EnSO
Energy for Smart Objects

Harvesting: A new challenge for powering IoT nodes

Organized by **EnSO** Project under **ECSEL Programme**

IoT Week Bilbao 2018
4-7 JUNE 2018, BILBAO (SPAIN)
EUSKALDUNA CONFERENCE CENTRE

ECSEL Joint Undertaking
Electronic Components and Systems for European Leadership

EnSO has been accepted for funding within the Electronic Components and Systems For European Leadership Joint Undertaking in collaboration with the European Union's H2020 Framework Programme (H2020/2014-2020) and National Authorities, under grant agreement n° 692482

Introduction & Keynote

Ramon Jane, WP leader, Gas Natural Fenosa

David Langley, WG2 AIOTI

Raphaël Salot, Project Leader, CEA Leti

Our Vision for this Workshop

EnSO implements a significant IoT ECOSYSTEM…

But our strategy is based on:

- ✓ **Open Innovation**
- ✓ **IoT Marketplace**

getting synergies with other EU Projects, stakeholder, SME,…

And in this Workshop focus on Harvesting as a hot topic

Workshop Agenda

INTRODUCTION & KEYNOTE	
9h00 - 9h05 **9h05 - 9h30** **9h30 - 9h45**	Welcome greetings *Ramon Jane, Workshop Chairman* Keynote "IoT Ecosystem and Business Creation", *David Langley , co-chairman WG2 AIOTI* Scope and Outcomes for EnSO Project, *Raphaël Salot, Project Leader*
PORTFOLIO OF HARVESTING TECHNOLOGIES – *Chairman: Peter Spies – FRAUNHOFER IIS*	
9h45-10h **10h-10h15** **10h15-10h30** **10h30-10h45**	Thermoelectric, *Janina Paris, MAHLE Thermolektronik* Solar, *Anne Labouret, SOLEMS* Mechanical, *Jerome Delamare, ENERBEE* Vibrational, *Gonzalo MURILLO, Energiot*
10h45-11h15	*Coffee Break*
USE CASES IN DIFFERENT DOMAINS – *Chairman: Daniel Martinez – RICOH SPAIN IT SERVICES*	
11h15-12h15	**Smart Health:** Freek Boesten, Maastricht Instruments **Smart Society:** Smart Lock, Julien Boullie, OJMAR **Smart Mobility/Industry:** Leonardo Goboni, AED Engineering
ROLE OF EU PROJECTS IN MARKET ROLL OUT - ROUND TABLE - *Chairwoman: Emma RICHET - AYMING*	
12h15-13h	**Introduction of projects & Round** Project VICINITY, Juan Rico, ATOS Project INSCOPE, Corne Rentrop, TNO Project EnSO, *Raphaël Salot, CEA-LETI* NMBP Committee H2020, Carles *Cané, CSIC-CNM*

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IoT ECOSYSTEM AND BUSINESS CREATION

David Langley,
Co-chairman WG2 AIOTI

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SCOPE AND OUTCOMES FOR ENSO PROJECT

Raphaël Salot, Project Leader.
CEA Leti

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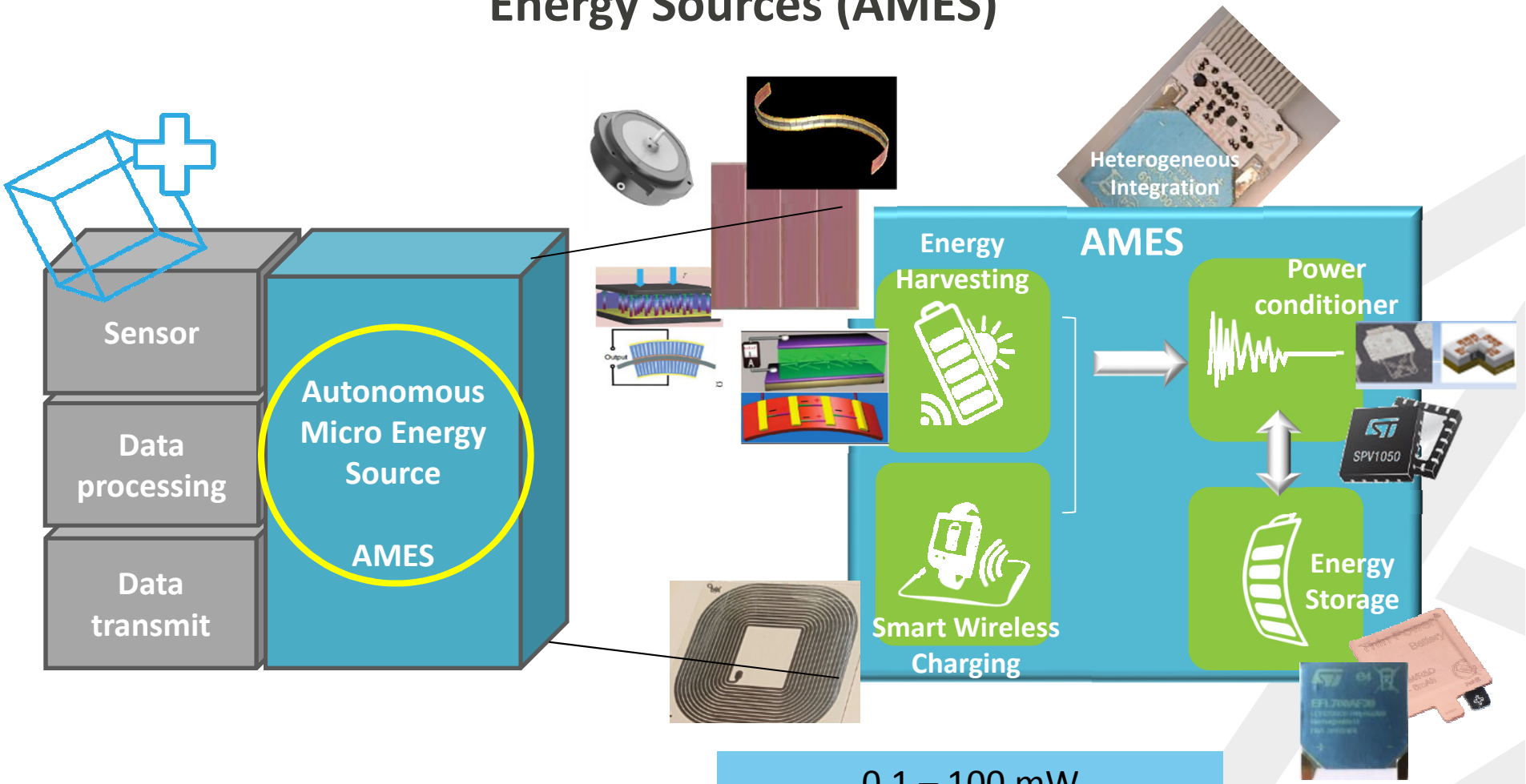
EnSO "Energy for Smart Objects" project is focusing on an essential generic need within IoT, providing **Autonomous Micro Energy Sources (AMES)**



0.1 – 100 mW
1-20 mA.h ; 300 Wh/l

Main EnSO's Objectives

- Demonstrate the **competiveness** and **manufacturing readiness** of EnSO energy solutions (AMES) in Europe.

- Develop and demonstrate high capacity (up to 20 mAh) and high density (> 300Wh/l), low profile, shapeable, long time, rechargeable **micro battery product family** supported by efficient and reliable **energy harvesters** as well as easy **charging**

- Disseminate and **standardize EnSO energy solutions** with easy to use demonstration kits **for a large number of use cases**

From **EnSO Pillars Advanced Technological Platforms & Pilot Lines** to a **Unique European Competence center** in the field of autonomous micro energy sources with all the value chain

33 Partners and 5 third parties
8 countries
Start: 1-1-2016
Duration: 48 months
Total investment: €M 82

Leader
leti
Grenoble

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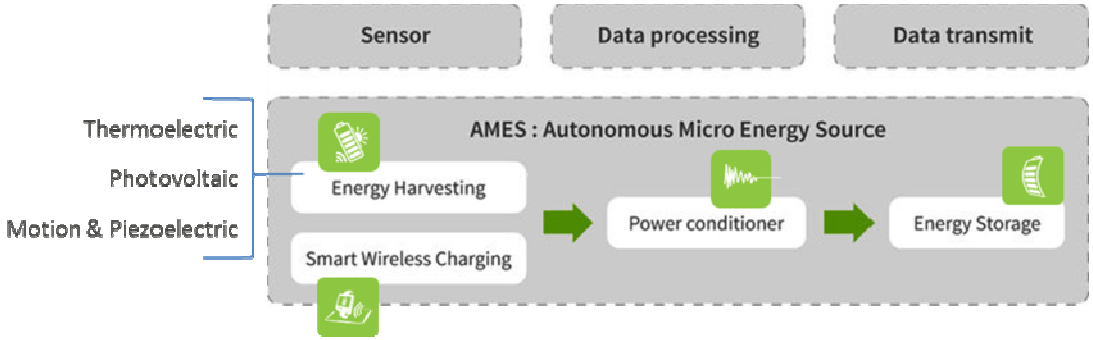
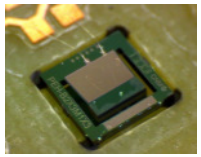
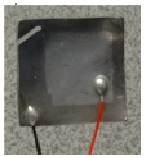
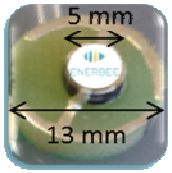
Most efficient Energy Harvester and Energy Storage solutions for Autonomous Power Supply



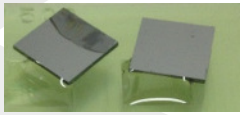




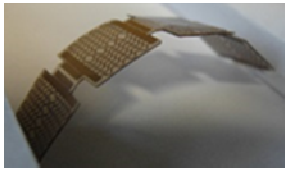
Resonant and Non-Resonant Mechanical Energy Harvesting Power Supply



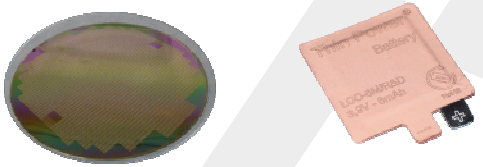
Thermo-electric Energy Harvesting Power Supply



Indoor and outdoor photovoltaic Energy Harvesting Power Supply



Motion-based Energy Harvesting Power Supply



Free Form Factor ultra-thin solid state lithium batteries (inorganic or polymer electrolyte solutions)

