Micro-Energy Harvesting

(µ-EH)

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Few considerations about µEH

«Energy harvesting», «Power scavenging» ...

… what does that mean exactly?

Talking about Energy we usually use the verbs:

- Produce
- Transform
- Extract (e.g. from fossil fuels)

but harvesting is unusual

and scavenging reminds us *«bums rummaging in the trash»*

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Few considerations about µEH

Even talking about «energy quantities» we are used to deal with

- KWh, M
- or, consi
  oil

Table 5.6: OPEC crude oil production based on *secondary sources*, tb/d

	2013	2014	4Q14	1Q15	2Q15	May 15	Jun 15	Jul 15	*Jul/Jun*
Algeria	1,159	1,151	1,152	1,112	1,110	1,120	1,104	1,104	*0.0*
Angola	1,738	1,660	1,688	1,746	1,712	1,745	1,738	1,777	*39.7*
Ecuador	516	542	546	551	545	552	530	525	*-4.8*
Iran, I.R.	2,673	2,766	2,763	2,779	2,836	2,836	2,829	2,861	*32.3*
Iraq	3,037	3,265	3,424	3,453	3,840	3,808	4,027	4,074	*46.7*
Kuwait	2,822	2,774	2,719	2,748	2,726	2,712	2,703	2,703	*0.0*
Libya	928	473	679	382	442	429	411	373	*-37.8*
Nigeria	1,912	1,911	1,904	1,886	1,845	1,816	1,871	1,852	*-19.6*
Qatar	732	716	682	679	667	664	669	656	*-12.6*
Saudi Arabia	9,586	9,683	9,608	9,809	10,210	10,187	10,313	10,352	*39.2*
UAE	2,741	2,761	2,757	2,817	2,839	2,848	2,845	2,865	*20.1*
Venezuela	2,389	2,373	2,364	2,367	2,376	2,378	2,373	2,370	*-2.5*
Total OPEC	**30,231**	**30,075**	**30,286**	**30,330**	**31,149**	**31,095**	**31,412**	**31,513**	***100.7***
OPEC excl. Iraq	**27,194**	**26,809**	**26,862**	**26,877**	**27,309**	**27,287**	**27,385**	**27,439**	***54.0***

Totals may not add up due to independent rounding.

Few considerations about µEH

- Today we talked about «Micro-energy harvesting»
- And our applications will regard harvesting µWs or mWs
- all that to specify the context

The Energy problem

- Fossil fuels are finite and environmentally costly.
- Sustainable, environmentally energy can be derived from ambient sources. Large-scale ambient energy (eg solar, wind and tide), is widely available and technologies are being developed to efficiently capture it.
- At the other end of the scale, there are **huge *'small amounts'*** of **'wasted' energy** that could be useful if captured. Recovering even a fraction of this energy would have a significant economic and environmental impact.
- **This is where µ-Energy harvesting (µEH) comes in.**

Energy Harvesting definition

Energy Harvesting is the process by which ambient energy, **that would otherwise be lost**, is captured and converted into electricity to power small devices (sensors, actuators) eliminating the need for connection to the grid.

This technology efficiently collects the ambient energy that **we usually discard** and merits a lot of attention. It is also known as **energy scavenging** or **power scavenging**.

Energy harvesting applications can help to engage the global energy demand, by capturing otherwise lost energy. This is beneficial both for the environment and for the financial performance of companies and households.

Sources of wasted energy

- Mechanical energy in the form of vibrations or pressure;
- Thermal energy in the form of ambient temperature differences, waste heat or friction;
- Light energy in the form of sunlight or room lighting;
- Electromagnetic energy produced by coils and transformers;
- Other forms of naturally occurring ambient energy such as wind, water flow but also energy generated by humans and other living creatures.

