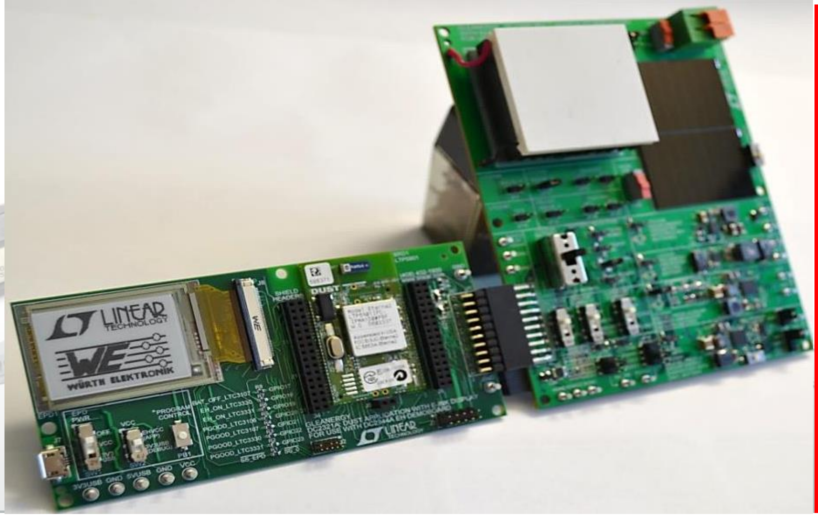
Make electronics autonomous & powered from environment

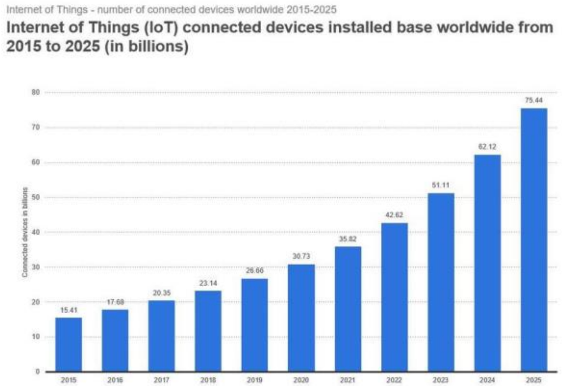


Speaker:
Lorandt Fölkel M.Eng

Field Application Engineer &
Business Development Manager
lorandt.foelkel@we-online.de

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

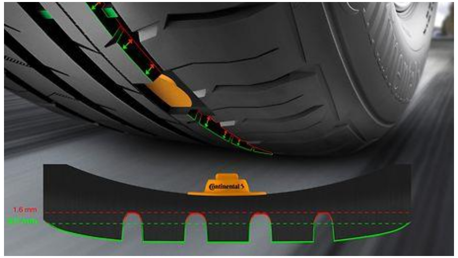


[1]

Predictive maintenance at rails (wired)

[2]

Predictive maintenance (battery)



[3]

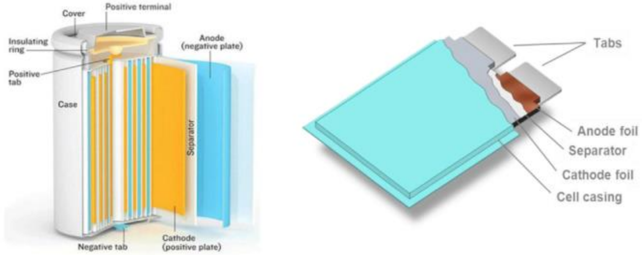
Wearables

[4]

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

Current Li-ion battery



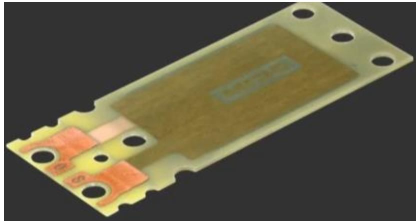
Zubi, G.; Dufo-López, R.; Carvalho, M.; Pasaoglu, G. The Lithium-Ion Battery: State of the Art and Future Perspectives. Renewable and Sustainable Energy Reviews 2018, 89, 292–308.

- 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

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

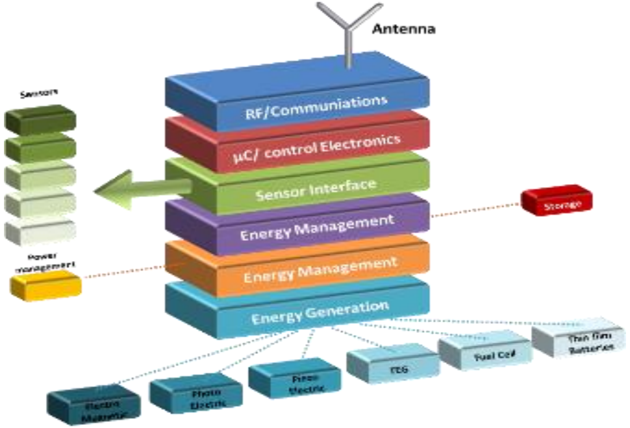
Energy Harvesting = Energy for free?

- **We have to consider that the laws of physics are still valid.**
- **But wasted energy are everywhere**
- **We just need to :**
  - **find them**
  - **convert them (harvest)**
  - **transform them into electrical energy**
  - **to store it for the time when not used**
  - **recall it when needed**

Mechanical Age

Source: Linear Technology

Digital Age



Source: Tyndall National Institute

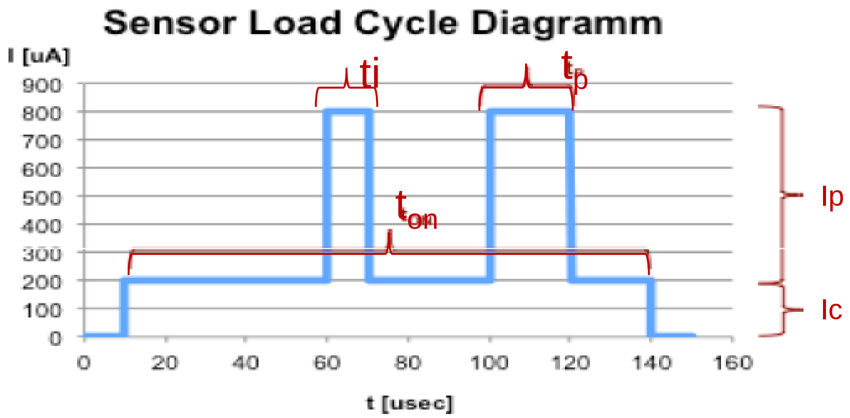
Wireless IoT devices

Basic consideration for Energy Harvesting

WÜRTH ELEKTRONIK

First step:

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



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

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

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

Vs: Supply Voltage
Ic: continuous current
Ip: pulsed current

tp,i: pulse duration
ton: system on time
DC: sequence Duty Cycle

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:

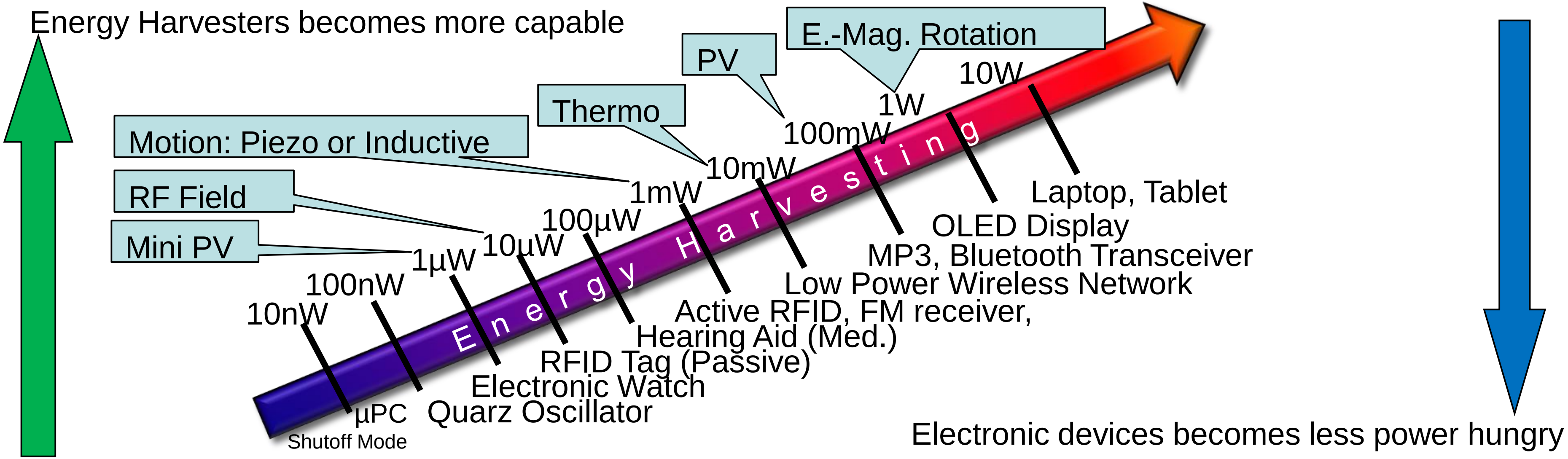
- choose the right harvester (transducer)
- build the right voltage converter (source impedance matching)
- consider an energy storage for back up
    - capacity bank
    - supercaps
    - ultracaps (Supercap/Lithium-Ion)
    - Li-Pol rechargeable

Where to find „free energy“

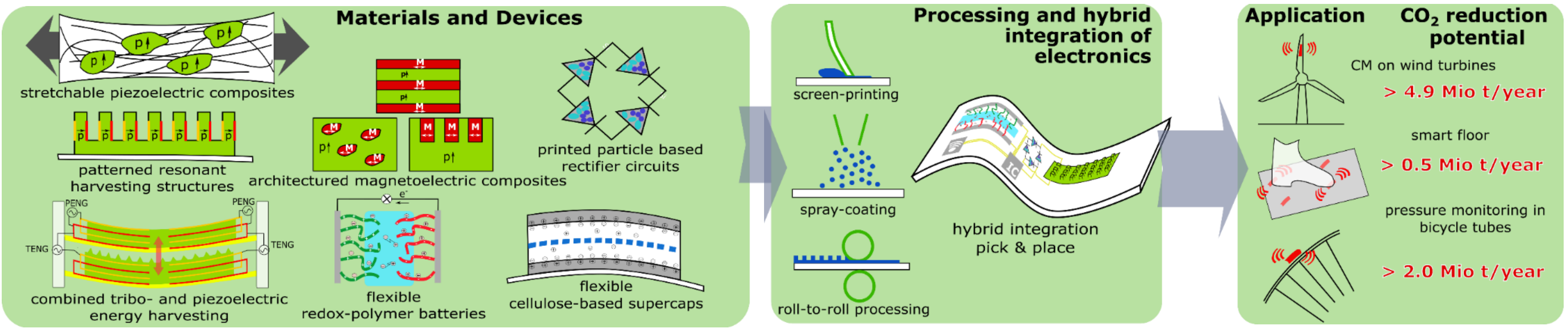
WÜRTH ELEKTRONIK

- **Typical energy harvester output power**
  - RF: 0.1µW/cm²
  - Vibration: 1mW/cm²
  - Thermal: 10mW/cm²
  - Photovoltaic: 100mW/cm²

- **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



Raw Materials

New Materials

New Devices

CO_2 relevant use cases

CO_2 savings and reduction of hazardous waste based on LCA

SYMPHONY fact sheet:

Start Date: 01/05/2020

End date: 30/04/2024

Duration in months: 48

Website: www.symphony-energy.eu

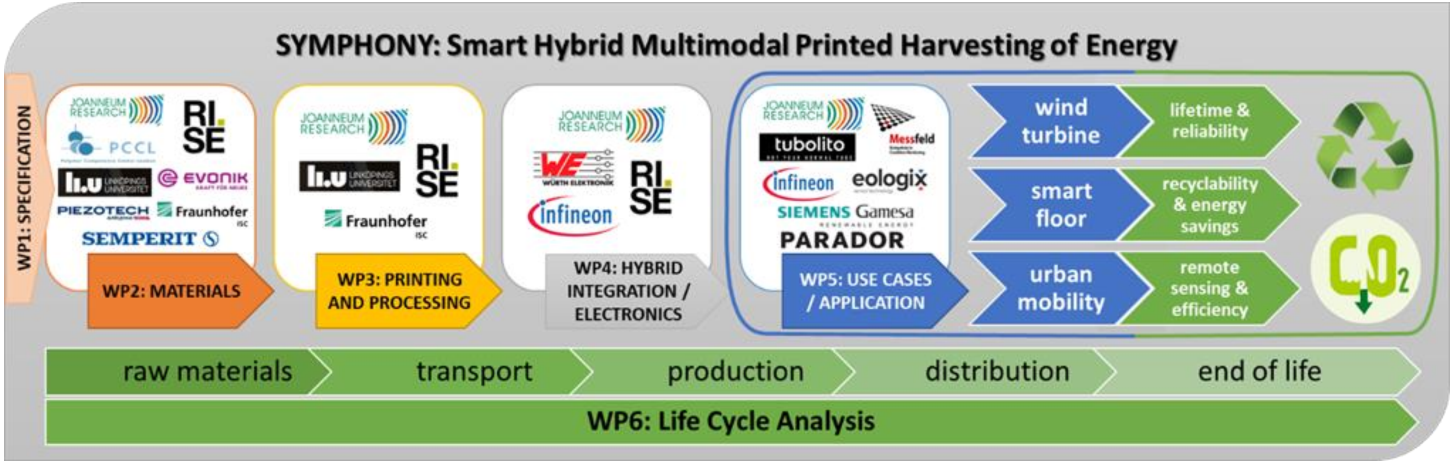
Grant Agreement number: 862095

Project budget: 6,82 M€

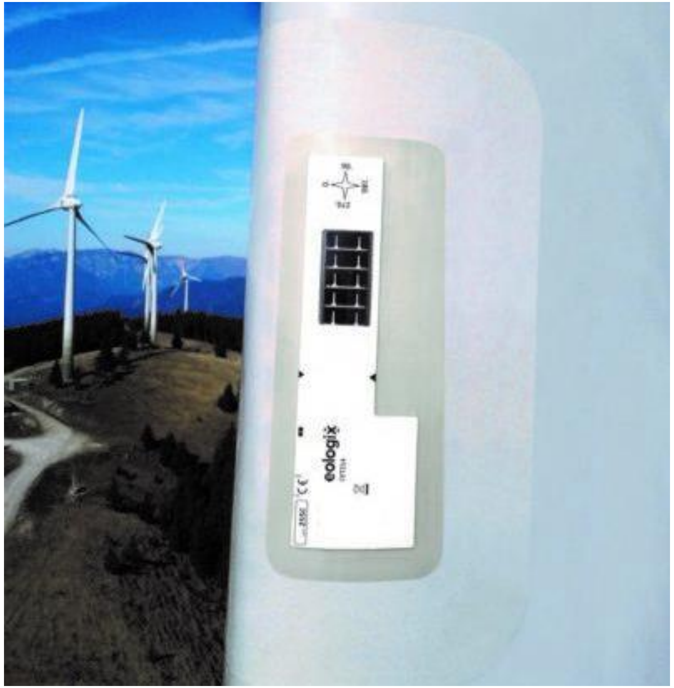
Joanneum budget: 1758615€

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

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.

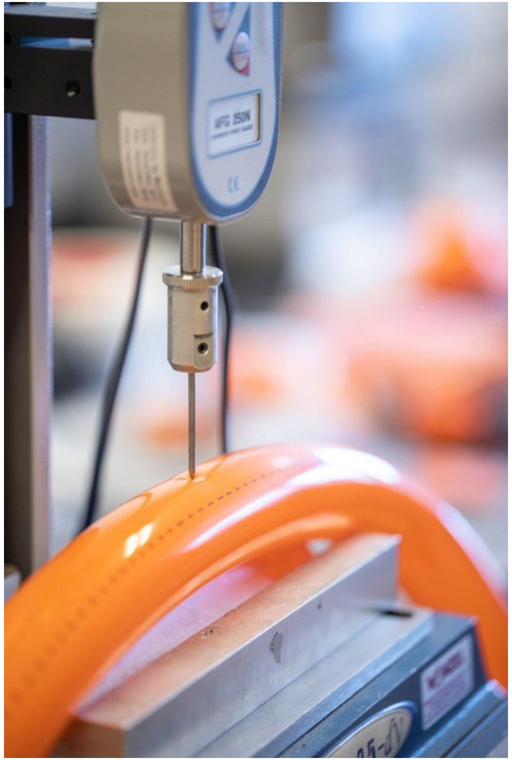
SYMPHONY use cases:

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.

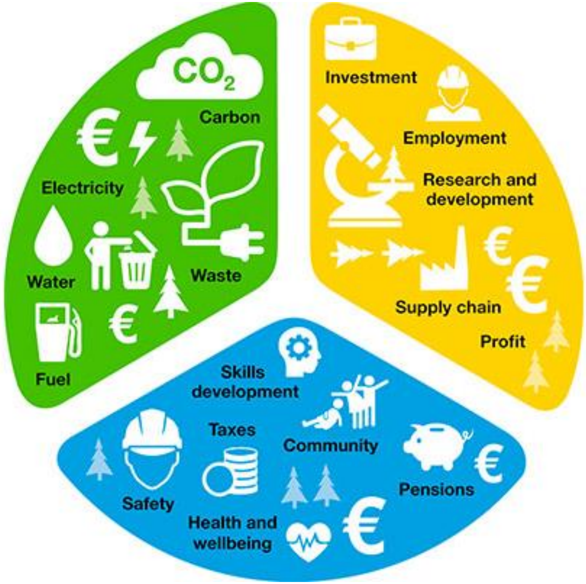
SYMPHONY impact:

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.

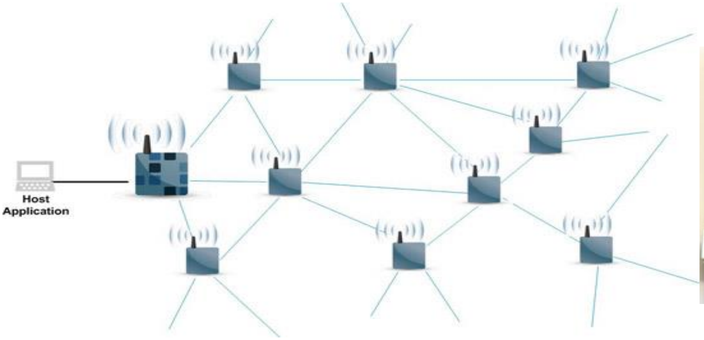
The SYMPHONY platform will provide functionalities such as Condition Monitoring, Predictive Maintenance or Energy Management in three application areas:

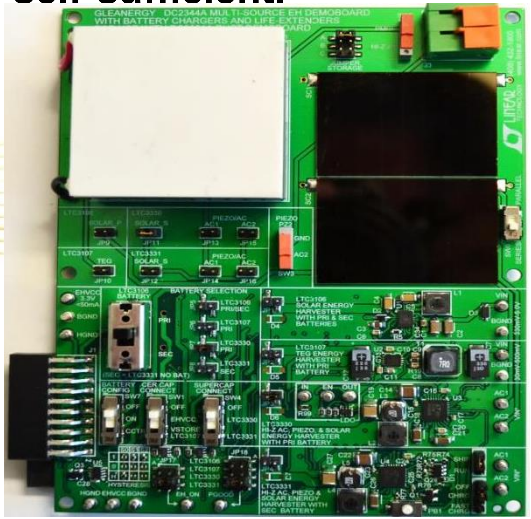
- **Renewable energy generation**
- **Room heating/cooling**
- **E-mobility**



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)

Energy Management & Storage

Regulated Voltage
Power Good
EH_ON or Batt. Information

Energy Harvesting Kit – Power Demoboard DC2344A

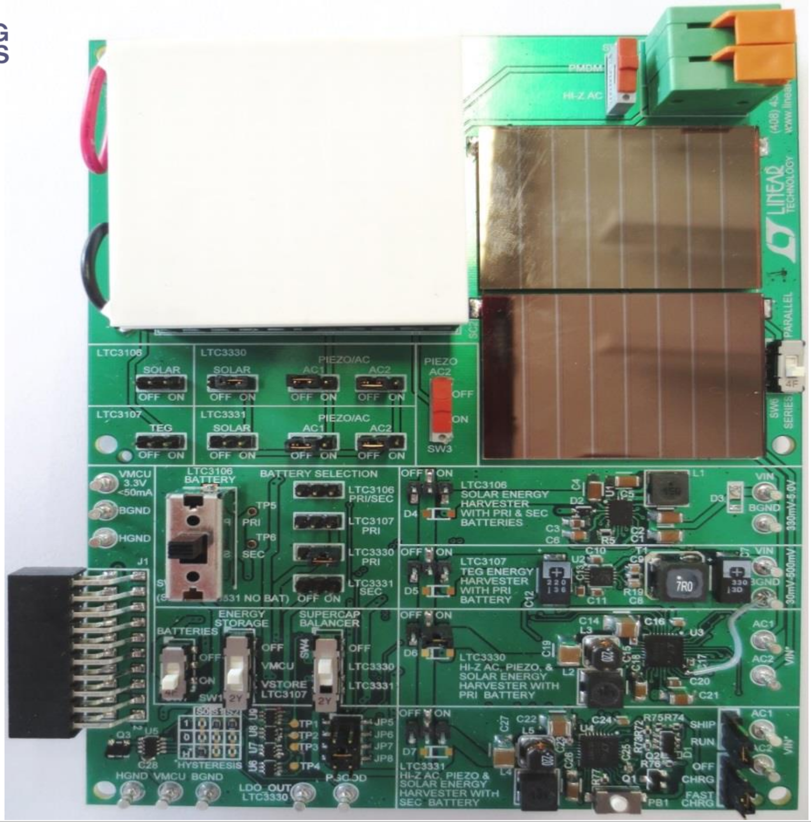
Featuring:

LTC3106 - Solar Harvesting
- Battery Lithium
- Li-Ion Rechargeable

LTC3107 - TEG Harvesting
- Battery Lithium

LTC3330 - Piezo Harvesting
- Solar Harvesting
- Battery Lithium
- Supercap Balancer

LTC3331 - Piezo Harvesting
- Solar Harvesting
- Li-Ion Rechargeable
- Supercap Balancer



Energy Harvesting Kit – µPC/RF Module Demoboard DC2321A

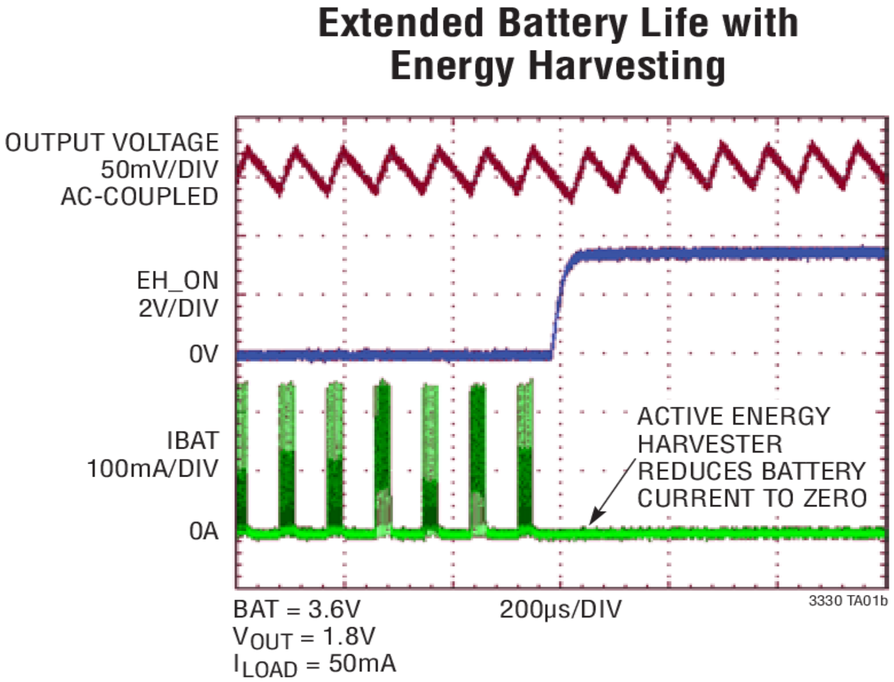
Featuring:

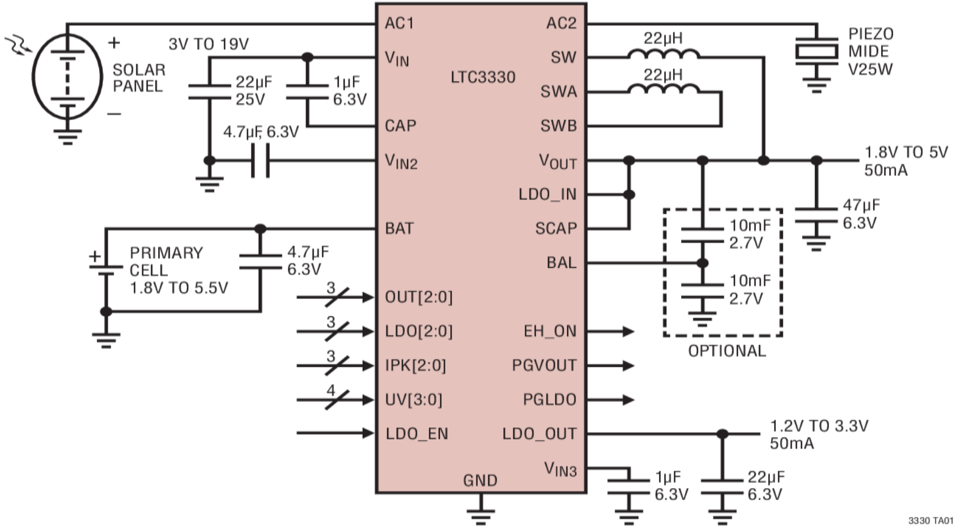
- TP5901 Dust assembly including ARM Cortex-M3 processor embedded with SmartMesh IP networking software (RF Module)
- E-Ink display for user feedback
- Two coulomb counters for battery data measurement
- Shield board headers and programming headers for development
- Optionally, use **DC2510A** shield board to connect extra components to the ADCs, GPIOs, and serial ports of the mote