AMES HIGH IMPACT TECHNOLOGY ON SMART OBJECTS

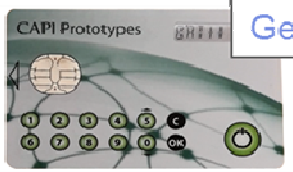
15 use cases

Glucose monitoring
Valotec

PaceMaker
Cairdac

Biometric card
Gemalto

Display card
Gemalto



Chronic Diseases Management Sensors
Maastricht Instruments

Bruxisme Treatment Splint
Maastricht University

Wearable Sensor
Evalan

Rechargeable Hearing aid
GN Hearing

Smart Society

Smart Health

Smart Mobility & Smart production

Gas Network Monitoring
Gas Natural

Industrial asset monitoring
Editag

Gas Meter Supervisor
Gas Natural

Indoor Localization and Navigation Support
AED Engineering

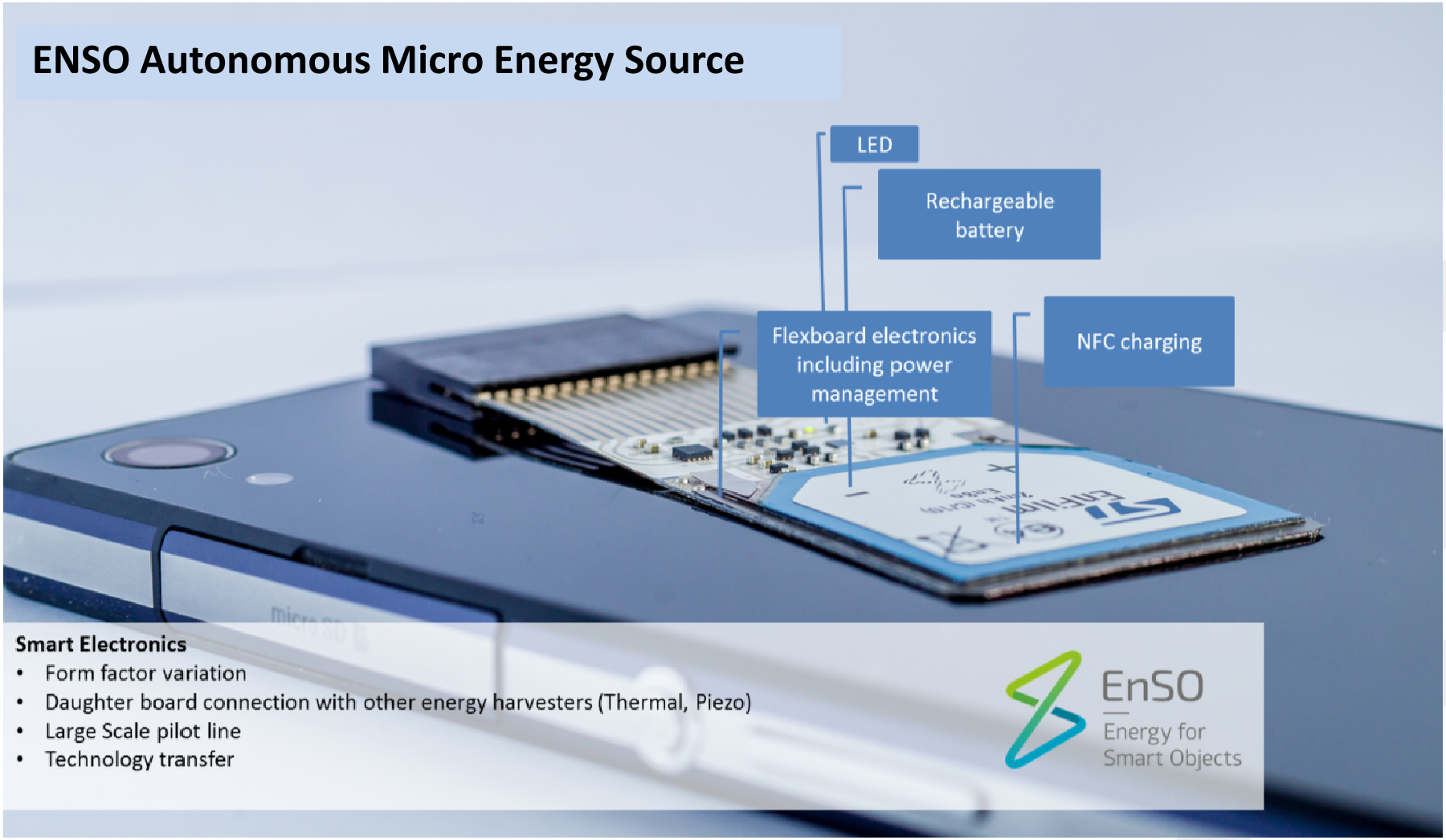
Smart Lock
Ojmar

Autonomous condition monitoring for bearings
SKF-NL

people & objects tracking with RF sensor Smart-TAG
Alpwise

First EnSO's Achievments

ENSO Autonomous Micro Energy Source



Smart Electronics

- Form factor variation
- Daughter board connection with other energy harvesters (Thermal, Piezo)
- Large Scale pilot line
- Technology transfer

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Thank you !

Questions ?

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PORTFOLIO OF HARVESTING TECHNOLOGIES

Peter Spies, FRAUNHOFER IIS

Fraunhofer IIS

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THERMOELECTRIC HARVESTING

Janina Paris,
MAHLE Thermolektronik

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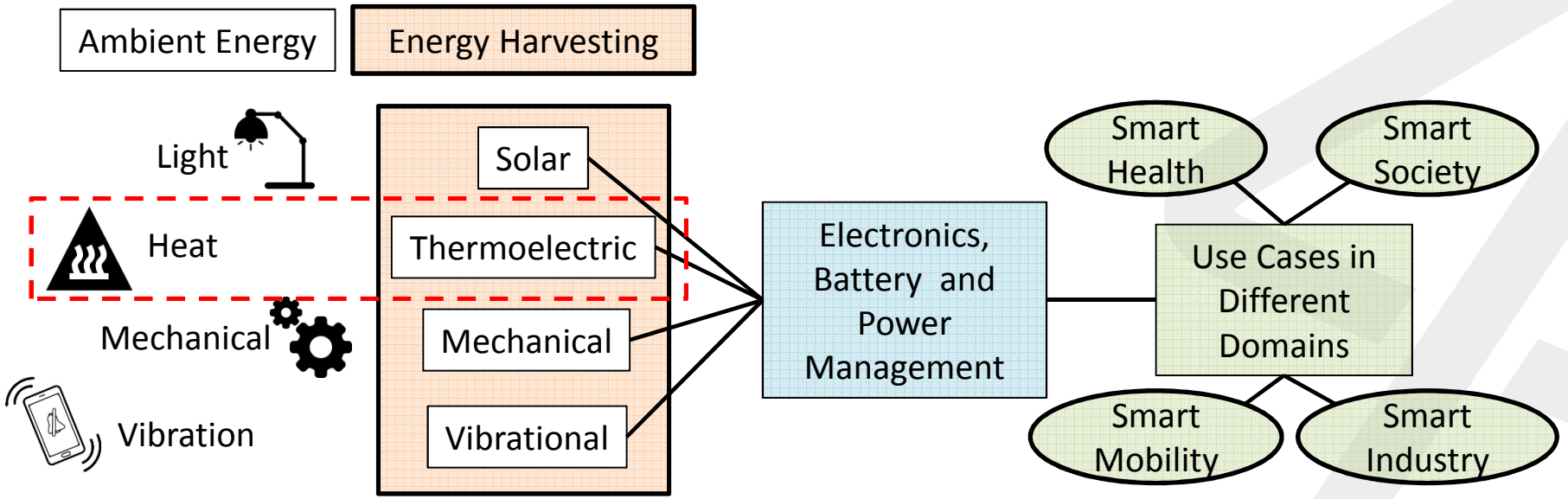
Introduction

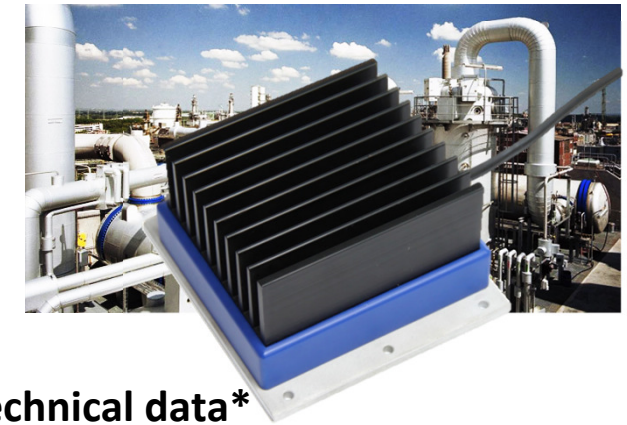
Energy Harvesting replaces batteries or extends battery runtime

“Fit and forget”

Using ambient energy



IoT Industrial Application

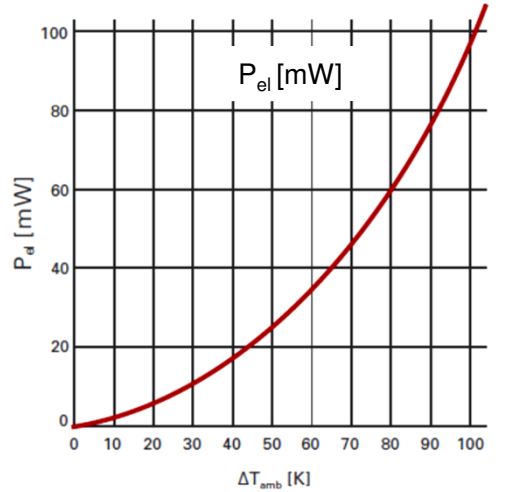


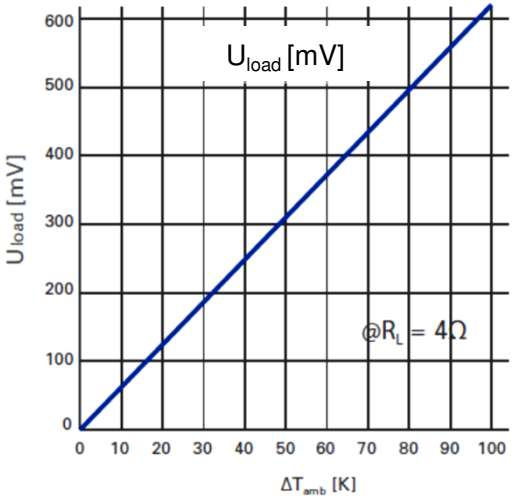
Technical data*

Power output**	hot side vs. ambient temperature	P_{el} (@ $T_{ambient}$ = 20°C, free convection)
	10°C	1.0 mW
	30°C	8.8 mW
	70°C	48 mW
Voltage output	DC, unregulated	
Dimensions	Height (incl. baseplate): 65 mm Baseplate: 112.5 x 119 mm²	
Weight	650 g (23 oz)	
Hot side temperature	-10°C ~ 140°C (14°F ~ 284°F)	
Ambient temperature	-20°C ~ 85°C (-4°F ~ 250°F)	

*) technical changes reserved
**) Power output may vary depending on mounting position, thermal interfacing and system environment

Typical performance curve





Cost Benefit: Avoidance of Battery Changes

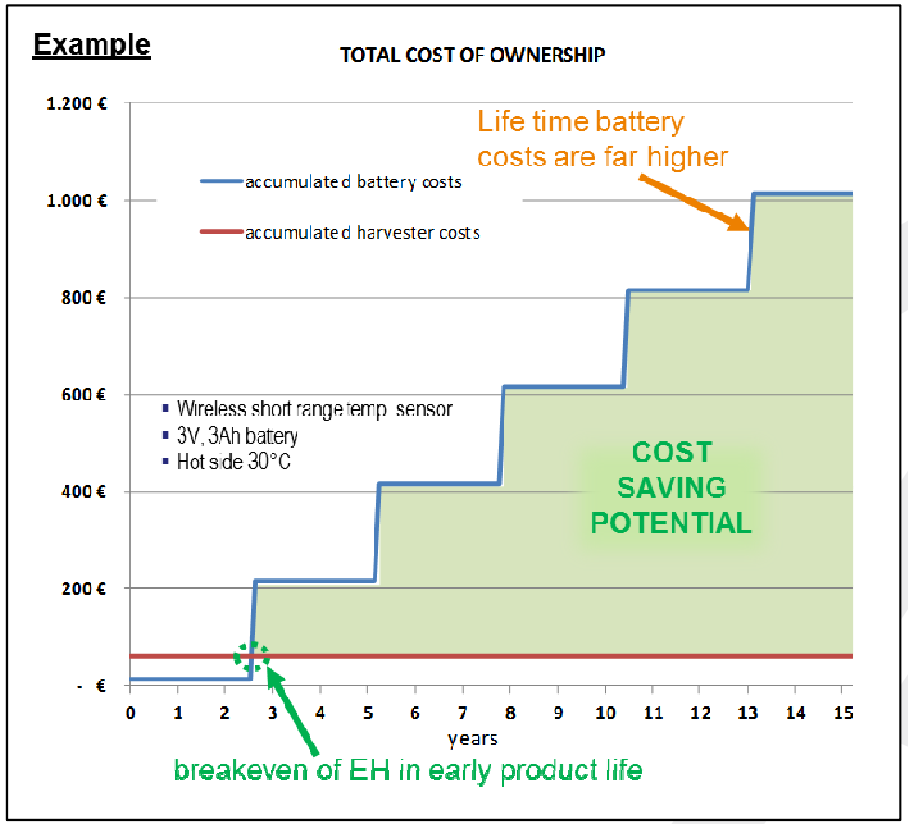
Wireless sensors save installation cost vs. wired sensors
=> Harvesters preserve this commercial advantage long term

Breakeven with 1st battery change!