Power available from different energy types

Source	Power	Notes
Cosmic radiation	0.1μW	Neglecting conversion inefficiencies
EM radiation	0.5 μW	10 x 10cm antenna 10m below a 10kV transmission line
Blood pressure	15 μW	Estimate of Southampton University hospital device
Machine vibration	5 mW	Perpetuum PP27
Indoor lighting	20 mW	5 x 5 cm solar cell
Human power	2 W	Winding a Baygen radio

Typical energy needs from a range of devices

Device	Power usage	Energy usage over 24 hours	Assumptions
Pacemaker	50 μW	5 J	70 beats per minute
Wired sensor	100 μW	10 J	1 Hz strain sensor
Wireless sensor	1 mW	10 J	Humidity sensor 10% duty cycle Zigbee radio protocol
Hearing aid	0.4 mW	70 J	Continuous
Mobile phone	15 mW standby 1.5 W transmit	5 kJ	23¼ hours standby 45 minutes talk time
GPS receiver	100 mW	8 kJ	Continuous
Low power computer	2W	60 kJ	8 hours on, 16 hours off
Laptop computer	15 – 25 W	500 kJ	8 hours on, 16 hours off
Desktop computer	50 – 150 W	5 MJ	8 hours on, 16 hours standby

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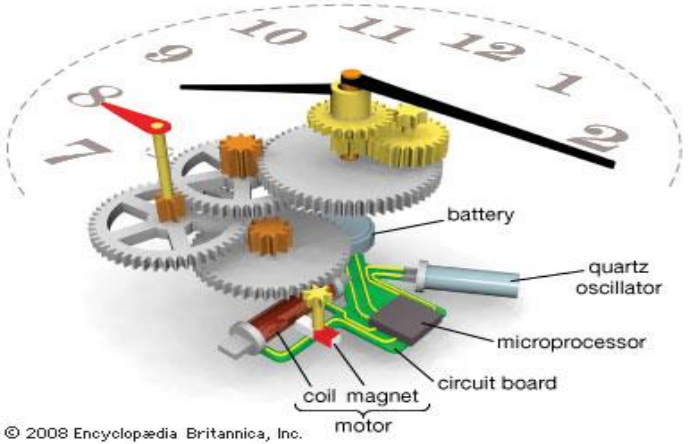
EH: a story started decades ago

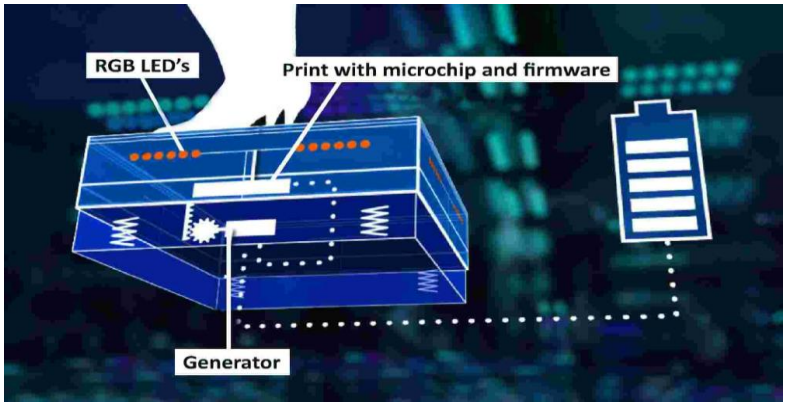
Harvesting technology has already been used for decades, such as in kinetic **wrist watches** that use body movement to wind a spring and store energy, or in **bicycle d**



A story that continued with more and more applications like ...

The Sustainable Dance Floor (SDF) uses the movement of people as source of energy. This kinetic energy is converted into electricity which powers the dance floor's LED lights which create the disco atmosphere.

Each module by the size of 75x75x20 cm can produce up to **35 watt** of sustained output. (Between 5-20 Watt per person)



A story that is on going with recent cutting edge solutions like ...