NOW PART OF ANALOG DEVICES

LTC3330 Energy Harvesting Solar

L = 2 pcs. 744773122





Source: Linear Technology Corporation

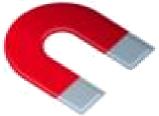
Typical Inductive Transducers

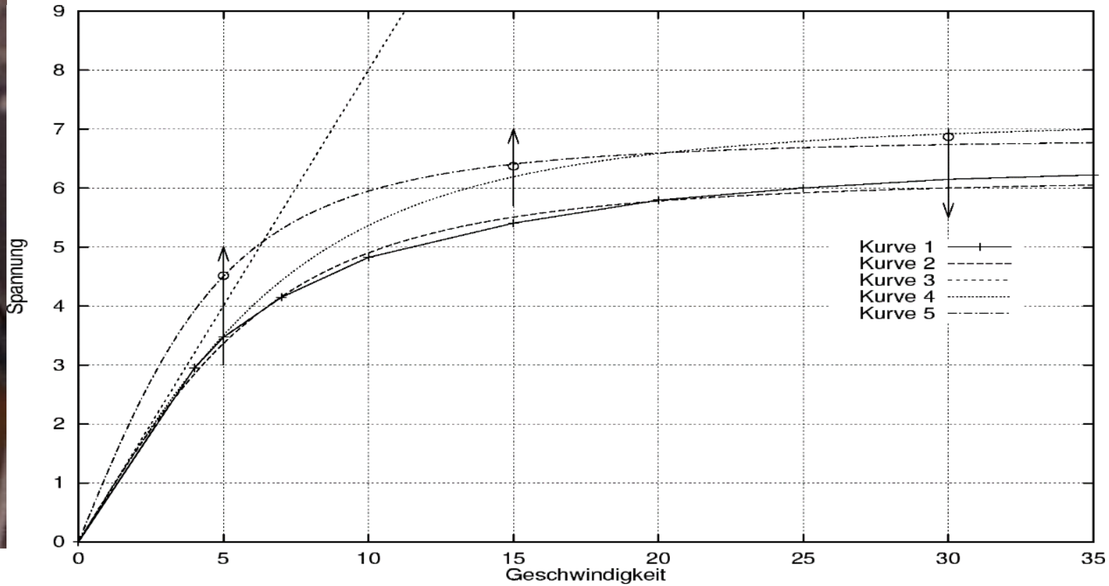
Average Power: 3W

Downhill Peak Power: 4W

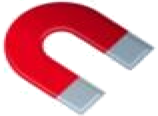
Output Voltage: 6V @ 12Ω Load

Felt Efficiency: <10%





Typical Inductive Transducers



EM-1D-09 Vibration Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	42	g
Inner Resistant	430	Ω
Resonant Frequency	14.2	Hz
Power Output (0.5*g* *continous*)	3.6	mW
Power Density	0.11	mW/cm^3
Specific Power	85.7	mW/kg
Frequency Range of 50% Power	12.4 - 16	Hz

Generator Code: 151001200019

EM-1D-10 Vibration and Push-Button Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	46.5	g
Inner Resistant	430	Ω
Resonant Frequency	47	Hz
Power Output (0.5*g* *continous*)	30	mW
Power Density	0.96	mW/cm^3
Specific Power	660	mW/kg
Frequency Range of 50% Power	42 - 48	Hz
Energy Output (1x Push Button)	1.5	mJ

Generator Code: 151001200018

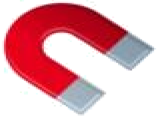
Source: www.pmdm.de

EnOcean

Per Click 30µC
6.38V @ 4.7µF

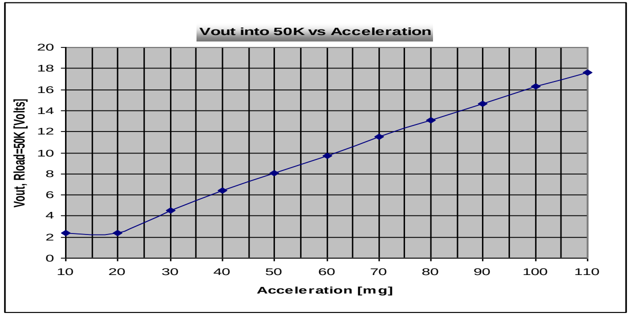
Source: www.enocean-alliance.org

Typical Inductive Transducers



Ferro Solutions

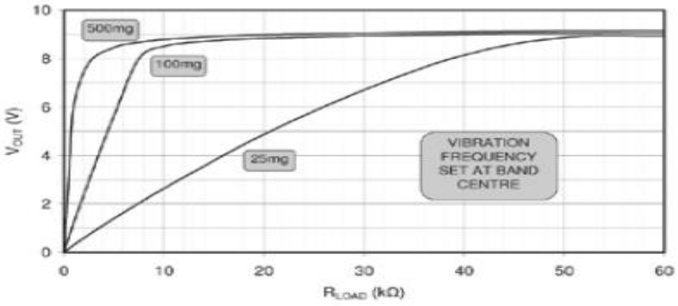
Size: DxH = 6cm x 6.75cm



POWER OUTPUT @ 60 HZ (Rectified DC Power)		
Acceleration	25 milli-*g*	0.3 mW
	50 milli-*g*	1.3 mW
	100 milli-*g*	5.2 mW
BANDWIDTH (Δf = 3 Hz)		
Peak frequency		60 Hz
50% power delivered		+/-1.5 Hz
Q @ 100 milli-*g*		18

