



## Industry Session 12.1:

# *Energy Harvesting powered sensors/IoT devices*

**Presented By –**

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**@Wurth Elektronik eiSos**

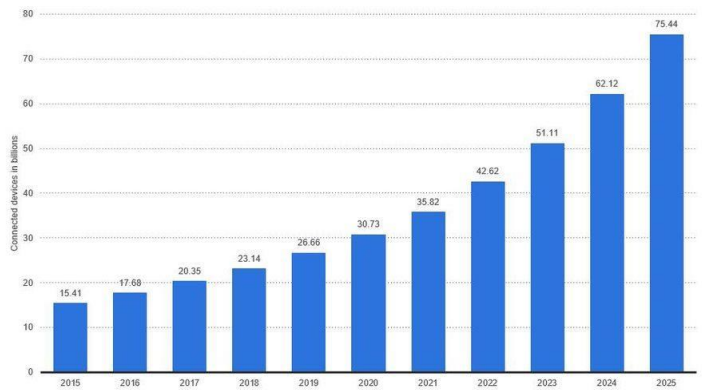
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**Day: June 9-12, 2021**

# Introduction:

- Growing markets of IoT and condition monitoring
  - 75 bn devices connected by 2025
  - Powering of sensors in remote locations, portable and wearable devices required
  - Electronics spreading in everyday products

Internet of Things - number of connected devices worldwide 2015-2025  
**Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025 (in billions)** [1]

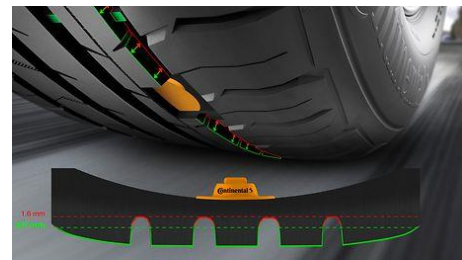


Predictive maintenance at rails (wired)



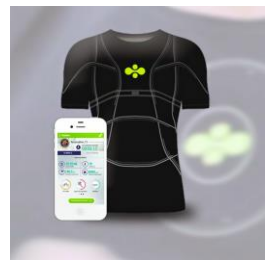
[2]

Predictive maintenance (battery)



[3]

Wearables



[4]

[1] <https://objectbox.io/top-5-reasons-why-edge-computing-crucial-for-iiot/>

[2] <https://www.lok-report.de/news/deutschland/industrie/item/4590-deutsche-bahn-sensor-zur-vorausschauenden-instandhaltung-von-weichen.html>

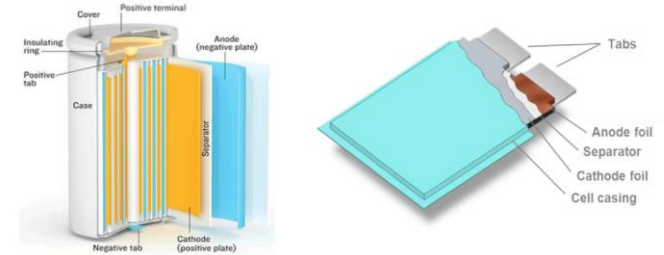
[3] <https://www.continental.com/de/presse/pressemitteilungen/2014-05-07-tpms-profile-105006>

[4] <http://sportmondo-sportsportal.blogspot.com/2014/04/e-textiles-electronic-textiles-2014.html>

# Current solutions:

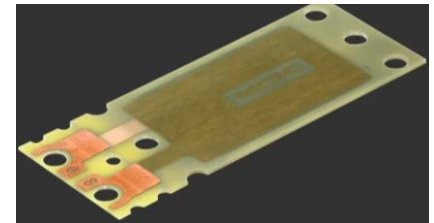
- Wiring of sensor nodes:
  - Tremendous installation effort
  - Often not possible (rotating parts, remote locations)
- Batteries:
  - Toxic waste
  - Limited lifetime
- Energy Harvesting:
  - Hazardous waste (Lead-based harvesters, batteries)
  - Hi amount of electronic required per mW
  - High cost Euro per mW
  - Short term energy storage required

Current Li-ion battery



Zubi, G.; Dufo-López, R.; Carvalho, M.; Pasaoglu, G. The Lithium-Ion Battery: State of the Art and Future Perspectives. *Renewable and Sustainable Energy Reviews* 2018, 89, 292–308.