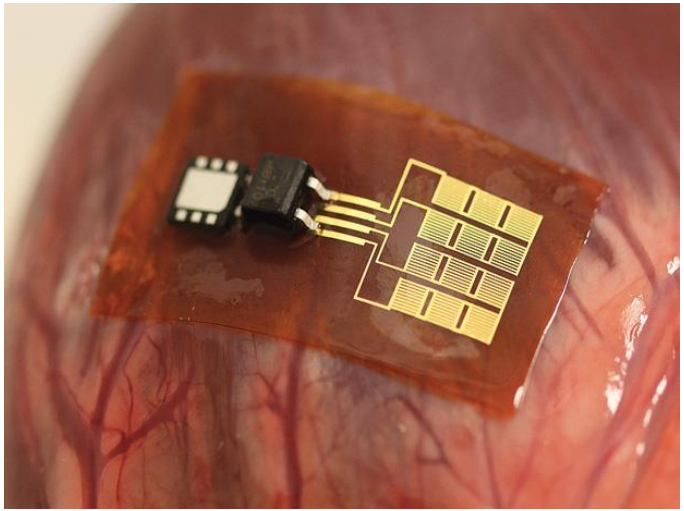
… Photo-Voltaic paint coating

- Solar cells made using a process like spray painting have been developed by a research collaboration between scientists at the University of Sheffield.
- Nanoparticles are basically extremely small semiconductor quantum dots, and high absorption cross section, it is possible to capture all of the visible light with an ultra thin layer of material. The photovoltaic active layer is simply spray-coated by an air-based process that is very similar to spraying ordinary paint.
- The federal government estimates the United States can save $40 billion per year by reducing energy use in commercial buildings by 20 percent by 2020.

A story that is on going with recent cutting edge solutions like ...

University of Illinois College of Engineering.

A piezoelectric harvester, made with thin ribbons of lead zirconate titanate (PZT) surrounded by flexible, biocompatible plastics, with an integrated rectifier and rechargeable battery, is shown attached to the surface of a bovine heart. The design can harvest enough energy for a pacemaker.



«The heart is a great place to do mechanical energy harvesting because it's constantly in motion» Prof. J Rogers – Univ. of Illinois

But let's get to today's topic

- I am not here to speak about science fiction.
- I work for a Company – Electrolux - that manufactures every year more than 50 millions products
- Products that enter our homes, our restaurants, our canteens
- So I am talking about «concrete things»

The Electrolux Group today

Net sales,SEKb

112

EUR 12.3 b
USD 16.3 b

Sales in

150

countries

People

60,000

in **60** countries

Annual Sales

+50

million products

Numbers from 2014, using 2014
average currency exchange rates

About Electrolux Products

- Power in the range from 1KW to several tens KWs
- Significant quantities of **wasted energy** in the forms of heat and vibrations

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Dispersed energy within appliances

HEAT

- From warm waste water (washing machines, dishashers)
- From hot surfaces (motors, heaters, water/steam pipes)
- From hot gases (burners, exhausts, cookers)
- ...

VIBRATIONS

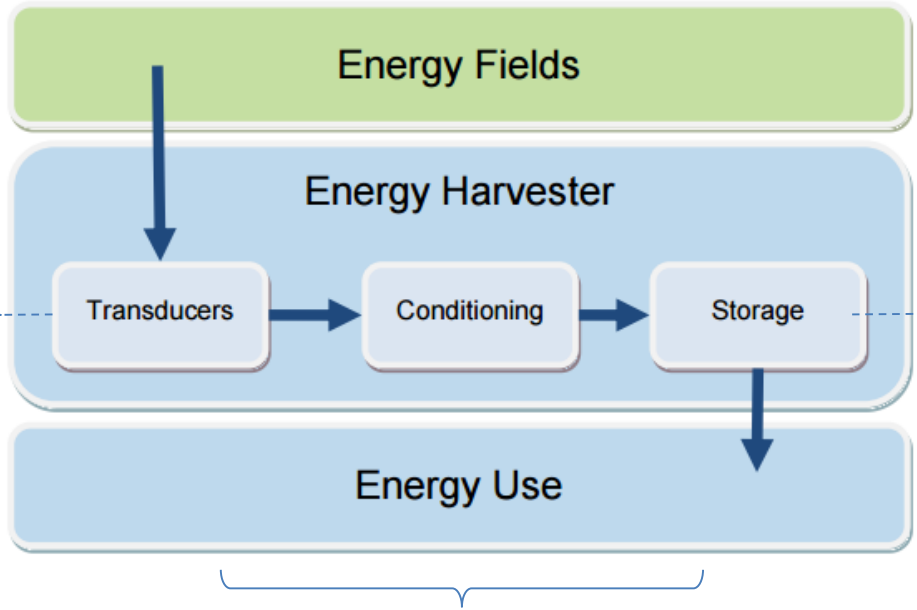
- From motors, ball bearings, hinges, moving components (baskets, drums), flowing air and water