“Fit & Forget” factor

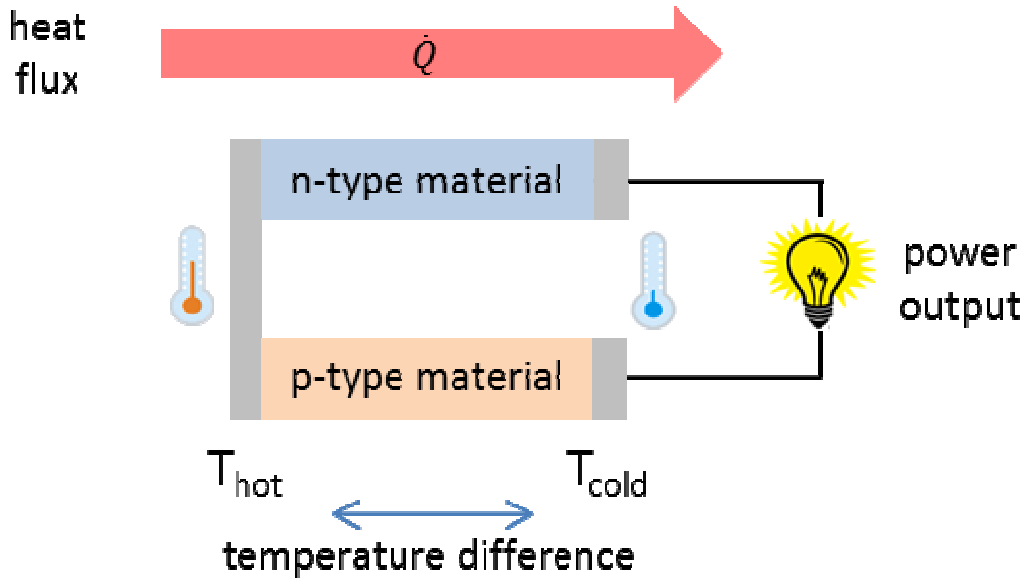
One-time accessible sensor applications

Allowing higher sensor update rates



The Technology: Thermoelectricity (Seebeck Effect)

Principle of a Thermoelectric Generator (TEG)

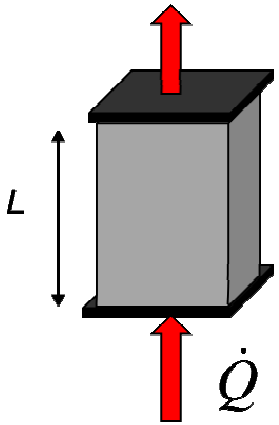


- Directly converting heat into electricity, using ambient heat
- Power is increasing with the available temperature difference
- No moving parts

MAHLE Thermoelektronik Approach

Other TEG Concepts vs. MAHLE Thermoelektronik

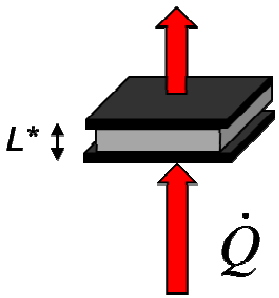
Bulk



- High material usage
- Medium heat flux
- Medium ΔT @ TEG

$\Delta T \rightarrow$, Costs ↑

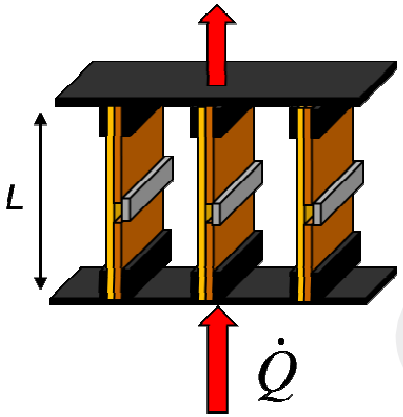
Thin film



- Reduced material use
- High heat flux
- Degraded ΔT

$\Delta T \downarrow$, Costs →

MAHLE Thermoelektronik



- Reduced material use
- Reduced heat flux
- High ΔT @ TEG

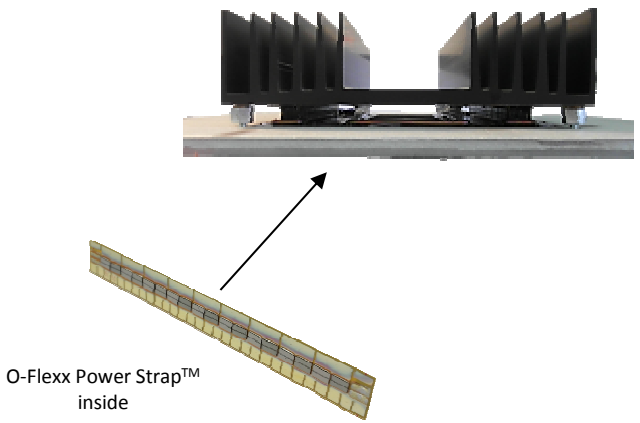
$\Delta T \uparrow$, Costs ↓

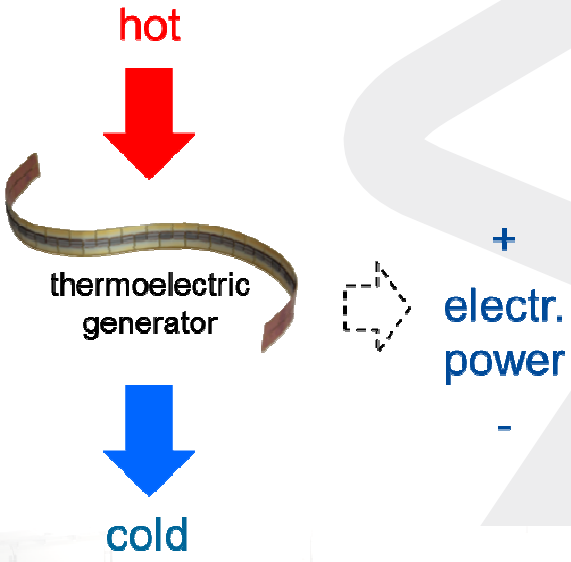
Key factors: higher temperature difference (ΔT) with minimum TE-material used

MAHLE Thermoelektronik Approach

Characteristics

- **Nano-structured** thermoelectric materials
- Low costs due to **reduced material use** (up to 16x less material)
- Optimized utilization of heat-flux due to **in-plane** TE structures
- Soldering of all internal thermal interfaces (**efficient and simple** manufacturing)
- **High volume** manufacturing process, pilot line used

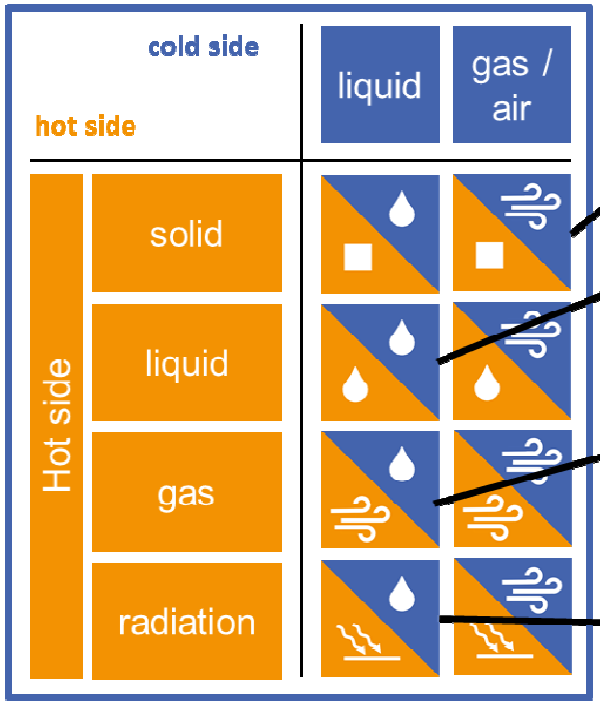


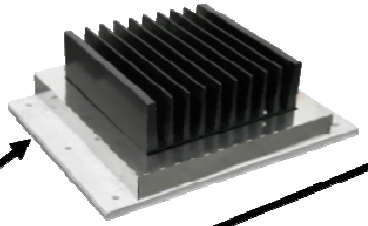


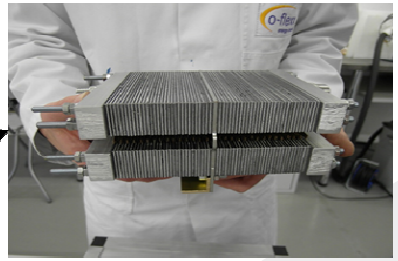
MAHLE Thermoelektronik Approach

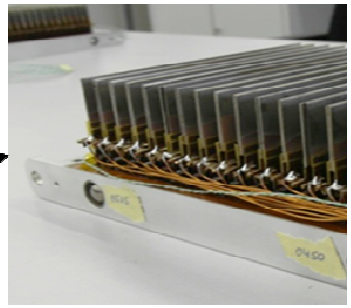
Thermoelectric Sub-systems

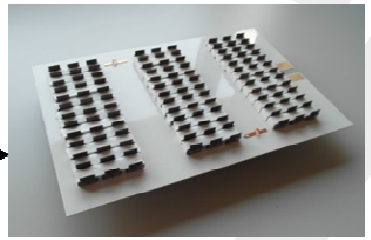
Flexible adaption to customer needs









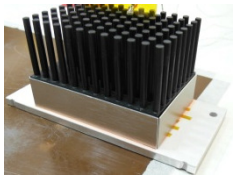


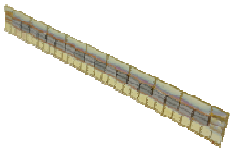
Very small temperature differences (2-3 K) up to 200 K

Thermoelectric Energy Harvesting in EnSO Project

Improvements

- Adaption to low temperature differences / small sizes
- Improving for thermal energy sources with low intensity





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SOLAR HARVESTING

Anne Labouret, CEO SOLEMS

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SOLEMS
L'énergie lumière

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Why solar on IoT ?