Piezo.com  
PZT based  
Harvester:  
14 mW  
234 \$



<https://piezo.com/collections/piezoelectric-energy-harvesters/products/piezoelectric-bending-transducer-s233-h5fr-1107xb#&gid=1&pid=1>

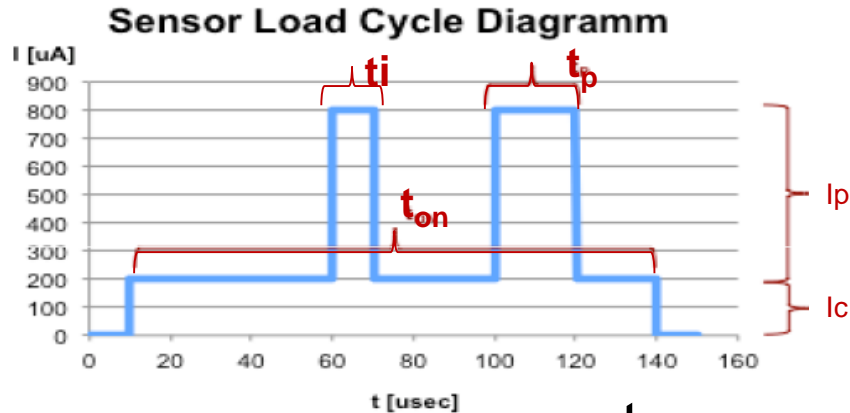
# Energy Harvesting = Energy for free?

- Energy harvesting has recently become a topic of much discussion with its potential to self-power autonomous devices for wearables, medical devices and for IoT (the Internet of Things)
- Examples of real life use cases demonstrating that Energy Harvesting has already progressed from the laboratory to commercial applications
- We need devices that are:
  - Wireless (avoid power and communications cables)
  - Totally autonomous
  - Highly reliable with backup battery lifetime up to 15~20 years

# Basic consideration for Energy Harvesting

## First step:

- calculate the total energy demand for your system
- watch out for your peak energy demand



$V_s$ : Supply Voltage

$I_c$ : continuous current

$I_p$ : pulsed current

$t_{i,p}$ : pulse duration

$t_{on}$ : system on time

DC: sequence Duty Cycle

$$E_{total} = \int V * I * dt$$

$$E_{total} = V_S * (I_c * t_{on} + \sum_i I_{i,p} * t_{i,p})$$

$$P_{AVG} = \frac{E}{\Delta t} = \frac{E_{total} * DC_{AVG}}{\Delta t}$$

# Basic consideration for Energy Harvesting

## Second step:

- consider the source capabilities
- check multiple source availability (solar, thermo, motion, chemical... etc.)
- watch out for the stability over the time (use a data logger)

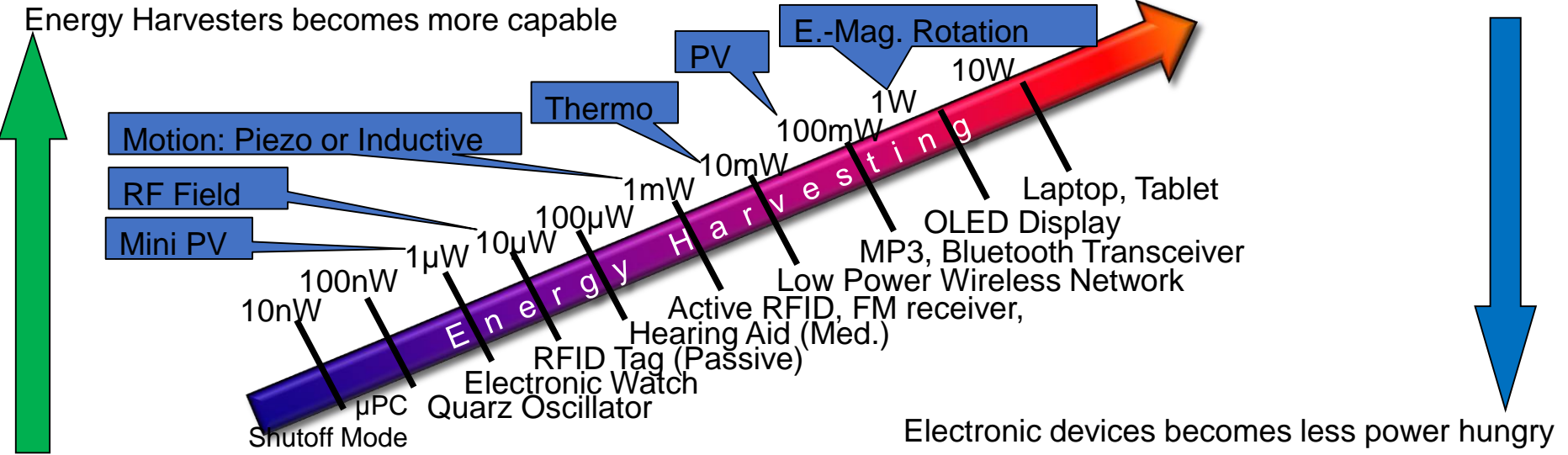
## Third step:

- choose the right harvester (transducer)
- build the right voltage converter (source impedance matching)
- consider an energy storage for back up
  - capacity bank
  - supercaps
  - ultracaps (Supercap/Lithium-Ion)
  - Li-Pol rechargeable

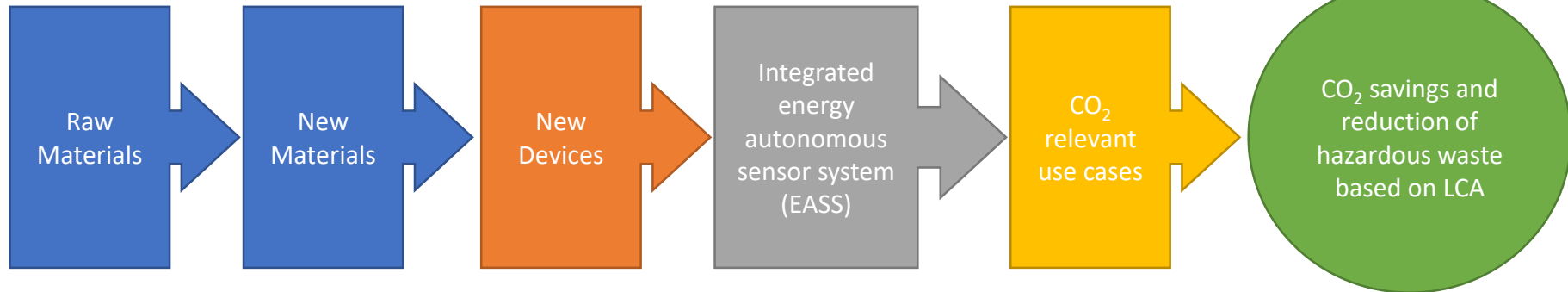
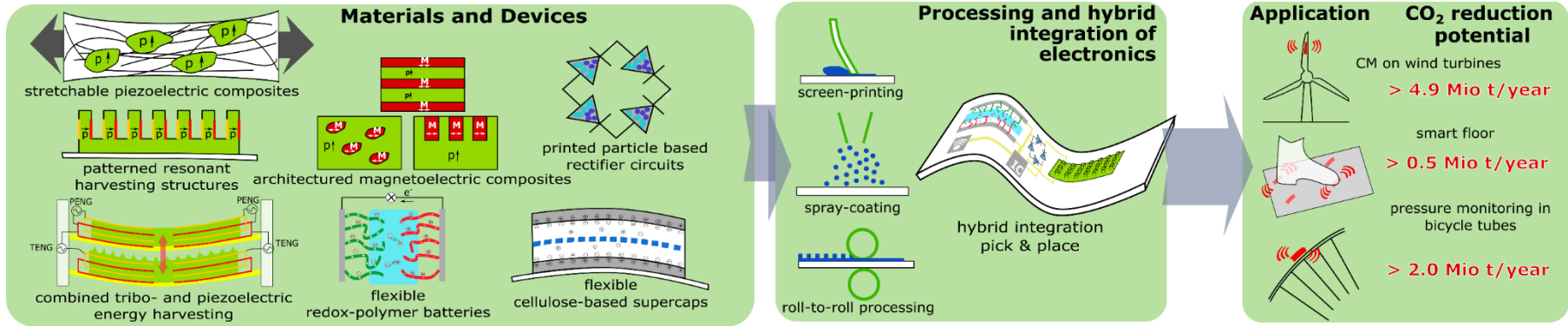
# Where to find „free energy“