E.m. fields

- From scattered e.m. fields: coils, wires, transformers

Typical harvesting system

- Piezo, E-static
- E.m., PV
- Thermoelectric



- Mechanical
- Thermal
- Electromagnetic
- Chemical
- ...

- Cap, supercap
- Thin film battery

- WSN: Wireless Sensor Networks
- RTL: Real Time Location
- .....

Key advantages

Harvesters are mandatory in harsh environments where:

- there is no electrical power available (e.g. endothermic engines)
- it is impossible to lay wires (e.g. the blades of a turbine, a car tire)
- the installation of battery-powered solutions are not applicable (harvesters eliminates the need for regular battery replacement)

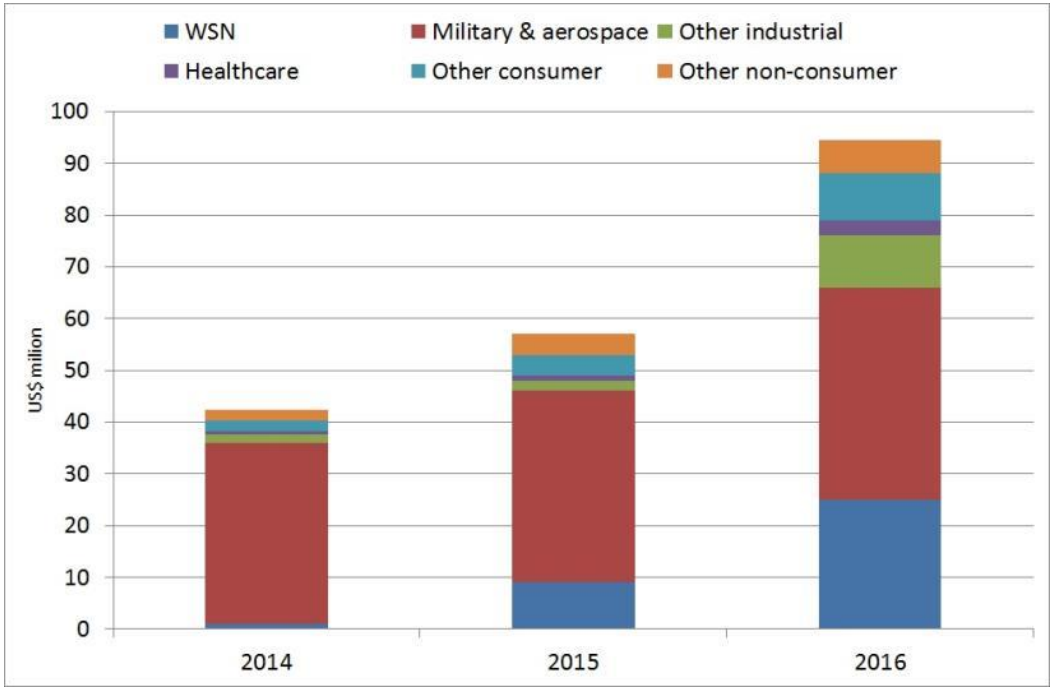
Expected growing trend

According to the Energy Harvesting Journal, the energy harvesting market is expected to grow to over EUR 3 billion annually by 2019, driven by energy harvesting for consumer products.

By 2040, energy harvesting, using existing and emerging technologies, will likely be incorporated in almost all manufacturing processes and manufactured devices.

This number is confirmed by two other reports which also forecast the market for energy harvesters to reach the EUR 3 billion mark around 2020.