Perpetuum

Size: DxH = 6.85cm x 6.85cm



Operates from prevalent 100Hz/ and 120Hz vibration bands found on electrical machines

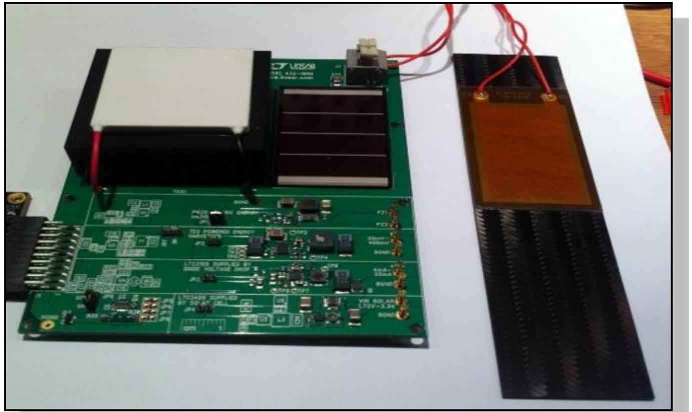
1mW peak power at 0.025G with >2Hz half-power bandwidth

Typically >0.3mW output on 95% of machines

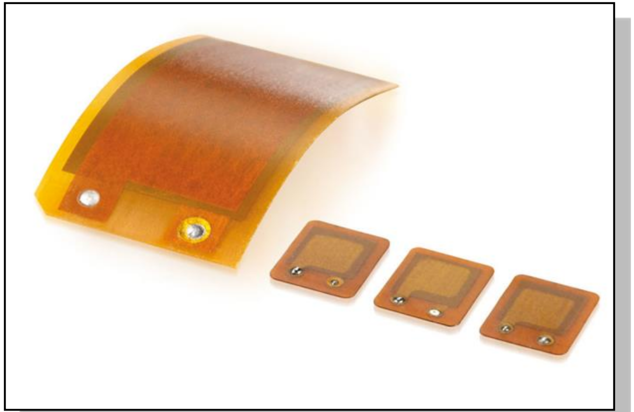
Examples for Piezo Transducers

WÜRTH ELEKTRONIK

PI Ceramic



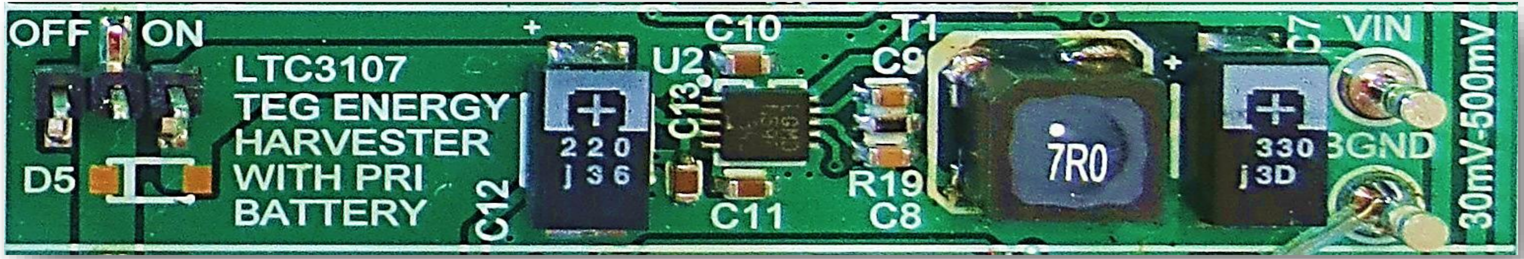
The “Piezo Ruler” Size: 150 x 35 x 2,5 mm³