- Typical energy harvester output power
  - RF: 0.1μW/cm<sup>2</sup>
  - Vibration: 1mW/cm<sup>2</sup>
  - Thermal: 10mW/cm<sup>2</sup>
  - Photovoltaic: 100mW/cm<sup>2</sup>

- Typical energy harvester voltages
  - RF: 0.01mV
  - Vibration: 0.1 ~ 0.4 V
  - Thermal: 0.02 ~ 1.0 V
  - Photovoltaic: 0.5 ~ 0.7 V typ./cell



# EU funding Project: SYMPHONY



# SYMPHONY fact sheet:

**Start Date:** 01/05/2020

**End date:** 30/04/2024

**Duration in months:** 48

**Website:** [www.symphony-energy.eu](http://www.symphony-energy.eu)

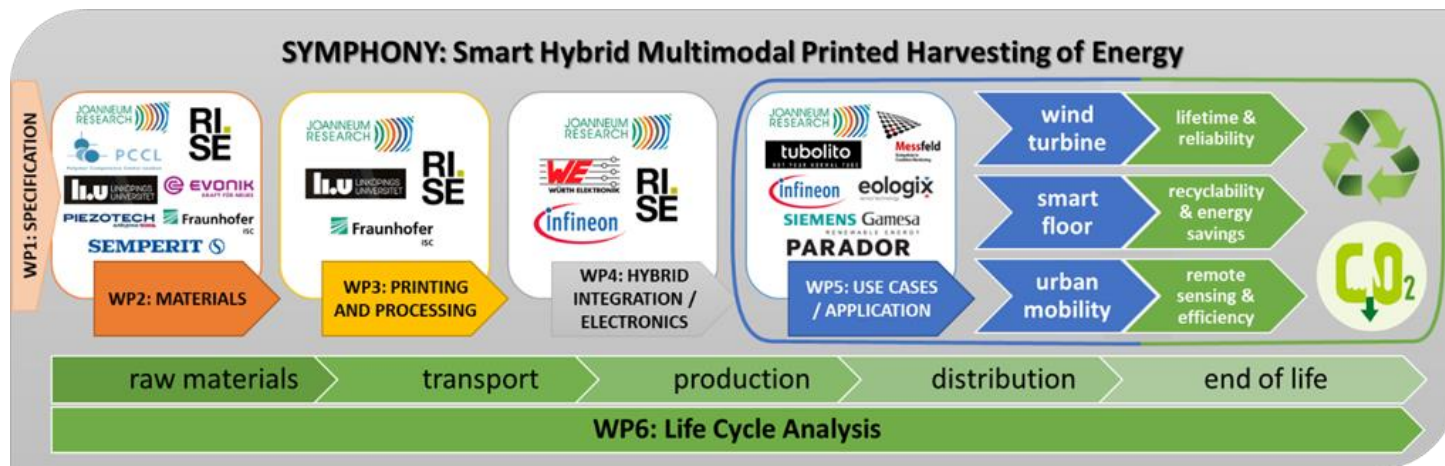
**Grant Agreement number:**  
862095

**Project budget:** 6,82 M€

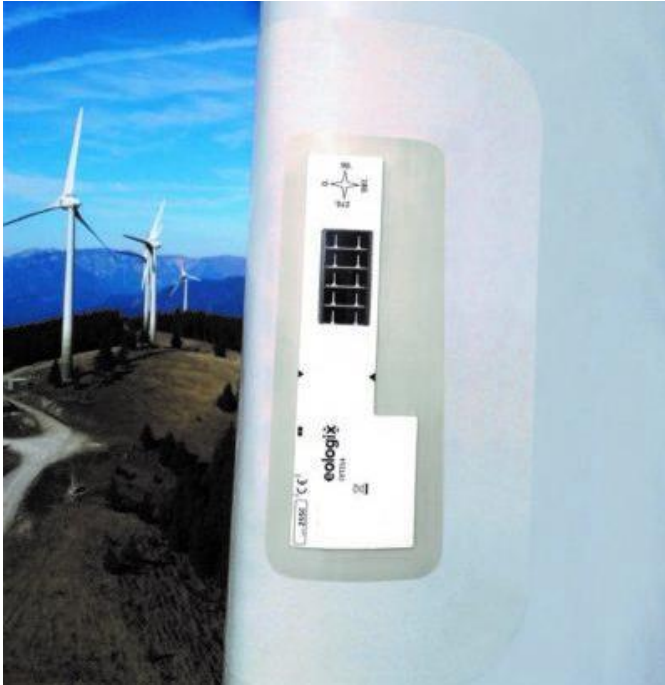
**Joanneum budget:** 1758615€

**Coordinator:** Dr. Jonas Groten, Joanneum HEP group (Austria), [jonas.groten@joanneum.at](mailto:jonas.groten@joanneum.at)

**Consortium:**



# SYMPHONY use cases:



Use case:

**Sensor** skin for wind turbine condition monitoring – energy self-sufficient eologix sensors are mounted directly on the rotor blade surface.

(Copyright: eologix sensor technology GmbH)

The project will develop an integrated sensor skin based on the SYMPHONY Energy Supply Platform and P(VDF-TrFE) sensors that allow Condition Monitoring of rotor blades of wind turbines to increase their lifetime and reduce downtimes.

# SYMPHONY use cases:



Use case:

## **Smart floor**

(Copyright: Joanneum Research – MATERIALS)

