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ENERGY HARVESTING: TOWARDS ENVIRONMENTALLY POWERED SYSTEMS

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Séminaire

we^n WEST ELECTRONIC & applications network

CAP'TRONIC

S2E2 SMART ELECTRICITY CLUSTER

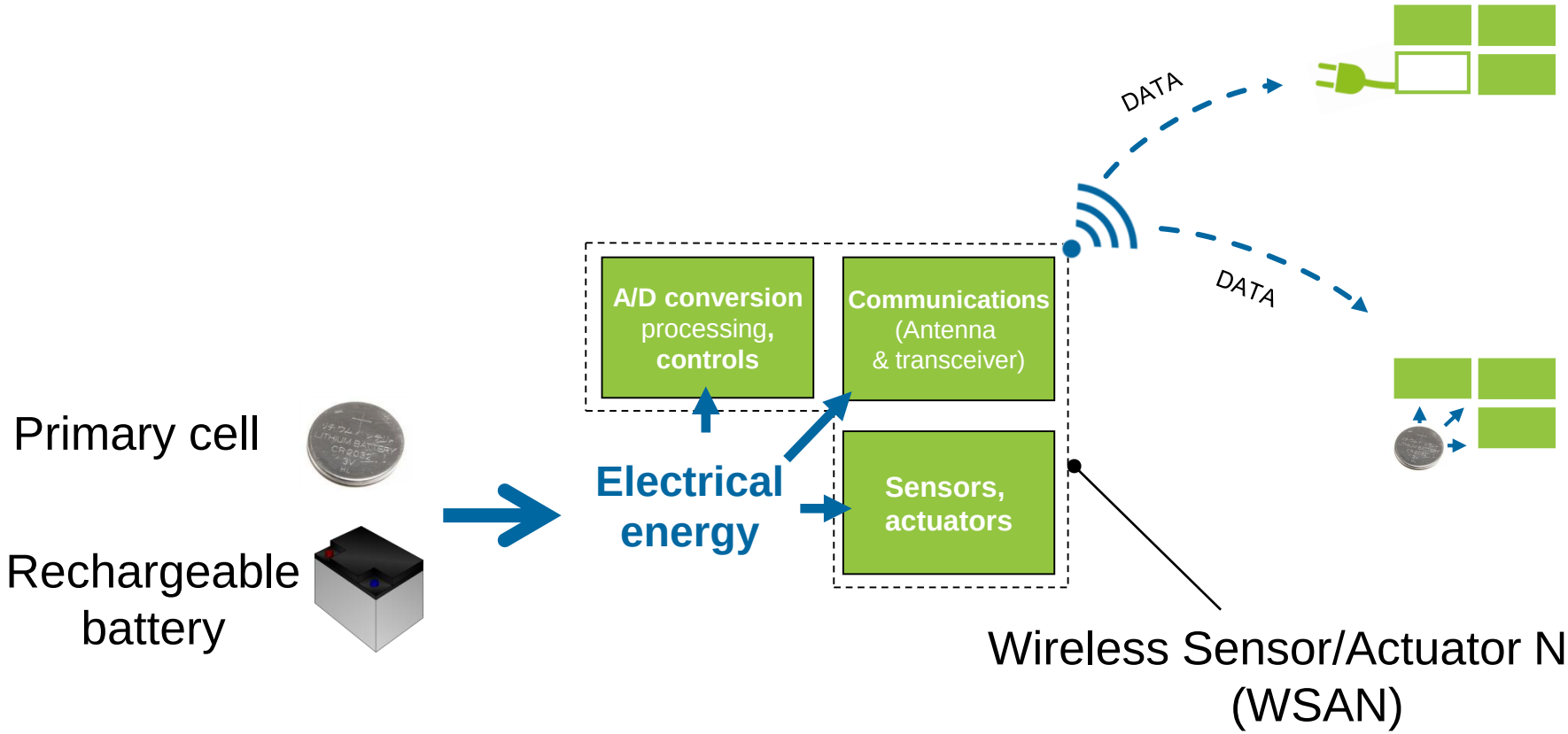
