customers Integrated the EnOcean Solution in 250.000+ Buildings worldwide

… and created more than 1000 interoperable products!

Who needs longer range radio sensors?
Structural Health Monitoring

Source: Kinemetrics.com

Problem:

- Structural health is rarely monitored today. With ageing structures, the need increases.

Solution:

- High range solar powered low cost sensors for strain, integrity, distance etc.
- Reporting to GSM or Internet

Who needs longer range radio sensors? Industrial Applications

Problem:

- Industrial sensors are cabled today. The cabling is expensive (e.g. 50% of the cost for industrial open range sensors) and limits the sensor use.

Solution:

- High range solar powered low cost sensors for temperature, position, fluid levels etc. in Industry or power supplies

Who needs longer range radio sensors?
Agricultural Monitoring sensors

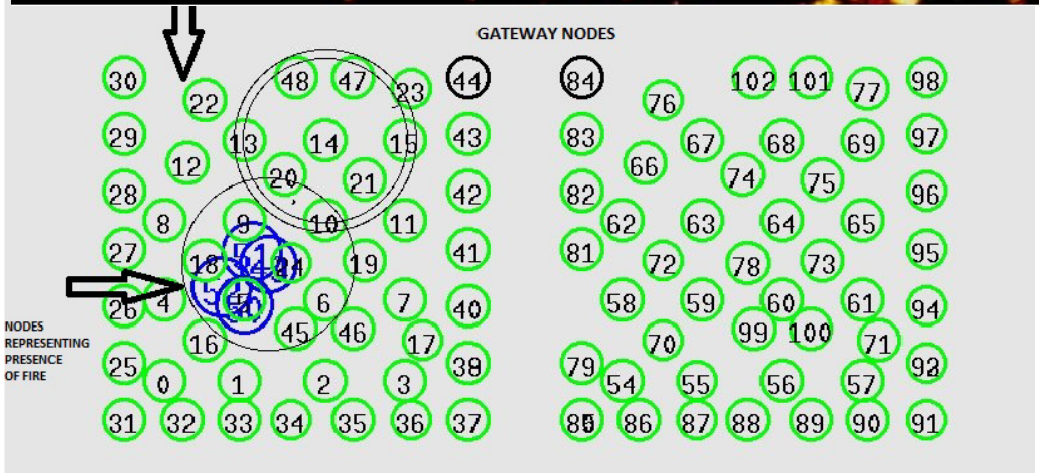
Problem:

- Food production is rarely monitored today, which leads to unused optimization potential.

Solution:

- Energy Harvesting sensors monitoring soil properties as humidity, fertilizer status, temperatures, gases.
- Sensors for stock-breeding

Who needs longer range radio sensors? Forest Fire detection



Source: Alice Abraham et al, Energy Efficient Detection of Forest Fires Using Wireless Sensor Networks, IWCN 2012

Problem:

- Wood fires cause enormous damage every year. A low cost infrastructure and manntenance free detection technology is missing.

Solution:

- High range and low cost solar powered sensors for fire detection.
- Reporting to GSM or Internet

Summary

- **Energy Harvesting has made it in the building automation and related environments**
- The key success factors where
  - A “construction Kit” approach, which combines Harvesting, Low power and Radio technology
  - In this way Using your innovation potential
  - Defining a radio standard and ensuring interoperability
  - Creating the Alliance user community that has the critical mass to set the ball rolling

- **Now it is time to tackle new application areas!**
- We know a lot of interesting applications that can solve urgent problems
- However, many of them need enhanced range performance

- **EnOcean started a development project addressing this needs**
- We intend to keep the things that worked in the past
  - The platform approach
  - Interoperability and standardization
  - Open Innovation
- And ask for your collaboration to make it a success again

Thank you for your attention.