SYMPHONY platform enables precise, high-resolution motion tracking to be carried out without endangering the customer's privacy or requiring additional installation steps.

The SYMPHONY self-powered solution will replace batteries and lead based energy harvesters, avoiding toxic waste, through the use of resource efficient and large scale production technologies.

# SYMPHONY use cases:



Use case:

## **Automated pressure monitoring of bike tubes**

(Copyright: Markus Frühmann, Tubolito GmbH)

Bicycle tire pressure directly affects rolling resistance, ride comfort, puncture protection, and grip. In e-biking (typically 3-5 bar), rolling resistance also affects battery life.

An automatic remote monitoring of the pressure of bike tubes will help to keep it, will reduce the maintenance costs for rental e-bike systems and will overall decrease the electrical energy consumption.

A wireless tire pressure sensor mounted in the tire tubes could improve driving experience and comfort as well.

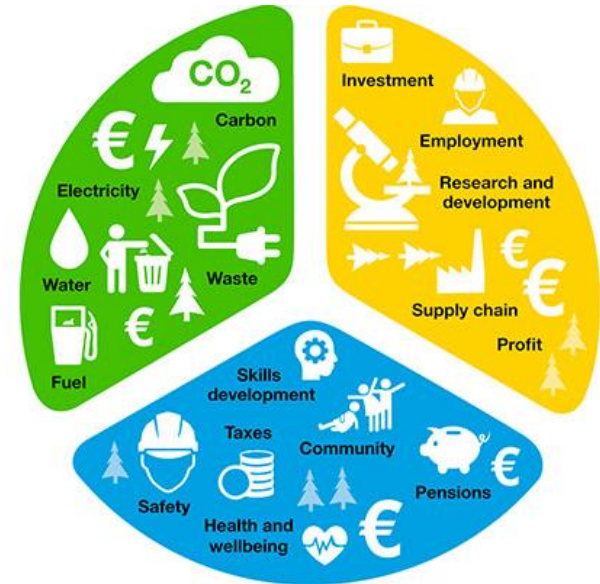
# SYMPHONY impact:

**SYMPHONY will contribute significantly to acceleration of future low-carbon competitive economy.**

The printed technology can be integrated cost effectively in stretchable and flexible devices, representing a huge potential for usage in a wide range of further IoT-supported applications.