Market forecasts for thermoelectric energy harvesters



Source: IDTechEx

EU project consortium funded under the 7th Framework

European Call (part) Identifier: FP7-NMP-2013-SMALL-7
Duration: November 2013 to October 2016

http://www.sinergy-project.eu

- **Goal:** Silicon materials and Silicon technologies & architectures for long term autonomy microenergy solutions
- **Focus: (1)** Technology development at device level (2) Systems integration feasibility
- **Devices**: (1) Harvesters based on thermoelectrics (2) Harvesters based on mechanical vibrations (3) thin film / 3D batteries
- Application scenarios: (1) Tire Pressure Monitoring (2) Appliances Monitoring

- **Why microenergy solutions:** Replace primary batteries (cost, environmental, deployment flexibility issues) by harvesters + secondary batteries
- **Why Silicon materials and architectures:** tap into the micro-nanoelectronics field which is an enabling technology, dealing with miniaturized and high density features (3D) implementations, offering economy of scale (serve mass markets) and the possibility of integration and addition of control and smartness
- **Why such applications:** complementary micro-energy test-beds from the perspective of silicon benefits ('smaller is better', 'cheaper is better') and availability of energy harvesting sources

Appliance Monitoring

Tire Pressure Monitoring

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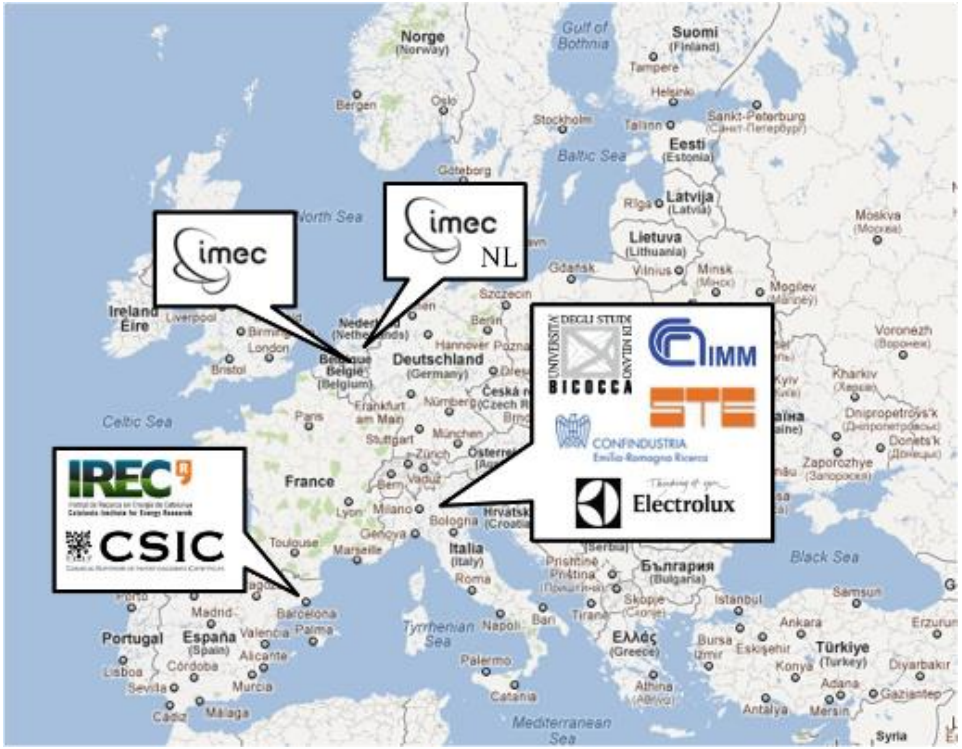

N.9 Partners (E, I, B, NL)
Coordinator: CSIC (IMB-CNM)