- Light is available (nearly) anywhere

- In a room : indoor light is 40 - 1000 lux
- Outside : outdoor light is 3000 – 120 000 lux

Electrical power produced

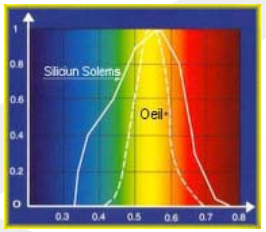
1 – 20 µW/cm²

50µW – 2mW/cm²

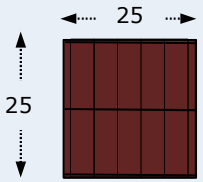
- Microstorage solutions are available

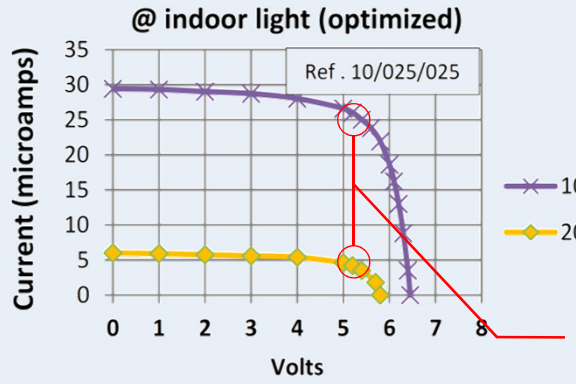
How ?

- **Photovoltaic thin-film silicon solar cells** (amorphous silicon technology)
  - Excellent under indoor light : charge is possible in all light conditions
  - Active under near UV and visible light 350 -750nm
  - Custom specific design : DC voltage, and size on request
  - Proven reliability 15 years



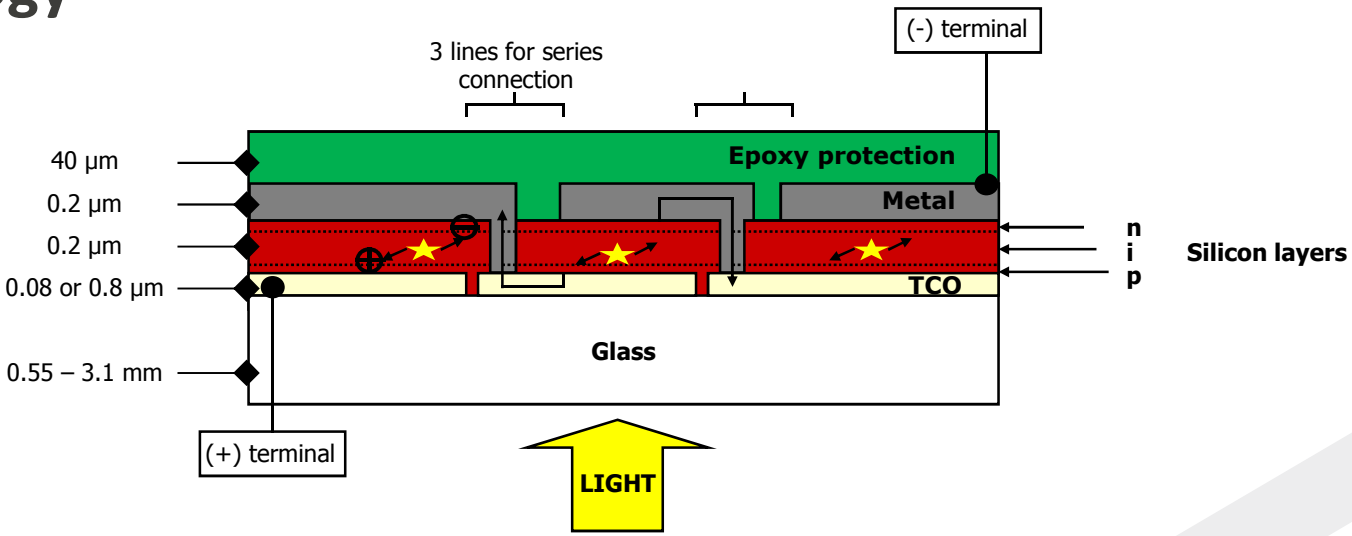
- *Example* : An indoor solar cell **developed in EnSO project** (charging ST Li-microbattery 4.5 V)





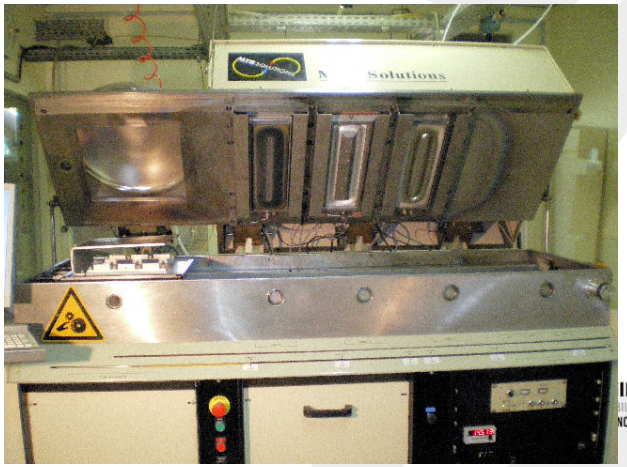
Quasi-constant working voltage = no DC/DC converter needed

Technology



PECVD : Plasma silicon coating (single junction pin)

PVD : Metal and oxides coatings by DC-magnetron (Al, Ni, ITO …)



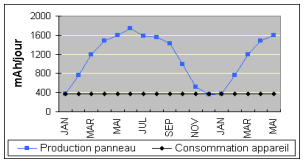
SOLEMS
L'énergie lumière

Who are we ?

A french manufacturing 25 years old SME (F-91120 Palaiseau)

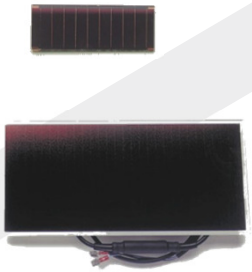
Consultancy and advice

- Specifications assistance
- Photovoltaic sizing
- Complete solutions



Amorphous Si production

- Indoor solar cells
- Low power PV modules
- Light sensors
- Customer specific designs



Small off-grid PV
Thin film silicon
B2B
Low consumption

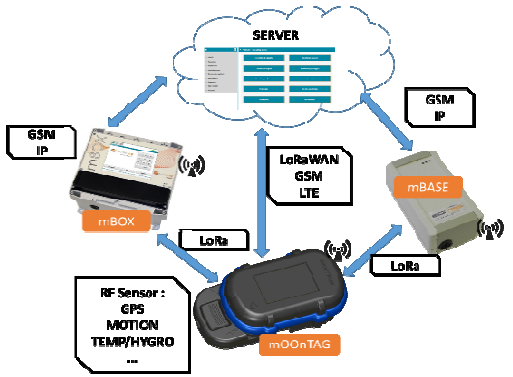
Market areas

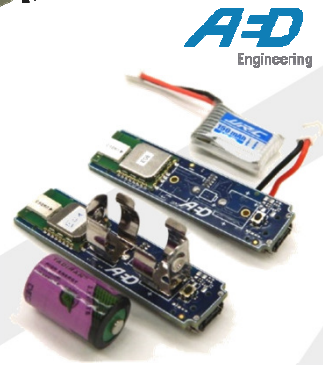
- Low power devices
- Telecom / remote control
- Household motors …

What do we do in EnsO project ?<f

1. Technical advice and prototypes for end-users

- **EDITAG -** IOT industrial asset tracking
- **OJMAR / IDNEO / GNF** – Smart lock
- **AED -** Indoor localization
- **SKF**, **OPHTIMALIA ...**





2. Innovation on solar cells

- **Development of curvable solar cells on very thin glass**
- Application : wearable IOT, design products

HIGH RELIABILITY OF OUR PROCESS ON GLASS + **ULTRA-THIN GLASS 100µm-thick** = **RELIABLE CURVABLE SOLAR CELLS**

Prototypes : end 2018

Production : 2020

IoT Week Bilbao 2018
4-7 JUNE 2018, BILBAO (SPAIN)
EUSKALDUNA CONFERENCE CENTRE

Thank you for your attention…

anne.labouret@solems.com

EnSO
Energy for Smart Objects

MECHANICAL HARVESTING

Jerome Delamare, Sophie Bouat
ENERBEE

IoT Week Bilbao 2018
4-7 JUNE 2018, BILBAO (SPAIN)
EUSKALDUNA CONFERENCE CENTRE

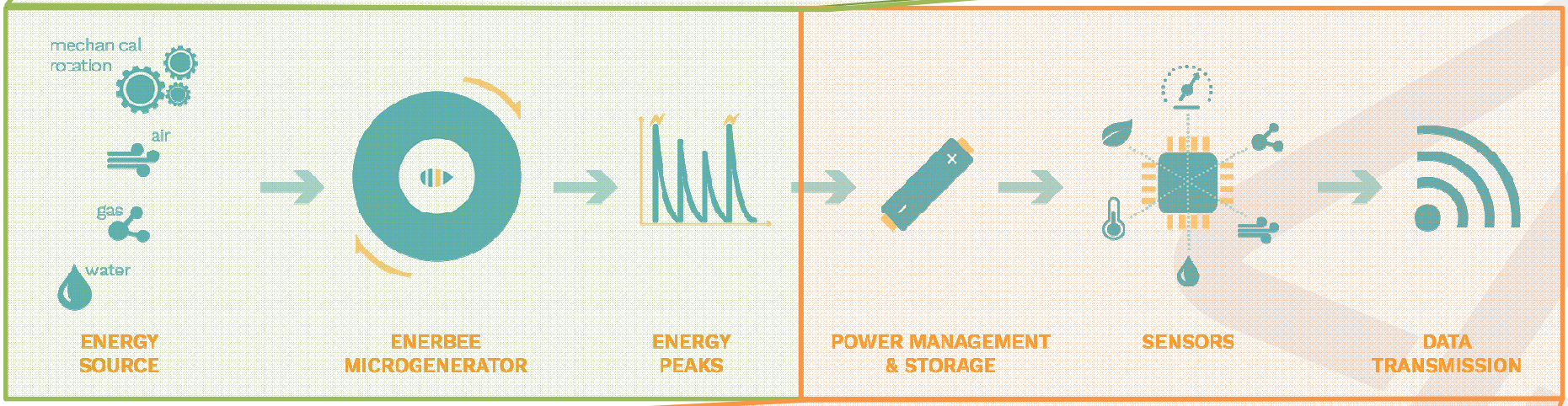
ECSEL Joint Undertaking
Electronic Components and Systems for European Leadership

EnSO has been accepted for funding within the Electronic Components and Systems For European Leadership Joint Undertaking in collaboration with the European Union's H2020 Framework Programme (H2020/2014-2020) and National Authorities, under grant agreement n° 692482