**The SYMPHONY platform will provide functionalities such as Condition Monitoring, Predictive Maintenance or Energy Management in three application areas:**

- **Renewable energy generation**
- **Room heating/cooling**
- **E-mobility**



# Typical Inductive Transducers

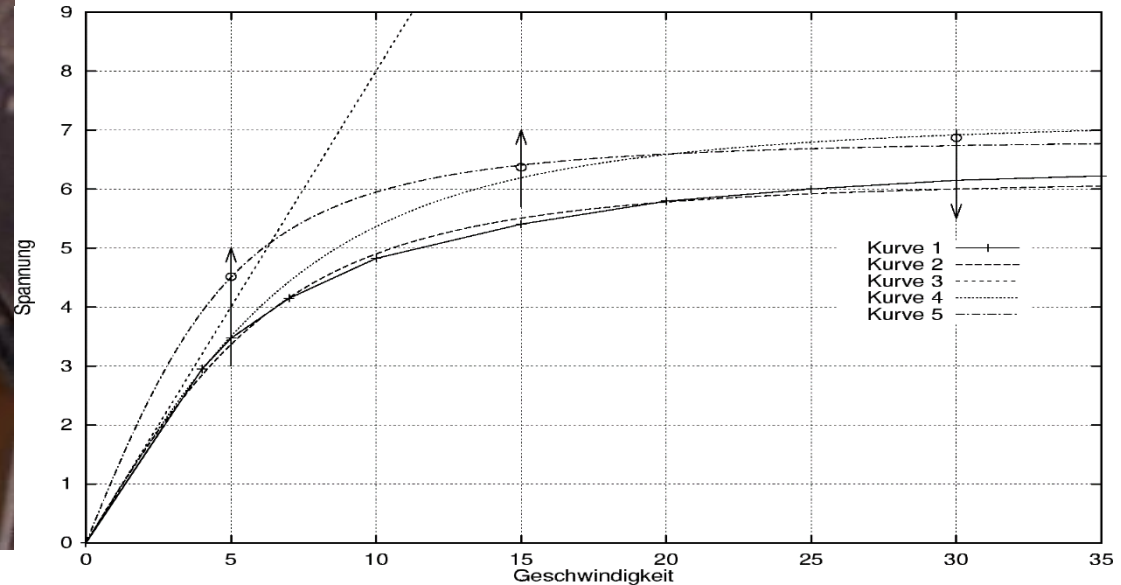


**Average Power: 3W**

**Downhill Peak Power: 4W**

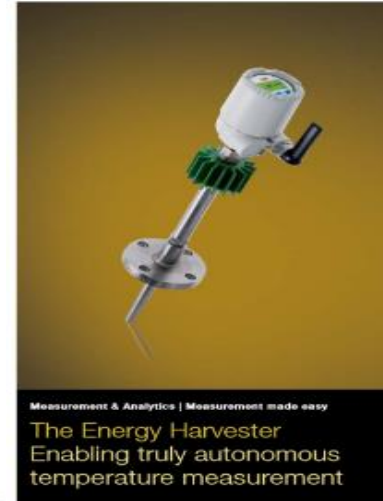
**Output Voltage: 6V @ 12Ω Load**

**Felt Efficiency: <10%**



# Industrial Application

- TSP300-W with Energy Harvester – the first autonomous Wireless temperature sensor.
- Enables the easy addition of temperature measuring points throughout operations.
- Shorten installation times by eliminating complex wired infrastructure and lower overall implementation costs of process measurement with ABB's wireless devices



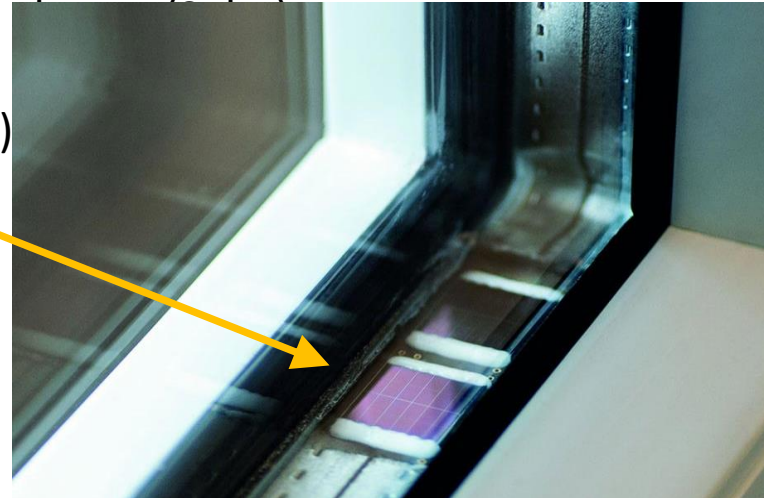
Source: ABB

# Energy Harvested Application

- Customer feedback for EH projects:
  - Total amount of harvested energy: min 50 $\mu$ W up to 200mW
  - The highest harvested energy was 5W using Solar cells