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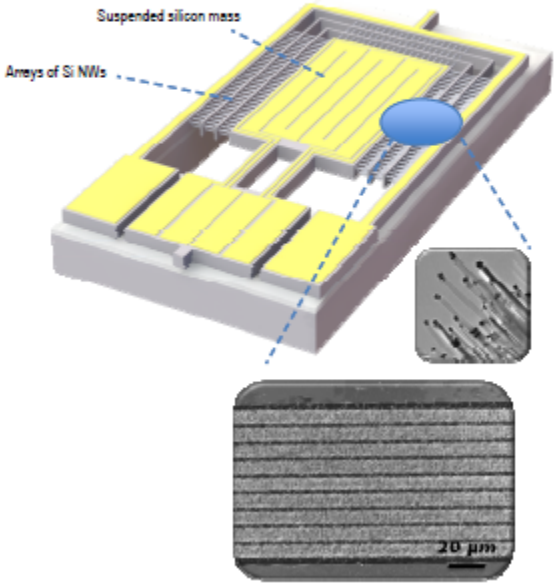
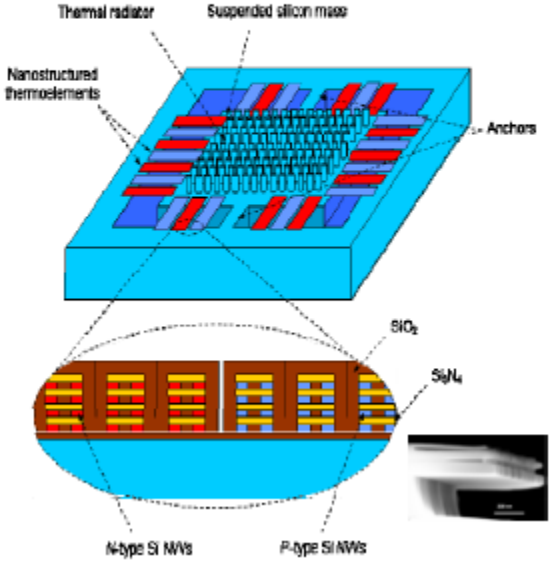
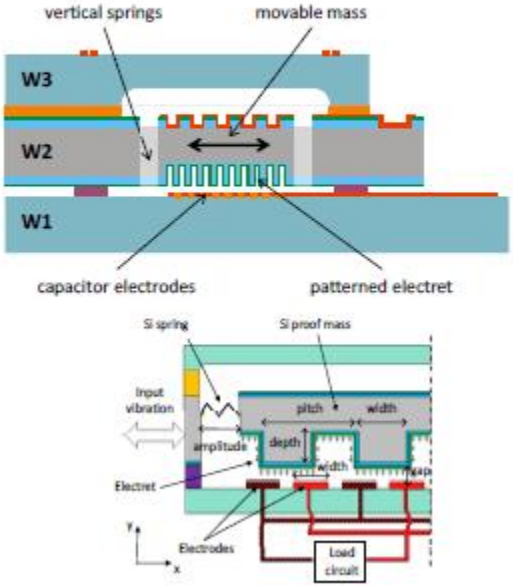
- 3D microstructures + bottom-up SiNWs