EnerBee – Energy Harvesting

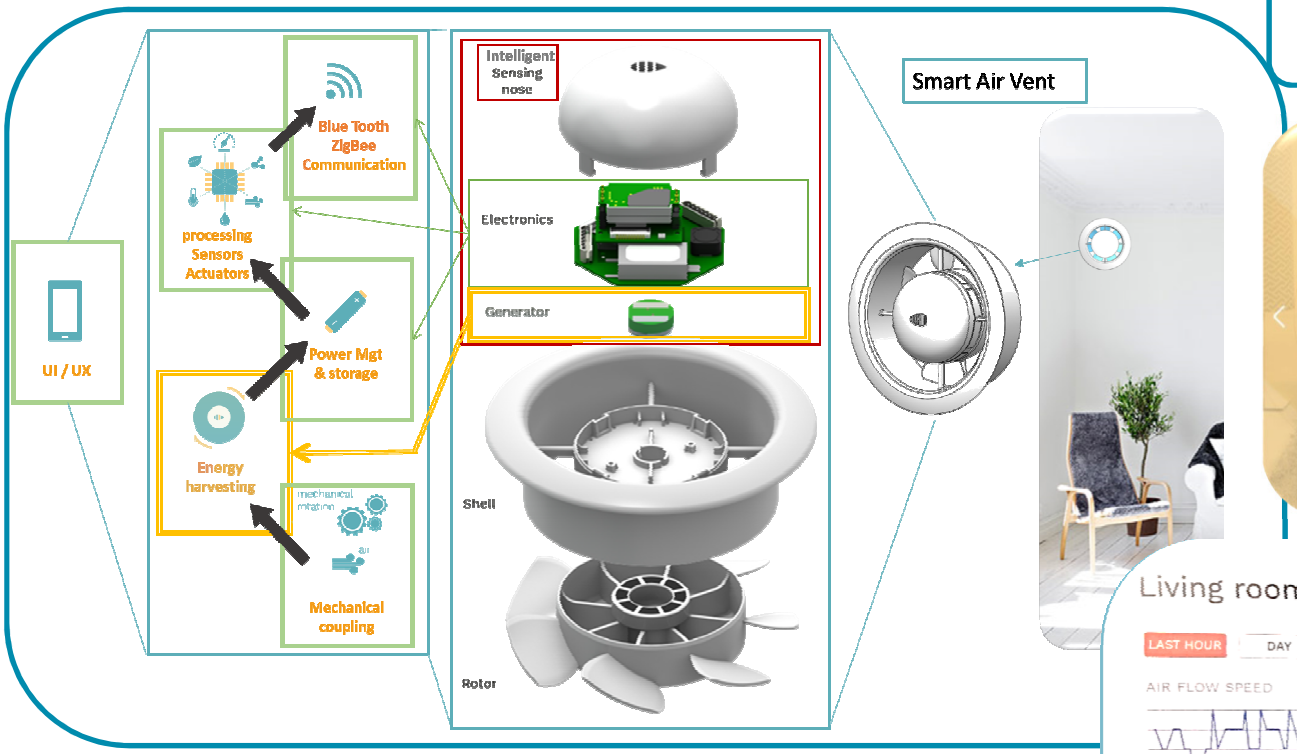
Generating Energy from Low speed and Low Force movements

- From an energy source that can be a gaz or liquid flux transformed into a mechanical rotation, the EnerBee Micro-generator harvest energy by delevering 4 energy peaks at each turn

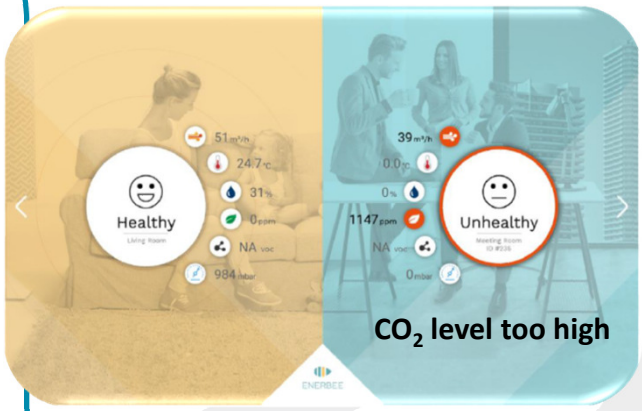


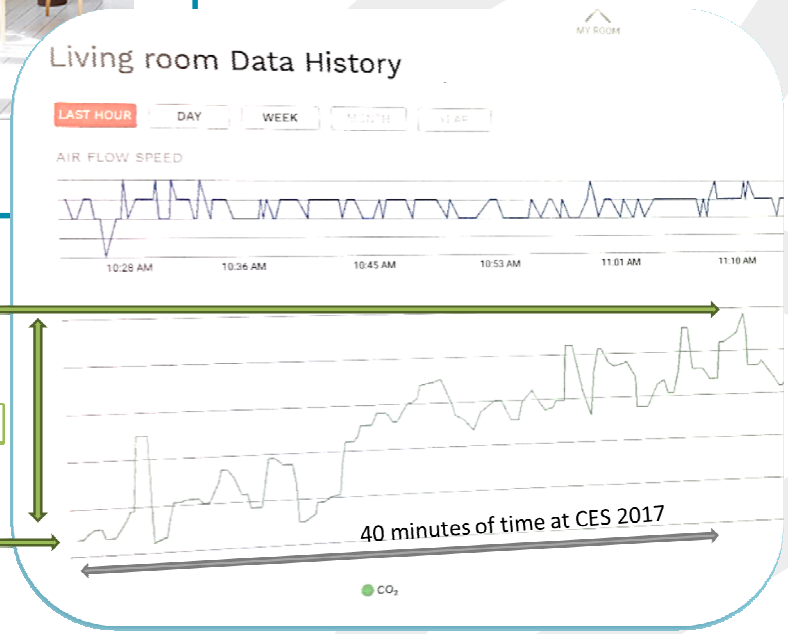
- Energy peaks are converted to useable energy via a high-efficiency patented power management electronics, delivering energy in the 100µW to 10mW range. This energy can be directly used to power, for example, a vibration sensor and for short-range radio. Or it can be stored in a supercapacitor and managed using Enerbee's ultra-low leakage power management, to power for example a CO2 sensor and for long-range communication

EnerBee – Example of HVAC application



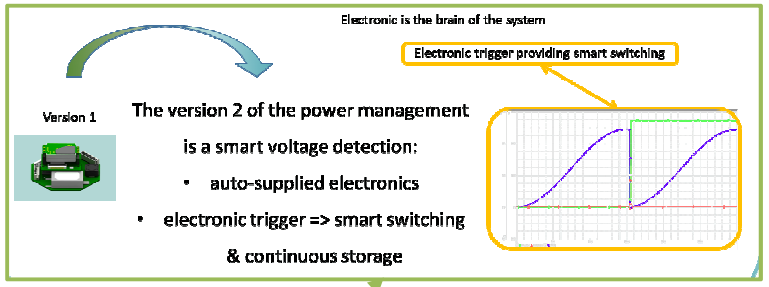
Plug & Play
Smart Air Vent



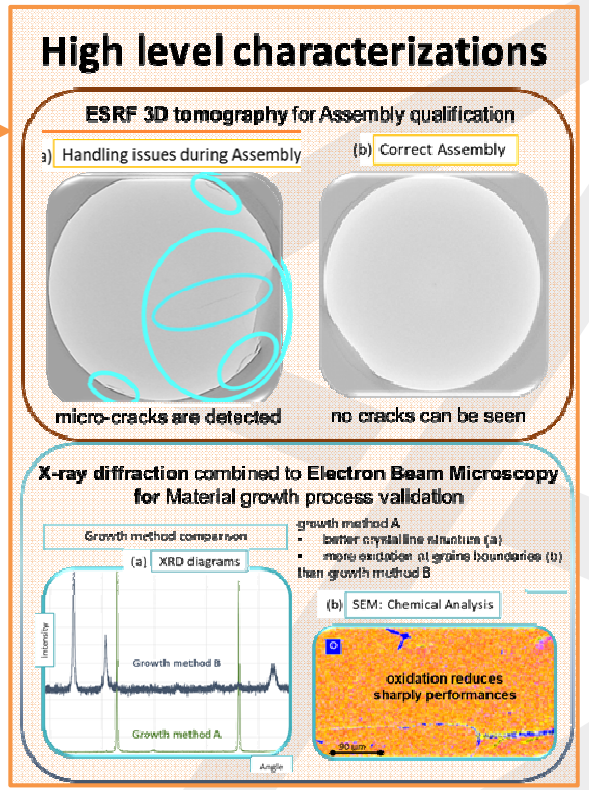


- Air speed, Humidity, Temperature and CO_2 sensors are powered and data are transmitted
- CO_2 level increases as more people are coming inside the CES 2017 booth hall

EnSO – Boost EnerBee solutions



- Support the development of EnerBee Energy Harvesting solutions
  - Power Management improvement
  - Enhancement of the heart of the EnerBee micro-generator
  - Device Size Reduction undertaken
- Intend to make EnerBee Harvesting Solutions meet Use Cases
  - OJMAR use case in EnSO: EnerBee technology not selected
  - SKF use case in EnSO: EnerBee technology under investigation



EnSO
Energy for Smart Objects

VIBRATIONAL HARVESTING

Gonzalo MURILLO,
Energiot Devices SL

Energiot

IoT Week Bilbao 2018
4-7 JUNE 2018, BILBAO (SPAIN)
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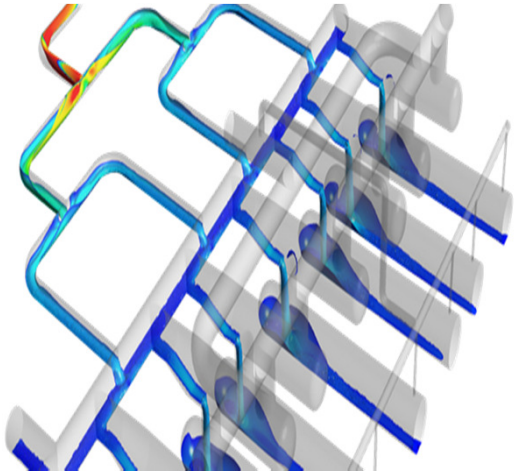
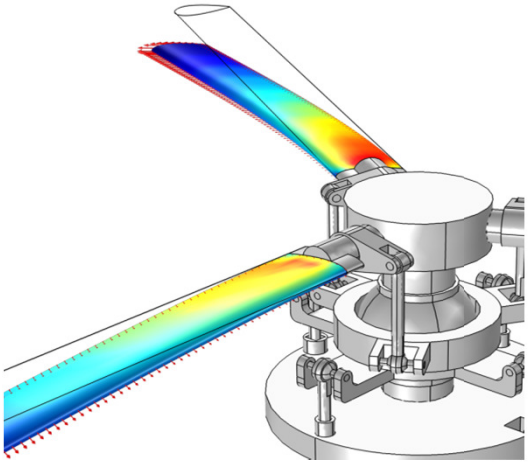
500M of batteries/year
only in Spain