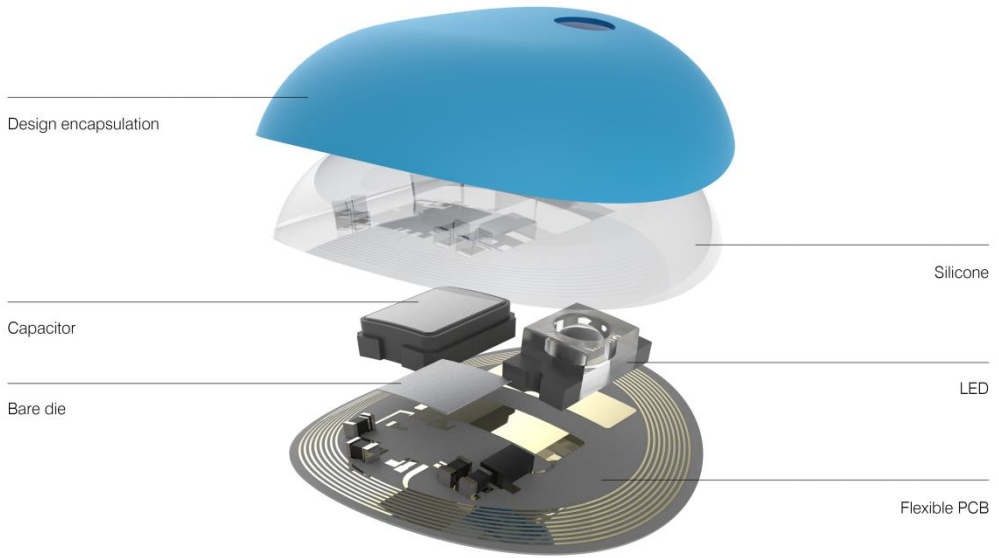
Devices are:

- Aftermarket solutions for Portable Navigators & Mobile
- GSM/GPS module (5W Solar)
- Window status monitoring for Hotels and Homes (Solar)
- Chainsaw electronic at engine (TEG)
- High Voltage cable status (Magnetic field)
- Water purification plant PH measuring (chemical)
- Temperature measurement for engines (TEG)
- Object tracking at airport (Piezo & RF-ID)