14 OCTOBRE 2014

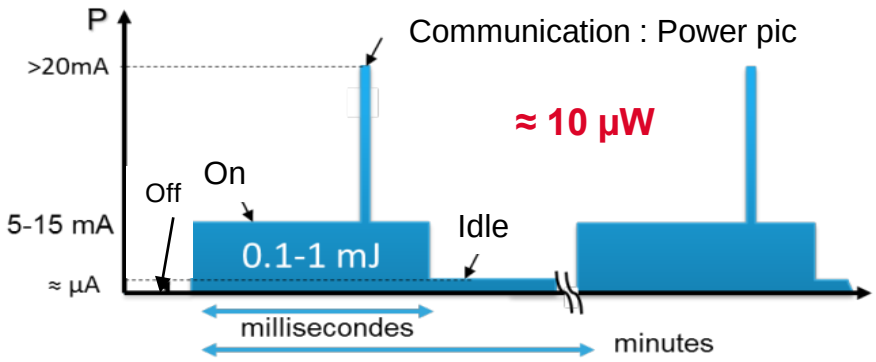
ENERGY HARVESTING

Main challenges :

Be more **dedicated**, more **efficient**, more **integrated**

ENERGY HARVESTING: WHAT IS IT?

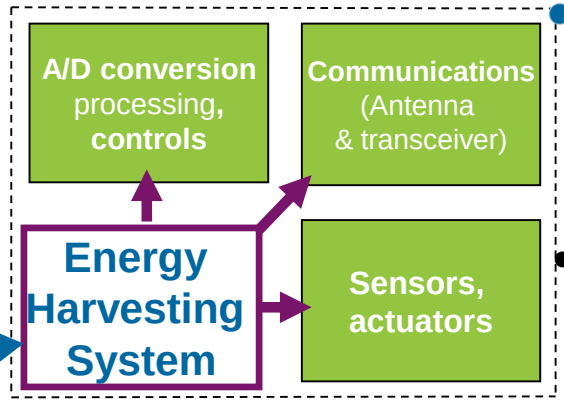


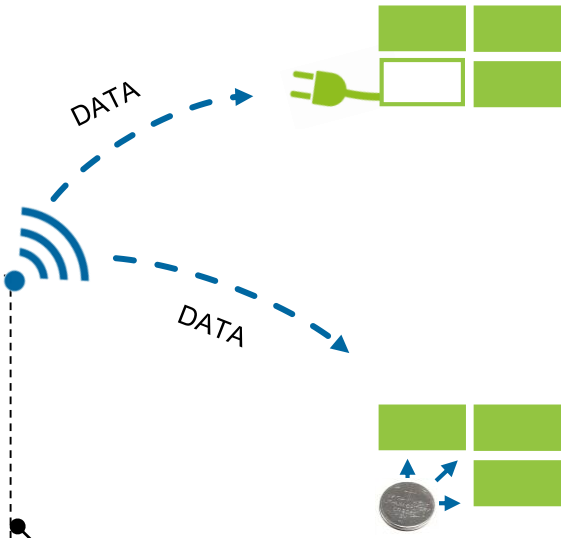


ENERGY HARVESTING: WHAT IS IT?