PIEZOELECTRIC ENERGY HARVETING

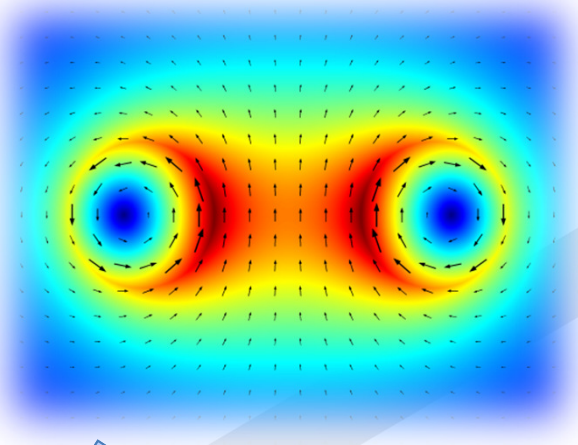
Fluid Flow

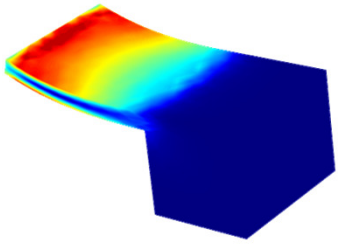


Vibrations

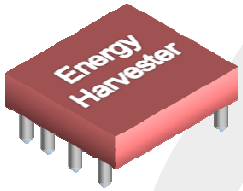


Electromagnetic Fields

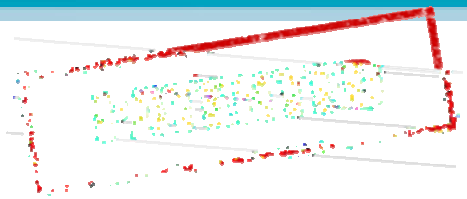


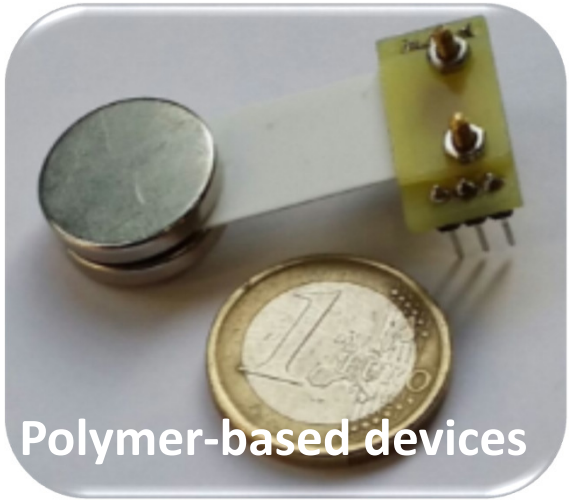


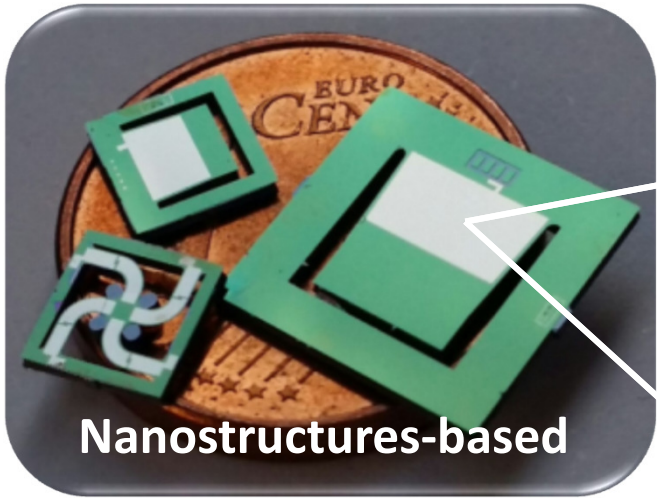
Piezoelectric Energy Harvester

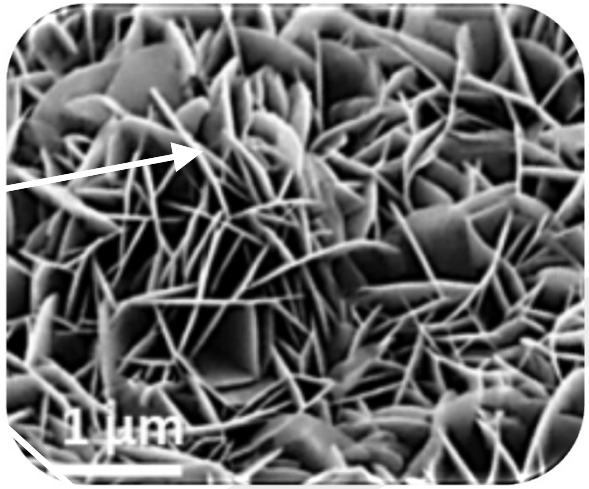


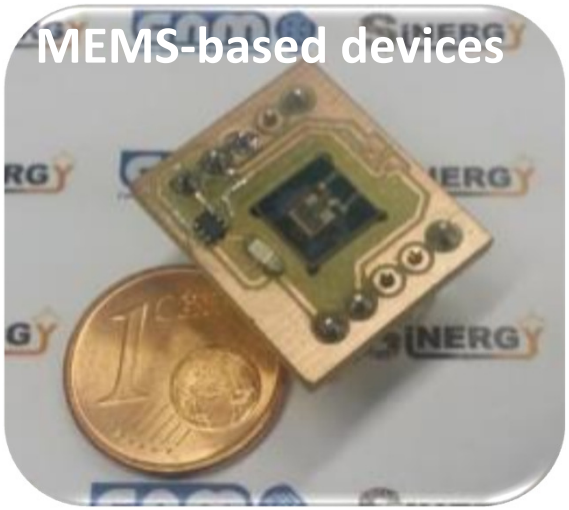
OUR CORE TECHNOLOGIES

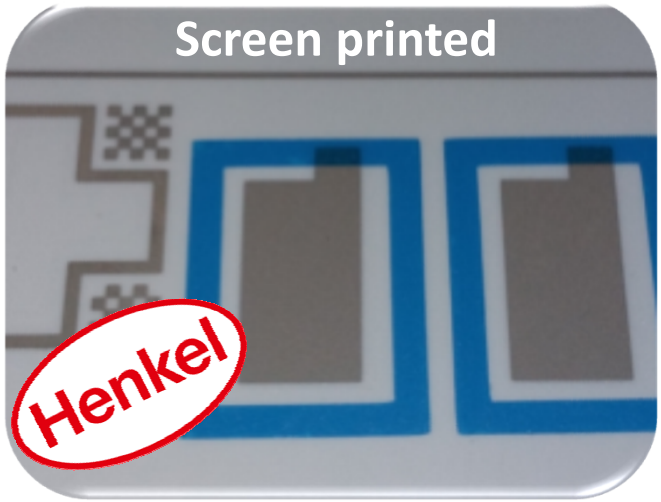


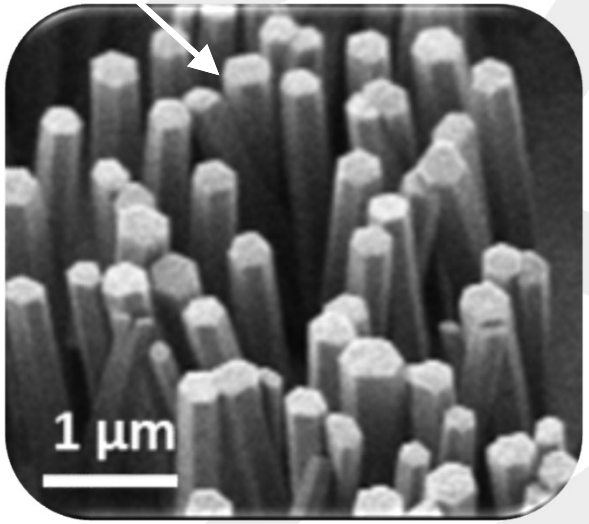




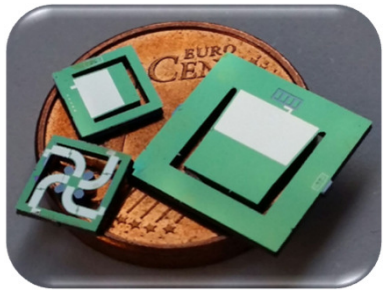


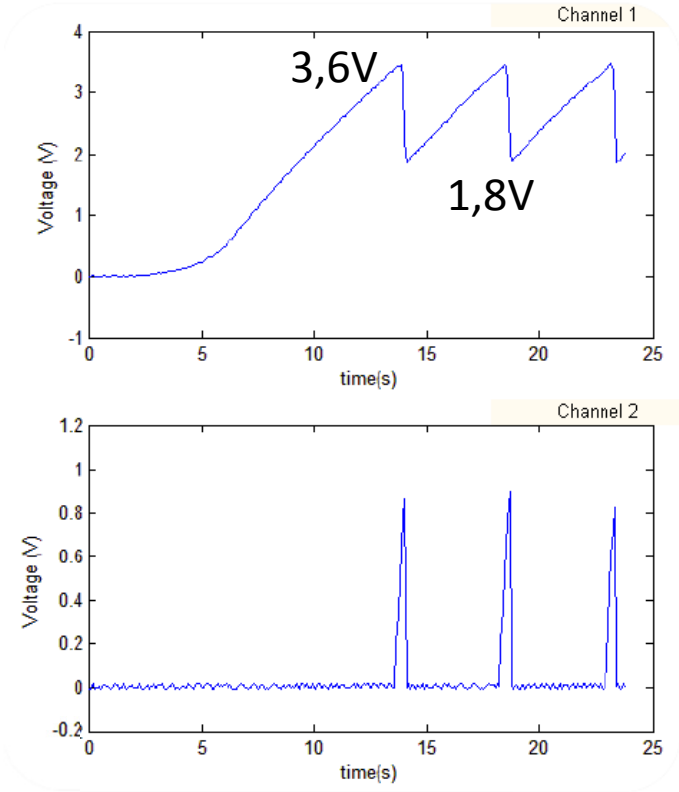






AUTONOMOUS IoT DEVICE

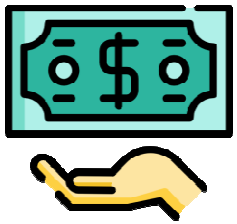




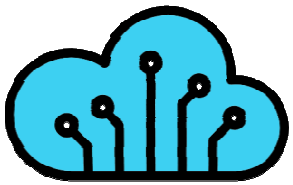
VALUE PROPOSITION

Ehergiot

Maintenance-free



30%
Cost reduction



Global Smart grid
& Big data

Green
solution

SPIN-OFF FROM MICROELECTRONICS INSTITUTE OF BARCELONA

- Public Research Organism belonging to Spanish Council for Scientific Research (CSIC)
- Located in the Campus of the Autonomous University of Barcelona (Spain)
- 175 people
- Devoted to Nano and Microelectronics
- Micro Nano Fabrication Facility (Clean Room)

Ehergiot

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

cnm
Centro Nacional de Microelectrónica
IMB

CLEANROOM

- 1.500 m2, class 100 to 10.000
- Micro and nano fabrication technologies
- Available technologies: CMOS, BiCMOS, MCM-D, MEMS/NEMS, power devices
- Packaging 200 m2, class 100
- Silicon micromachining