# L'Oreal UV sensor

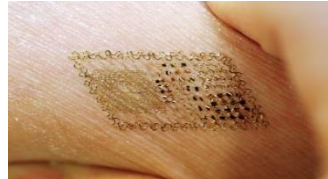
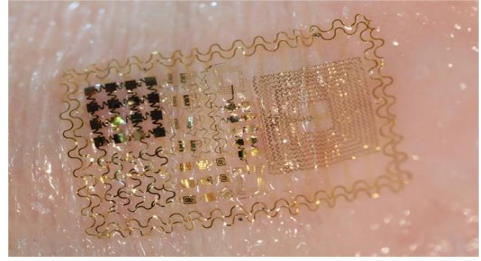
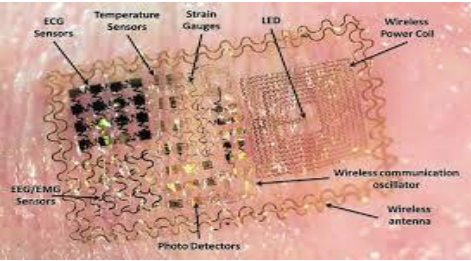
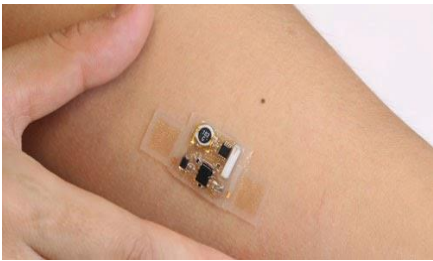
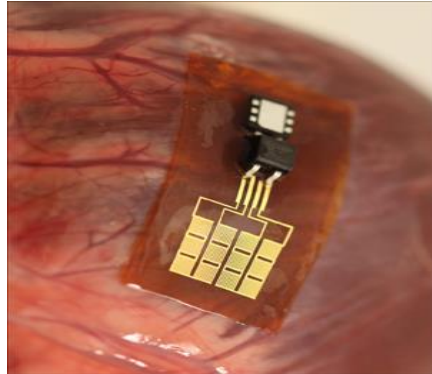
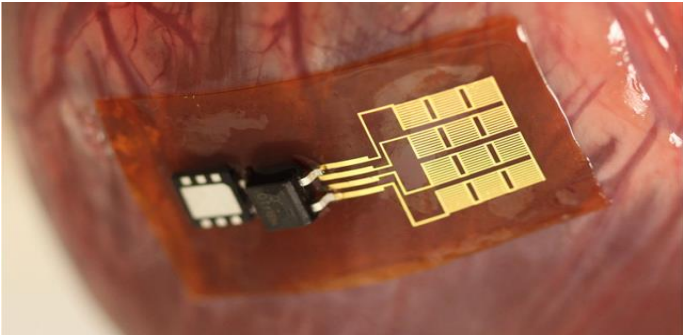
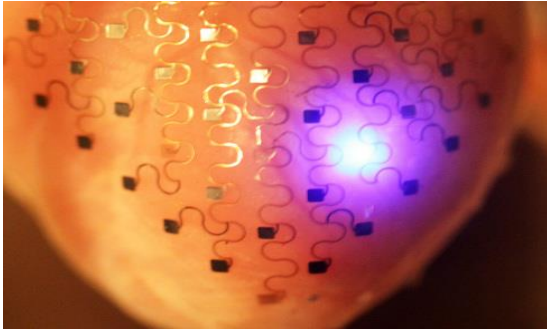
The device is battery-free electronic UV sensor and it's small enough to wear on one of your nails. Using NFC, the device can connect to your phone and deliver log data on sun exposure.



Source: L'Oreal at [dezeen.com](http://dezeen.com)

# Energy Harvesting Healthcare Application

- Pacemaker

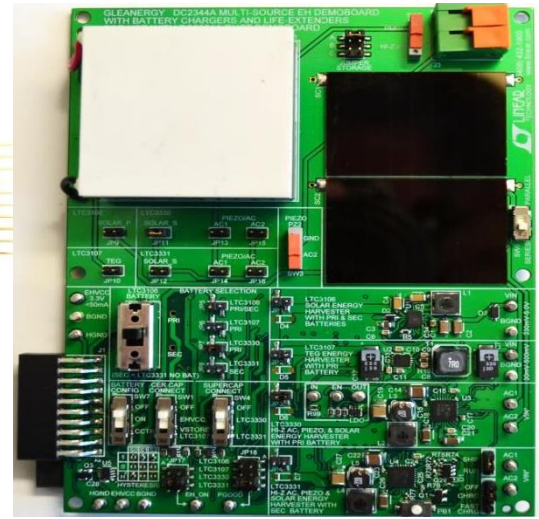
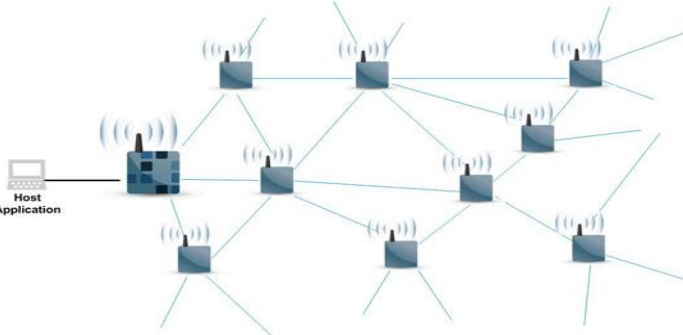


Source: Prof. John A. Rogers University of Illinois

# Energy Harvesting Kit “Gleanergy” with Battery lifetime extender



- Environment energy captured and converted into electricity for small autonomous devices making them self-sufficient.



- ❖ Thermo Electric Generator (heat)
- ❖ Piezo Electric (vibration/strain)
- ❖ Photovoltaic (light)
- ❖ Induction (motion)
- ❖ Battery (Lithium)



Regulated Voltage  
Power Good  
EH\_ON or Batt. Information