Energy source coming from the environment

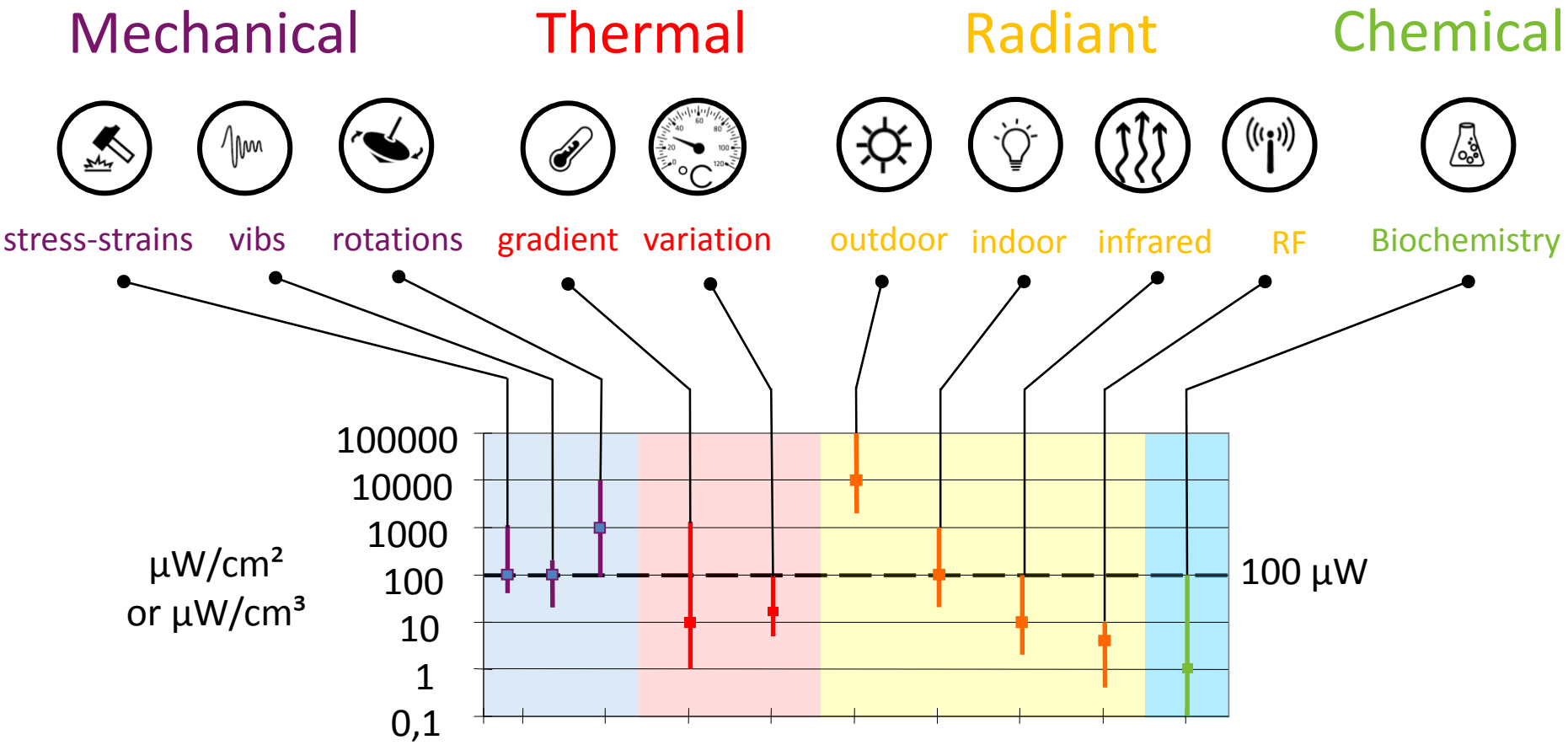
Autonomous





Wireless Sensor/Actuator Node (WSAN)

SUPPLY AND DEMAND : VARIOUS SOURCES, VARIOUS POWER RANGES



→ Light energy harvesting works well but…

what about dark or dusty environnements?

ENERGY HARVESTING: THE DREAM

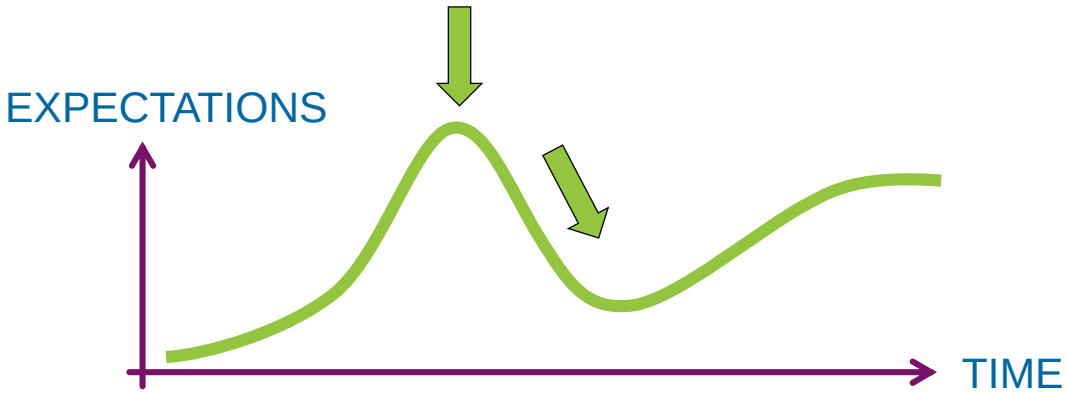
10 mW-100 mW

"Clothes can supply your GPS!"

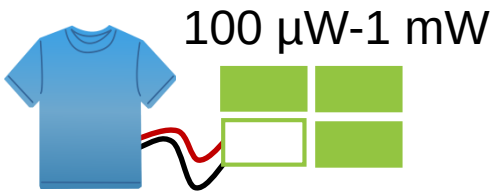
10 mW-100 mW

"Shoes can supply your iphone!"