OUR COMPETITIVE ADVANTAGE

Energiot

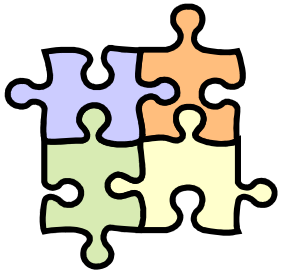
Multisource of Energy

Reduced size

MIT Technology Review INNOVATORS UNDER 35 EUROPE

10 year of experience

Low-cost Manufacturing



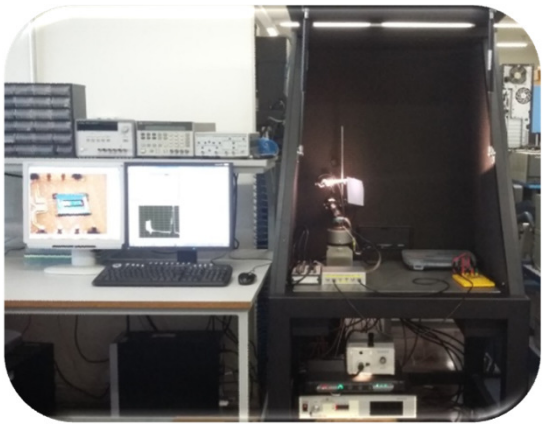
Modular and Reliable

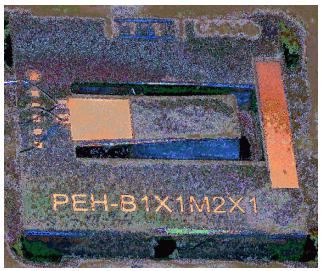
Continuous Innovation

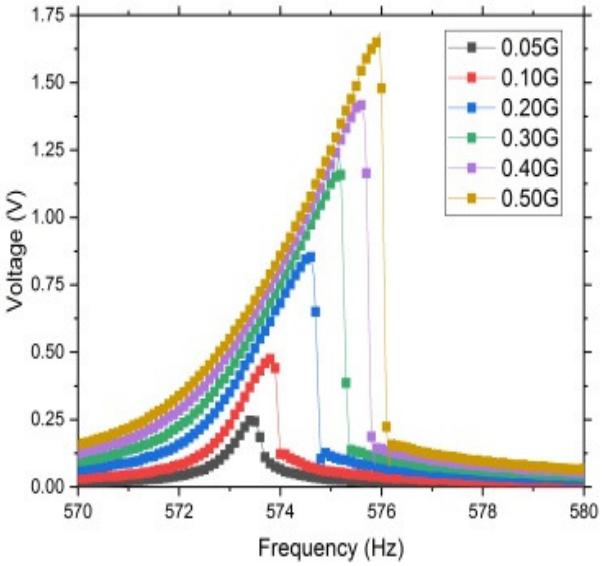
OUR DEVICES CAN HARVEST ENERGY FROM VIBRATIONS…

Energiot

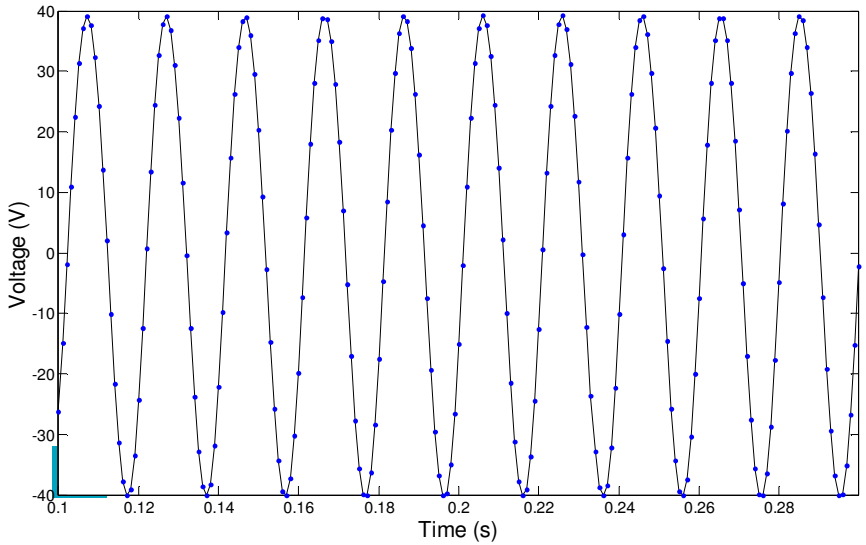
MEMS-based devices

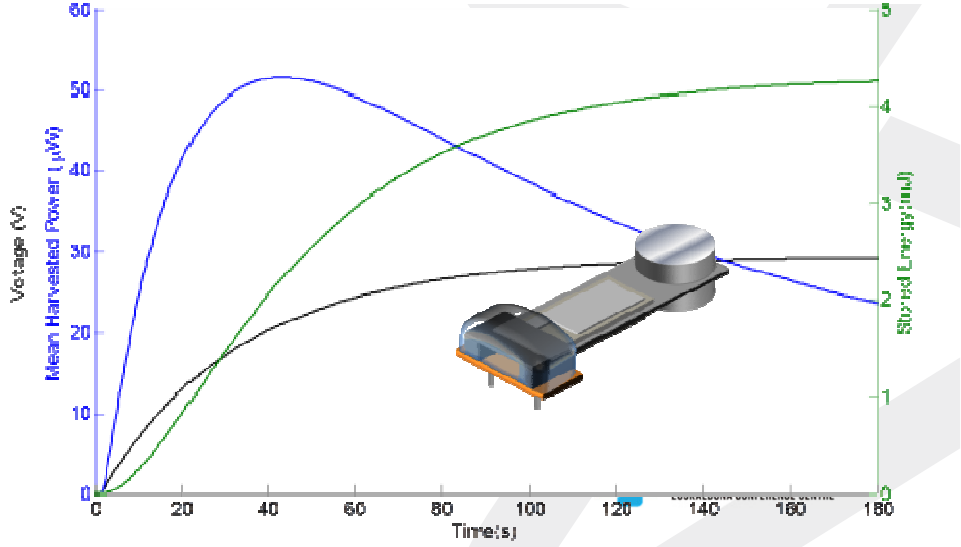






Polymer-based devices

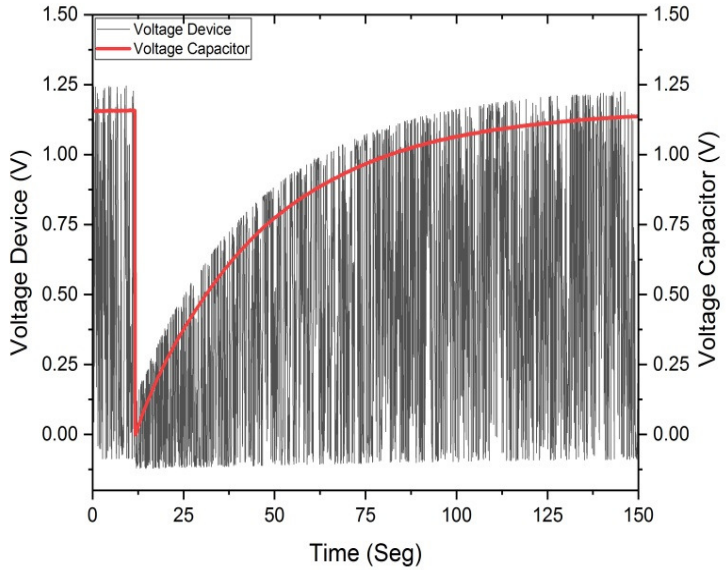




POWER MANAGEMENT AND WIRELESS TRANSMISSION

B3x5M3x5 with diode bridge and capacitor

It allows the charge of a capacitor for the later use of the energy



Polymer-based devices with Energiot-cube

They allow the collection and use of a wireless sensor node to transmit the sensor data (temperature and voltage) to another sensor, gateway or a computer.

Energiot

DATASHEET

PEH-B1x1M1x1-v1

Description

This vibration-driven energy harvester is based on a lead-free piezoelectric material deposited on top of a silicon structure made by MEMS technology.

The resonant motion the structure is translated into a piezoelectric charge generation, which produces an electric power that can be used to supply low-power integrated electronics.

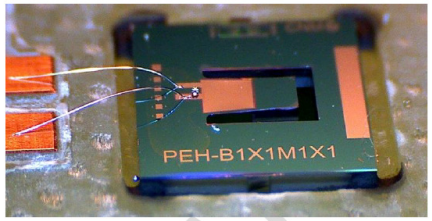
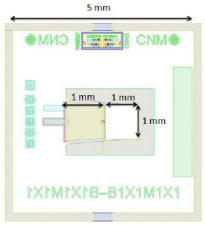


Diagram and size



Materials and thicknesses

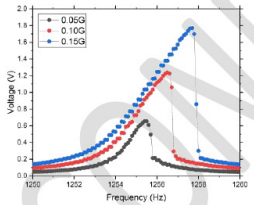
Substrate
Silicon: 15 µm – SiO_2: 1 µm – Silicon: 500 µm

Piezoelectric material
Aluminum nitride - 1 µm

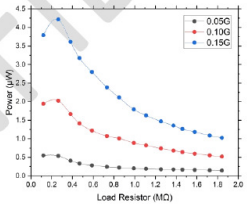
Volume
12.9 mm^3 (5 mm x 5 mm x 0.516 mm) (chip)
3.1 mm^3 (3 mm x 2 mm x 0.516 mm) (EH)

Electromechanical characterizations

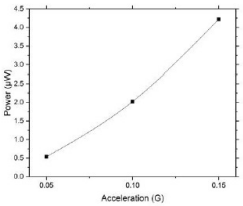
Voltage vs Load resistor



Power vs Load resistor



Power vs Acceleration



Key output values

Input acceleration	Resonance frequency	Bandwidth	Open-circuit voltage	Optimum load resistance	Maximum generated power	Maximum power density
0.05 G	1255.4 Hz	2.9 Hz	0.65 V	263 KΩ	**0.53 µW**	**171.18 µW/cm³**
0.10 G	1256.5 Hz	2.4 Hz	1.23 V	263 KΩ	**2.02 µW**	**652.45 µW/cm³**
0.15 G	1257.7 Hz	1.4 Hz	1.77 V	263 KΩ	**4.21 µW**	**1359.8 µW/cm³**

Link to raw data: *B1x1_M1x1_1_0G05_RL_119K_1M85_data_Acc_1*

Energiot

DATASHEET

EHProto-PET-v1

Description

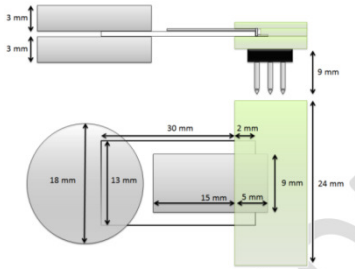
This device is a vibration-driven energy harvester based on a piezoelectric material laminated into a plastic substrate (PET).

The vertical motion of the substrate is translated into a piezoelectric voltage, generating an electric power that can be used to supply integrated electronics.

Materials and thicknesses

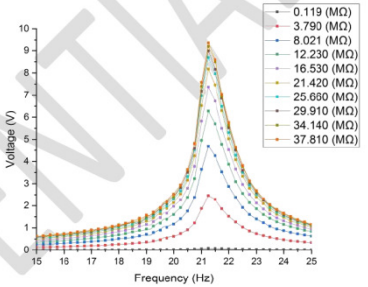
Substrate
Polyethylene terephthalate (PET) - 500 µm
Piezoelectric material
Piezo polymer - 110 µm
Mass
19.8 g – 2 x Ø18mm x 3 mm
Volume
19.5 cm^3 (2.4 cm x 5.8 cm x 1.4 cm)

Diagram and size



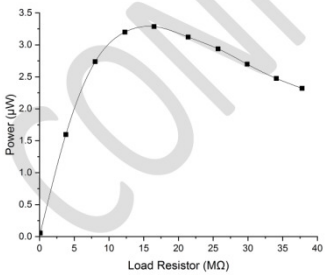
Electromechanical characterizations

Voltage vs Frequency (Acc 0.1G)

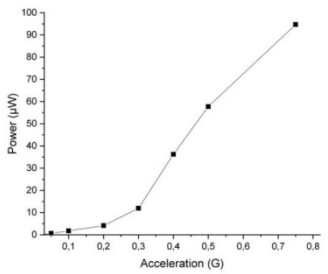


Electromechanical characterizations

Power vs Load resistor (Acc 0.1G)