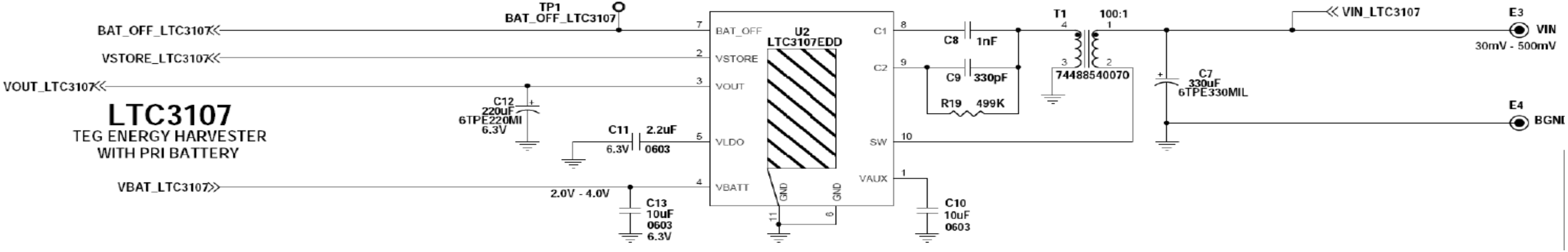


Made from DuraAct Transducers

Source: Linear Technology Corporation

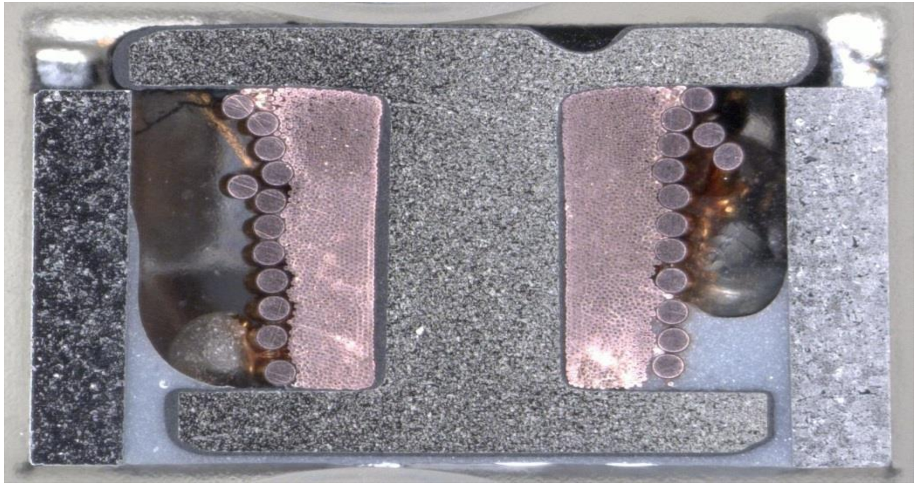
EH-Kit: LTC3107 - TEG

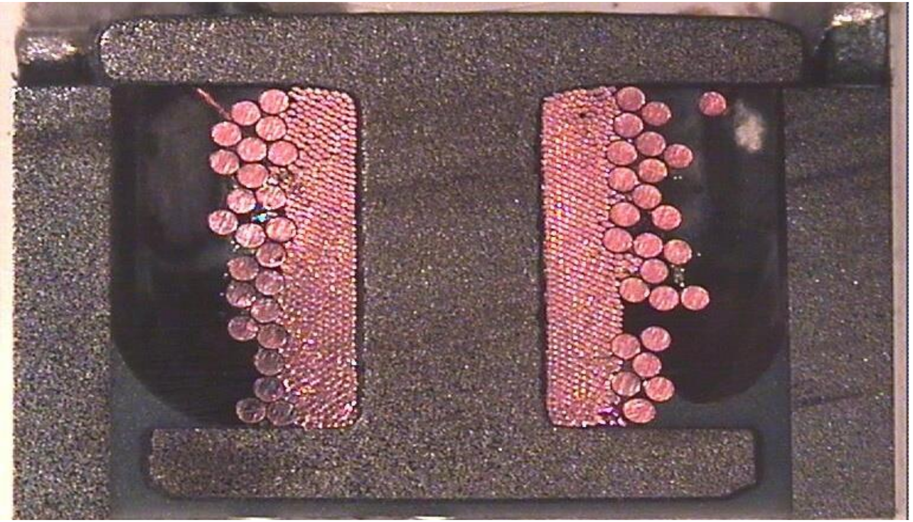




What is behind the WE-EHPI transformer?

- winding style





Würth Elektronik eiSos components WE-EHPI

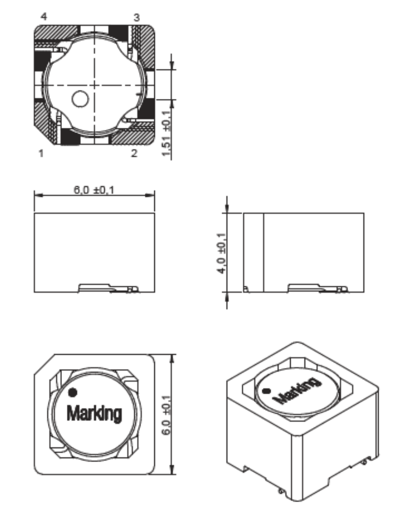
Characteristics:

- Low profile: 4 mm
- Small footprint 6 x 6 mm
- Very low secondary R_{DC}
- Multiple options of turn ratios available
- Separated welding/soldering pads for increased reliability
- Optimized winding technology for increased performance & reliability

Applications:

- Wireless fire, alarm, gas and metering remote sensors driven by environmental energies based on energy harvesting voltage transformers like LTC3108/LTC3109
- Sensors with predictive battery replacements in applications which are difficult to access
- Energy self-sufficient supply using subsequent installed sensors for energy harvesting

Dimensions: [mm]



Electrical Properties:

Order Code	L_1 (µH)	Tol. L_1	L_2 (µH)	Tol. L_2	n	I_R (A)	I_{SAT} (A)	$R_{DC1\ typ.}$ (Ω)	$R_{DC1\ max.}$ (Ω)	$R_{DC2\ typ.}$ (Ω)	$R_{DC2\ max.}$ (Ω)
74488540070	7		70000		1 : 100	1.9	1.3	0.085	0.095	205	240
74488540120	13	±20%	33000	±20%	1 : 50	1.7	1	0.09	0.1	135	155
74488540250	25		10000		1 : 20	1.5	0.7	0.2	0.24	42	48

I_R: Rated Current ; I_{SAT}: Saturation Current ; L_1: Inductance 1; L_2: Inductance 2; n: Turns Ratio; $R_{DC1\ max.}$: DC Resistance 1; $R_{DC1\ typ.}$: DC Resistance 1; $R_{DC2\ max.}$: DC Resistance 2; $R_{DC2\ typ.}$: DC Resistance 2; Tol. L_1: Inductance 1 (Tol.); Tol. L_2: Inductance 2 (Tol.)

Transformer designed on EP7 cores are available on request – Order code: 760370096, 760370097, 760370098
During design stage of this series, we used S11100032, S11100033 & S11100034.
With our standard series we have replaced these order codes.

Where is it useful?

- Where line power is unavailable or costly
- Where batteries are costly or difficult to replace
- Where energy is needed only when ambient energy is present

Asset Tracking/Monitoring

Building Security, Lighting & Climate Control

Plant Automation

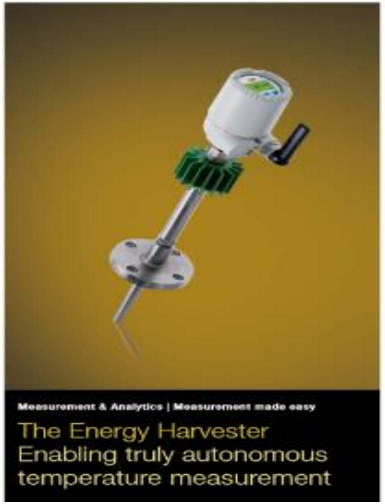
Remote Monitoring

TPMS

Source: LTC - Sam Nork – Energy Harvesting Presentation

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



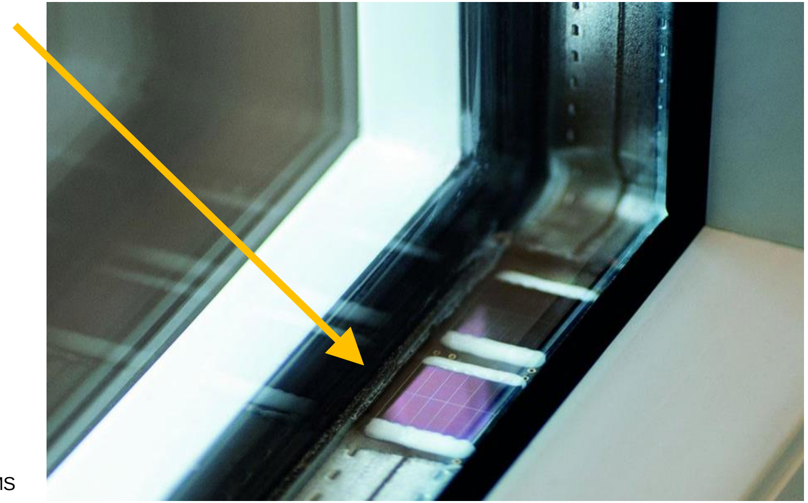
Source: ABB

Energy Harvested Application

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

Devices are:

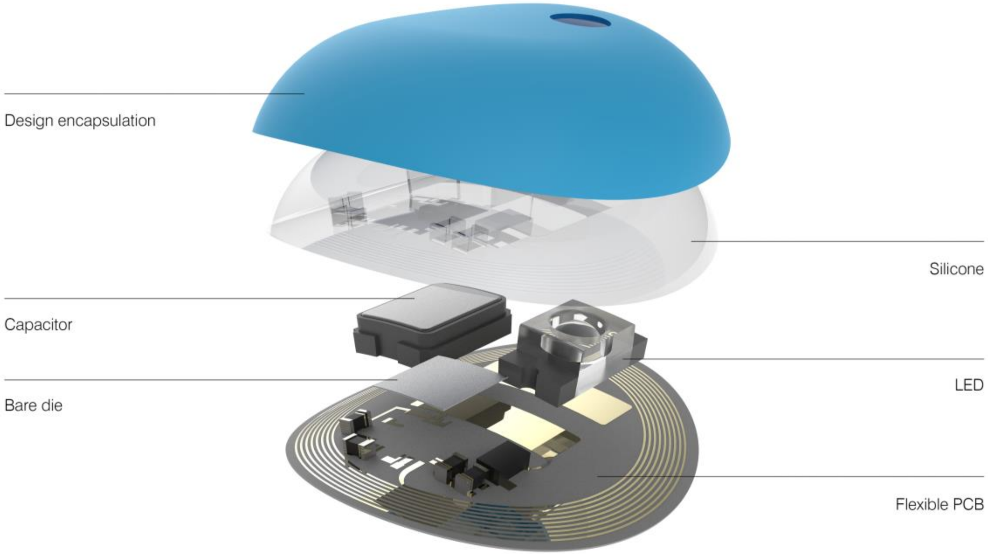
- Aftermarket solutions for Portable Navigators & Mobile Phones (Solar)
- GSM/GPS module (5W Solar)
- Window status monitoring for Hotels and Homes (Solar)
- Chainsaw electronic at engine (TEG)
- High Voltage cable status (Magnetic field)
- Water purification plant PH measuring (chemical)
- Temperature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



Source:© Fraunhofer IMS

L‘Oreal UV sensor

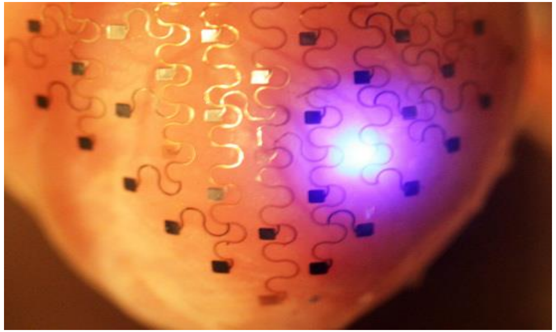
The device is battery-free electronic UV sensor and it’s small enough to wear on one of your nails. Using NFC, the device can connect to your phone and deliver log data on sun exposure.

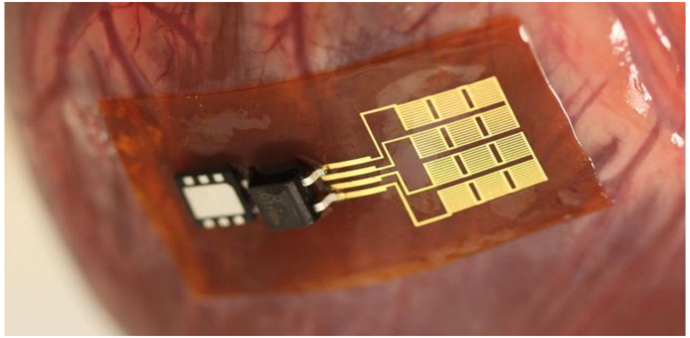


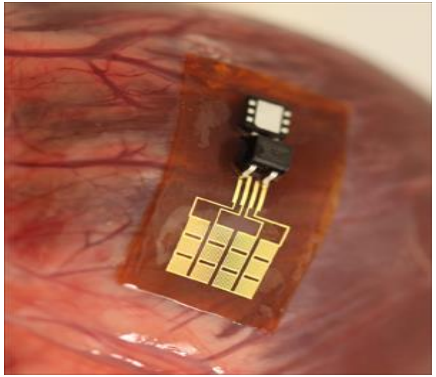
Source: L‘Oreal at dezeen.com

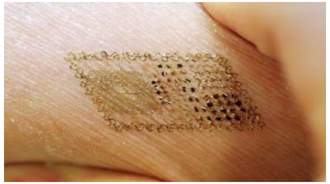
Energy Harvesting Healthcare Application

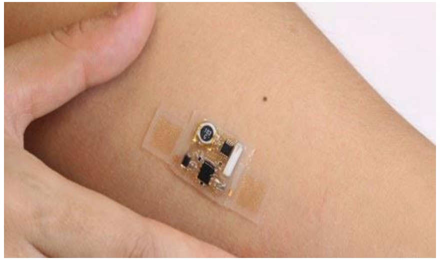
- Pacemaker

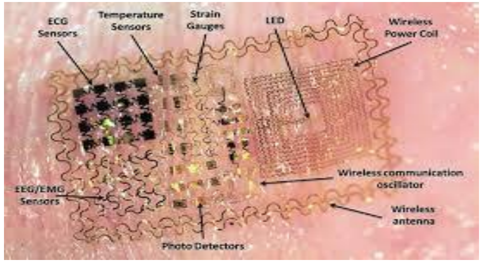


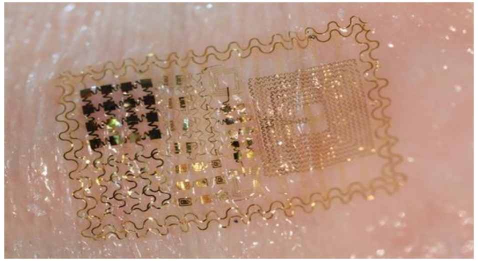












Source: Prof John A. Rogers University of Illinois

WÜRTH ELEKTRONIK

Another application for Harvesting?

Source: http://www.joaolammoglia.com/concept/1/aire-concept/

Energy Harvesting Evaluation Boards:
"Gleanergy" p/n: IC-744 888
"To Go" Kit p/n: IC-744 885

More information at our website:

www.we-online.com/gleanergy

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