Frank Schmidt, CTO
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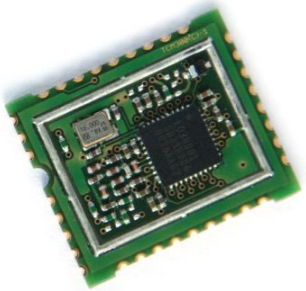
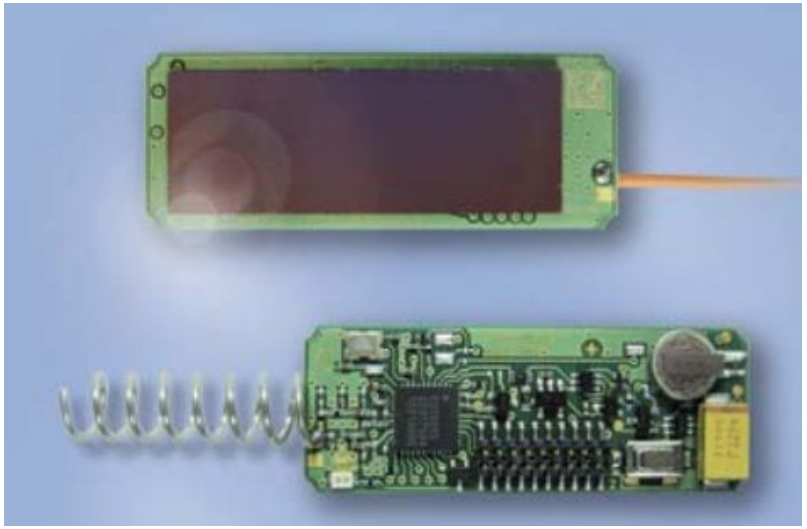
The next Generation: SoC allows compact and lower cost solutions

2003: Discrete components on both PCB sides,
42 x 24 x 5 mm, 5V, 33 mA



2009: 22 x 19 x 3 mm, 2.5V, 25 mA

2010:
Multi Purpose Sensor Module,
Solar Powered, Programmable,
Energy Store on PCB



Development Platform for Self-powered Sensor Applications

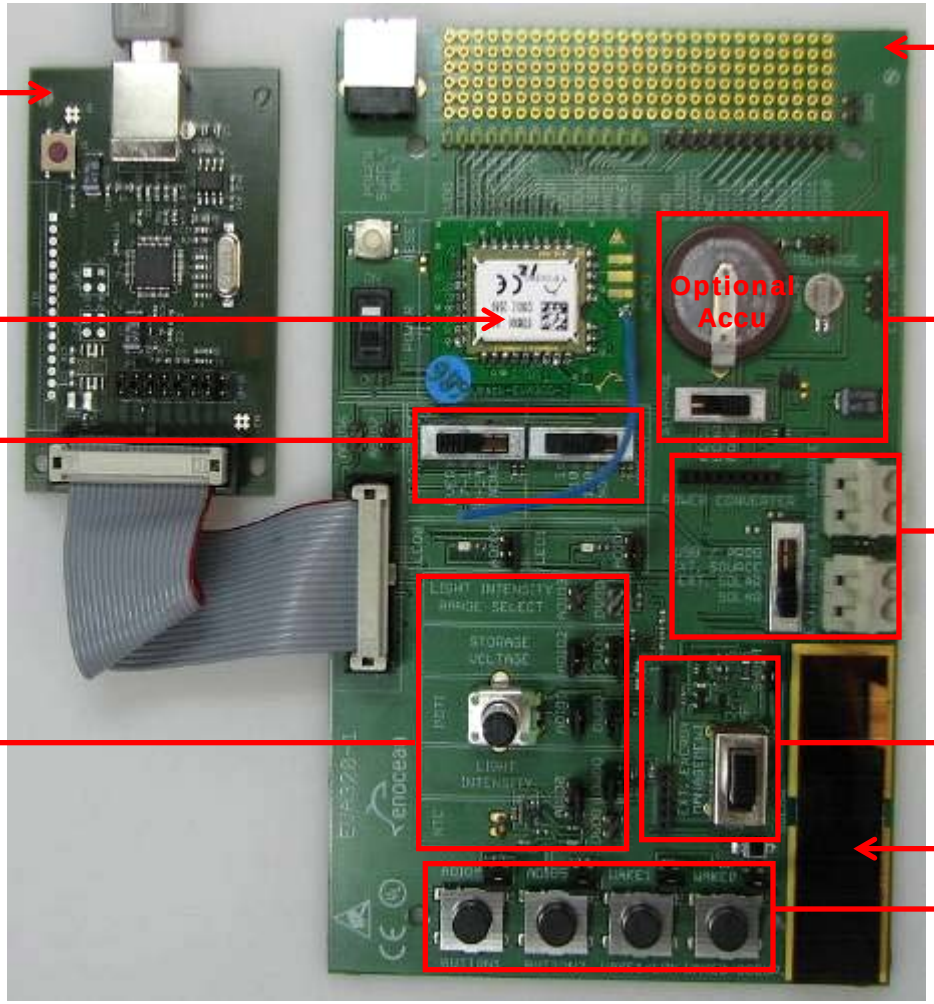
EOP 300 Programmer

STM 300 on Adapter Board

STM 300 config.

STM 300 sensor examples:

- Temperature
- Light intensity
- Poti
- Energy storage voltage



EVA 320 Board

Multiple energy storage

Multiple energy harvesters

Energy management

Solar cell

Buttons