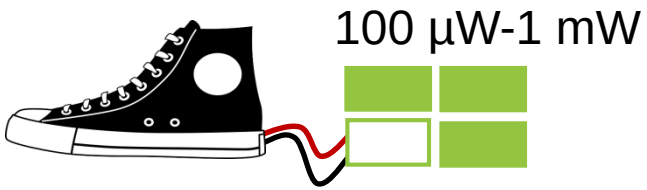
Technology hype cycle:



ENERGY HARVESTING: THE REALITY

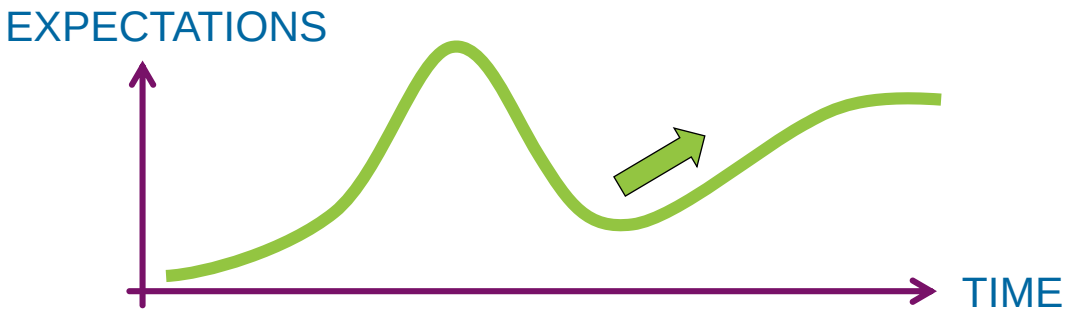


"Tee-shirts could power an optimized wireless cardio"



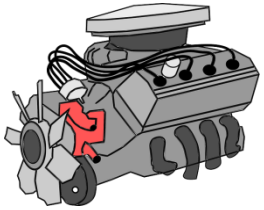
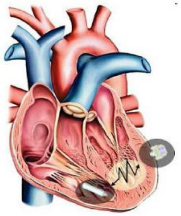
"Shoes could power optimized wireless force sensors"

Technology hype cycle:



ENERGY HARVESTING: THE UNAVOIDABLE

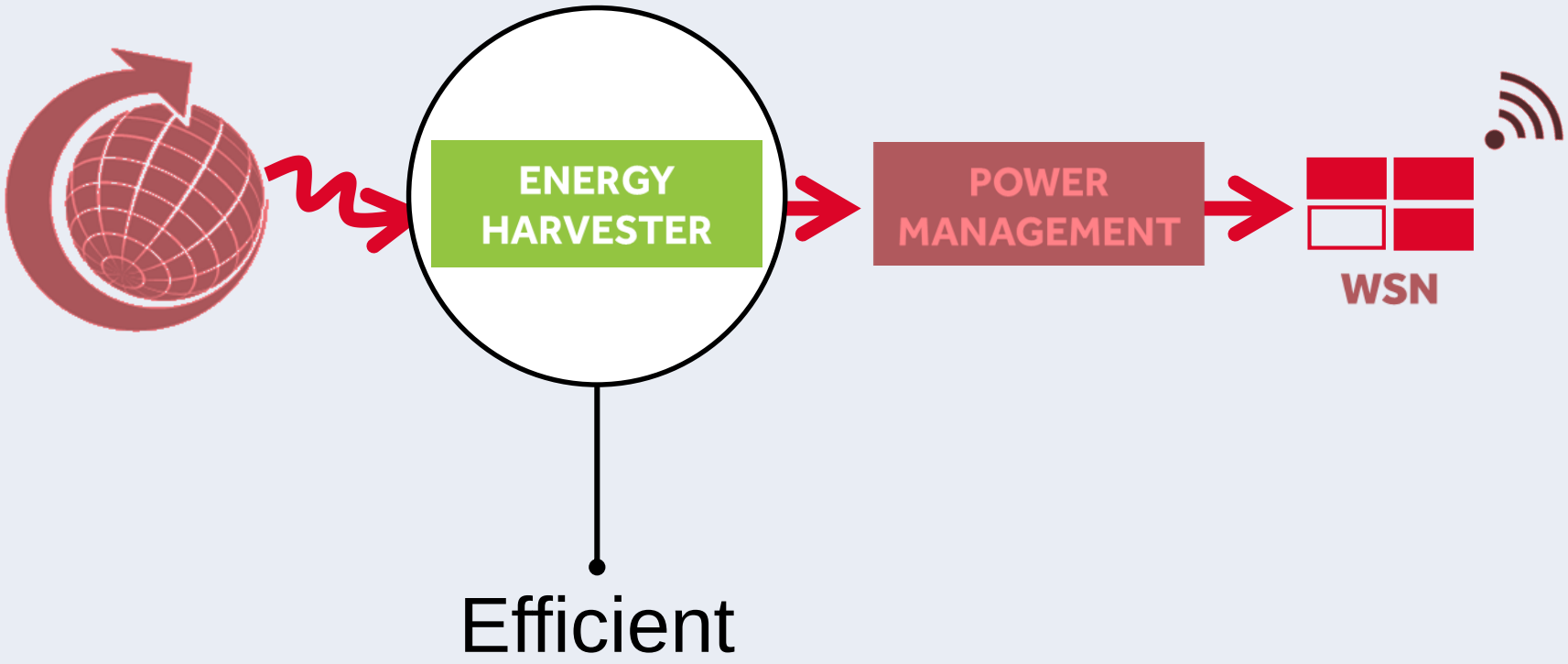
Vehicle health monitoring, Medical application…