Power vs Acceleration

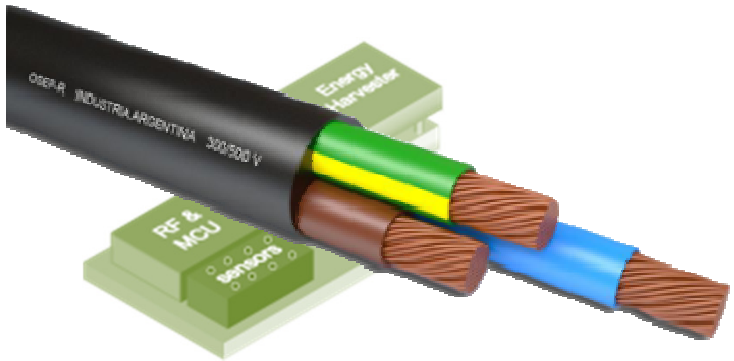


Key output values

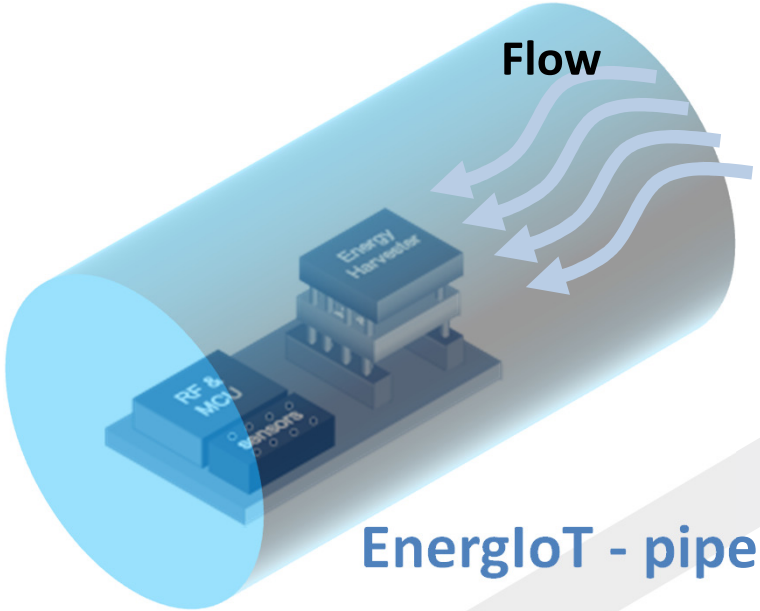
Input Acceleration	Input Frequency	Open circuit voltage	Optimum load resistance	Maximum generated power
0.1 G	21 ± 2 Hz	9.5 V	16.53 MΩ	**3.25 µW**
0.5 G	-	52.3 V	-	**57.8 µW**
0.75 G	-	67.1V	-	**94.7 µW**

Link to raw data: *Piezoelectric PET 500um Epoxy 21hz25 0G1*

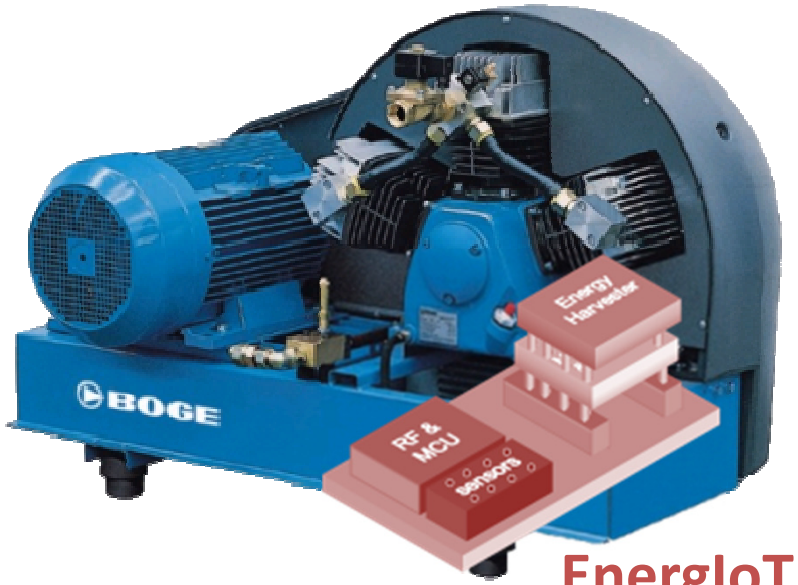
PRODUCT PORTFOLIO



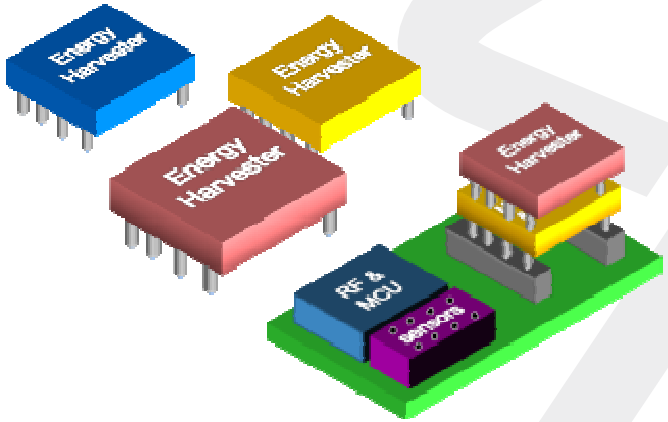
EnergIoT - grid



EnergIoT - pipe



EnergIoT - vibe



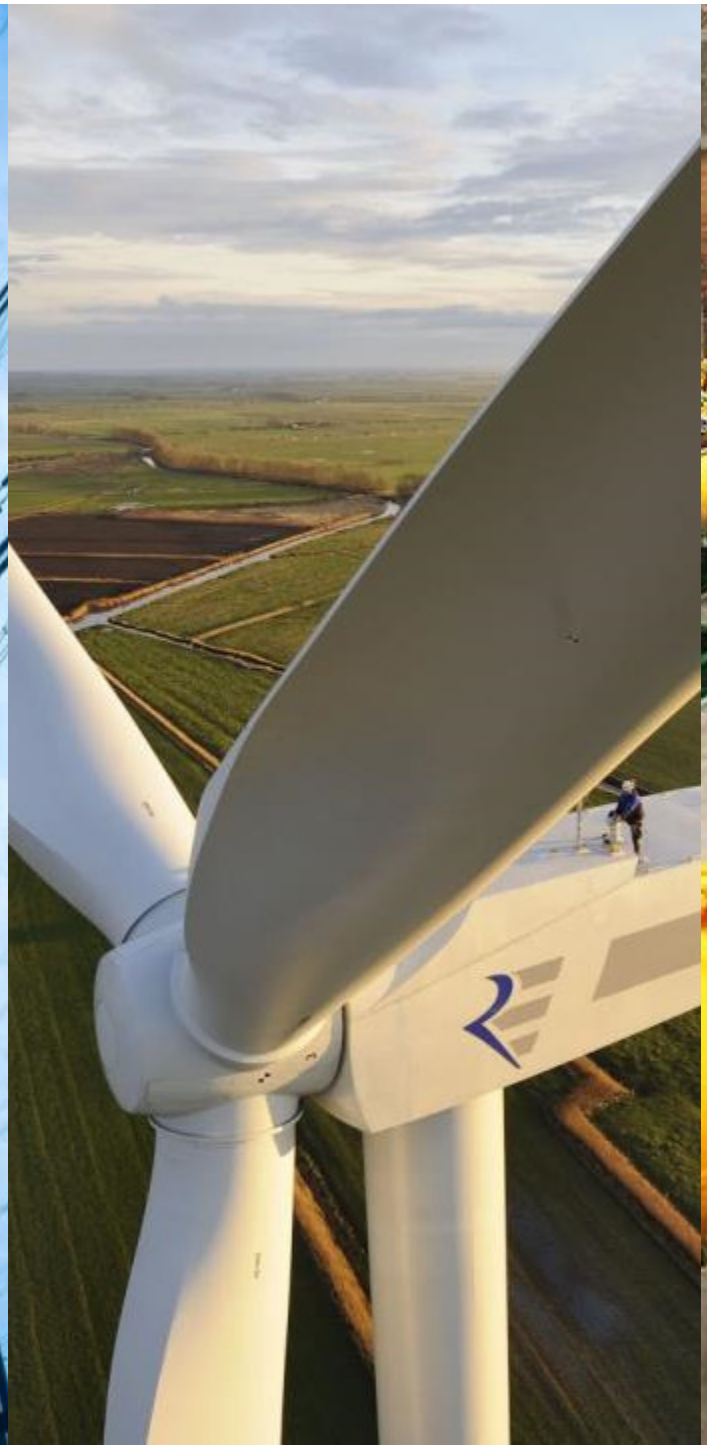
EnergIoT - proto


SKF
EnSO
Energy for
Smart Objects


AIRBUS
EnSO
Energy for
Smart Objects
AIRBUS A350
A350


AIRBUS


gasNatural
fenosa
EnSO
Energy for
Smart Objects

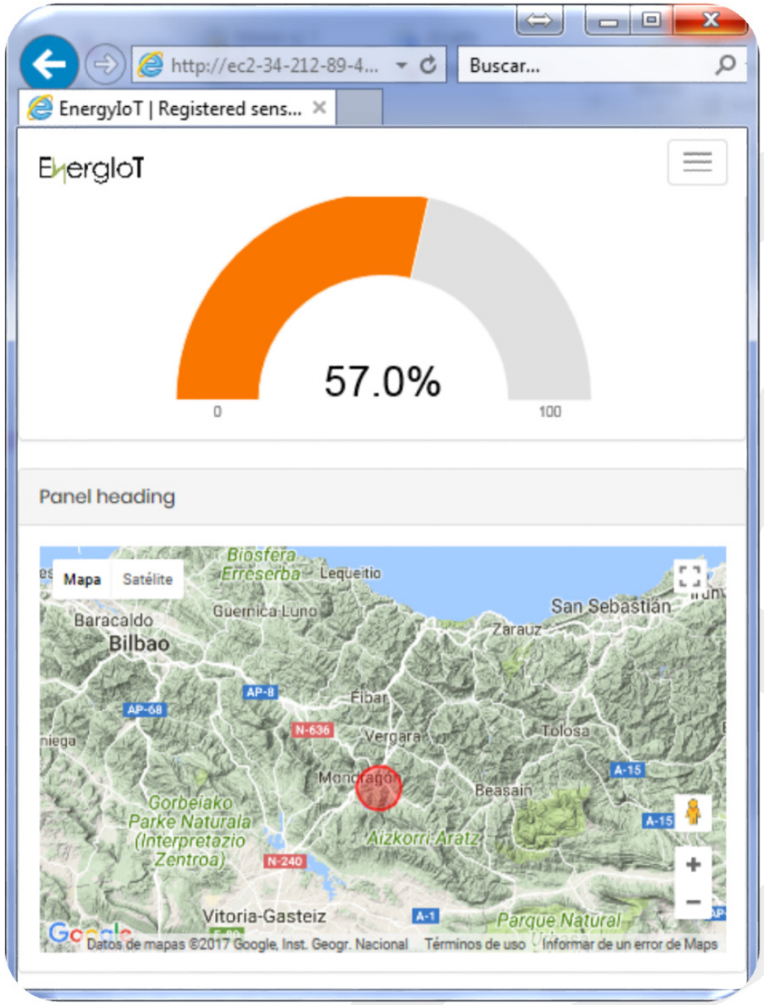


CORE ACTIVITIES

Development of ad-hoc projects with customers and partners

Designing and producing customized high-tech devices

Offering a service of IoT Platform



OUR TEAM

Invested by

eit InnoEnergy
Knowledge Innovation Community

Gonzalo Murillo
PhD and Electronics engineering
Founder

Joana Cases
Chemical Engineer
Sales Manager

Technical team

Marcos Duque
Telecommunications Engineer
Technical team

Edgardo Uriel
Mechanical Engineer
Technical team

Jaume Esteve
Research professor
Technical Advisor

Raul Gomez
PhD and Electronics engineering
IoT Expert

+ **2 new positions** in 2018!

With the advise of

Maria Sansigre
Demeter partners
Mentor at Engega in 2015

David Reyero
HR in Sanofi
Mentor at Circulo Ecuestre

Gabriel Masfurroll
President of Tres Torres Hosp.
Mentor at U2B 2012

EnSO
Energy for Smart Objects

Thanks for your attention!

Energiot
Harvesting energy for the Internet of Things

Centro Nacional de Microelectrónica IMB
CSIC
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ECSEL Joint Undertaking
Electronic Components and Systems for European Leadership

EnSO has been accepted for funding within the Electronic Components and Systems For European Leadership Joint Undertaking in collaboration with the European Union's H2020 Framework Programme (H2020/2014-2020) and National Authorities, under grant agreement n° 692482

THANK YOU!

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