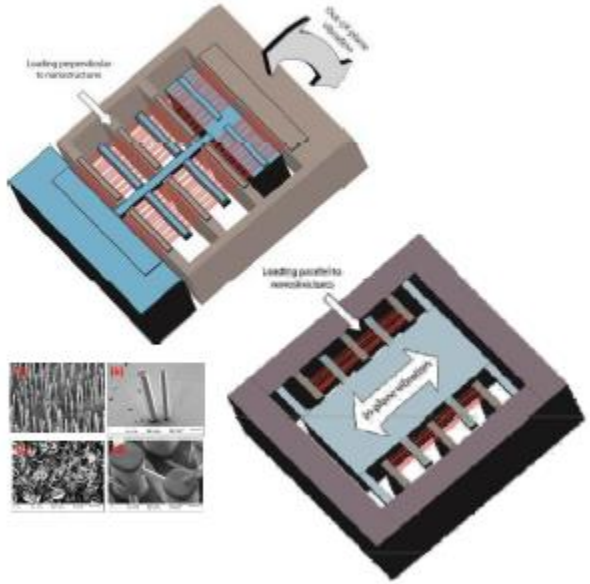
- 3D microstructures + top-down SiNWs



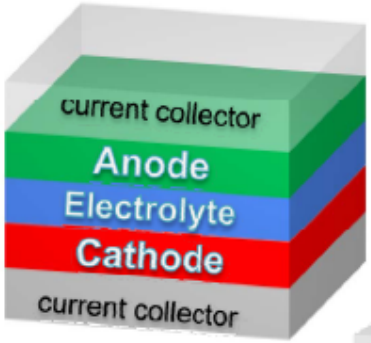
- 3D microstructures + electrostatic



- 3D microstructures + piezoelectric

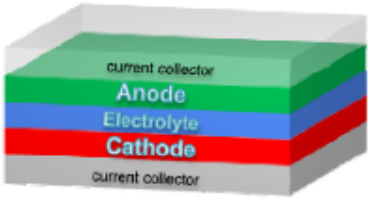


- Materials for Si compatible batteries
- 3D microstructures



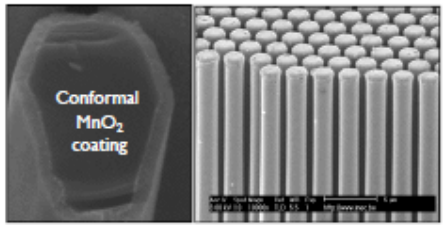
Thin film

Low capacity
High power

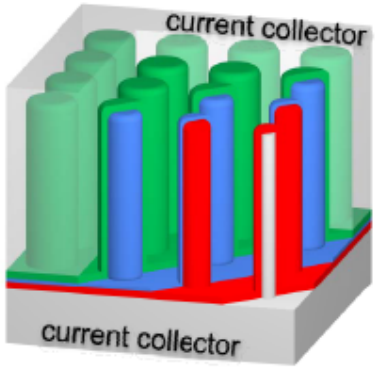


High capacity
Low power

3D



High capacity & power



Sinergy use-case

Monitoring functions within a gas-powered equipment

- Chimney with very hot exhausted gases
- A TEG harvests energy and powers a wireless sensing system capable to monitor the appliance
- The information collected by the sensing system is transmitted to a kitchen control station for different purposes (e.g. HACCP, maintenance)

- Example of professional, gas-powered fryer
- Being gas-powered, it has no electricity on-board

Other future expected use-case

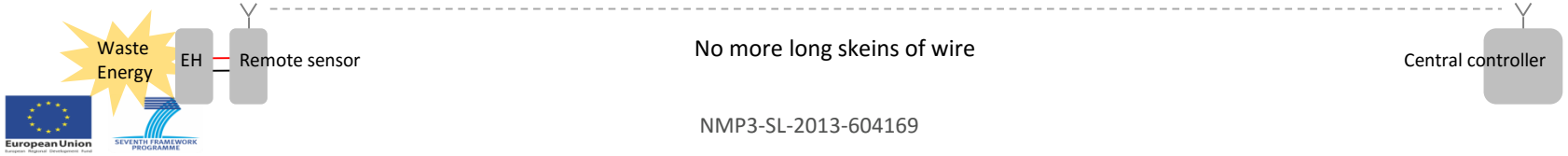
Preventive maintenance in production lines

- In complex equipment Maintenance, Repair and Overhaul operation are expensive and time consuming
- By monitoring critical parameters like: changes in *shaft speed*, *vibrations*, *bearing temperatures* failures can be detected before they happen reducing equipment shutdown
- Downtime is greatly reduced
- Total operational life is increased
- Material waste is controlled
- Collateral damage and potential safety problems are minimized

Other future expected use-case

Harvester-powered wireless technologies simplify wiring harness

- In complex equipment, wiring harness requires long skeins of wire
- Wireless technology can simplify wiring harnesses, providing ***cost reduction***, ***manufacturing flexibility*** and ***easier maintenance***
- A wireless approach would allow to install a new item without disturbing the total electrical architecture



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Thank you for your attention

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