Smart-Building, industrial maintenance…

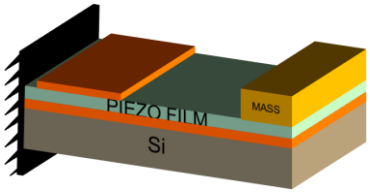

- harsh environments (high temperature…)
- location difficult to access
- many WSAN: changing the batteries is expensive
- long-life WSAN (>10-20 years)

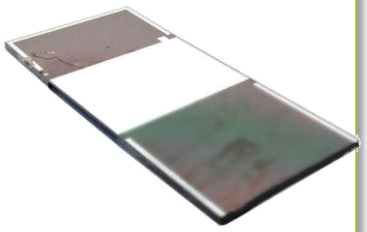
Need for dedicated application


ENERGY
HARVESTER
POWER
MANAGEMENT
WSN
Efficient

MECHANICAL GENERATOR

Efficient material: AlN thin film



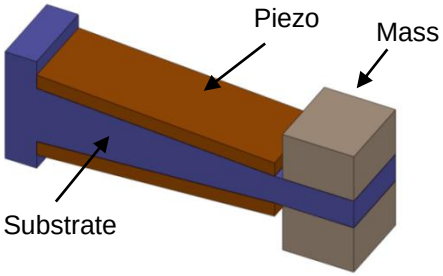


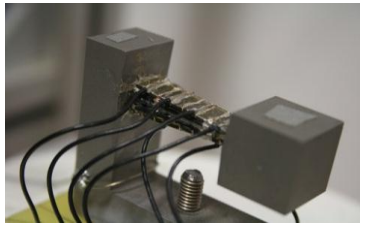
> 200 µW/cm³

1 mW reached on a 1x2.5 cm² device

Mech. vibrations	Power
0,07 G @155 Hz	28 µW
0,2 G @155 Hz	150 µW

Efficient piezoelectric structure





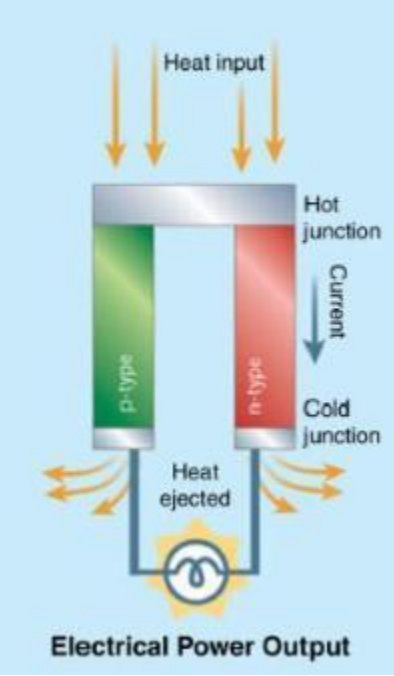
Improved cantilever shape

High coupling coefficient bulk materials (PZN-PT, PMN-PT)

Mech. vibrations	Power
0,1 G @280 Hz	450 µW

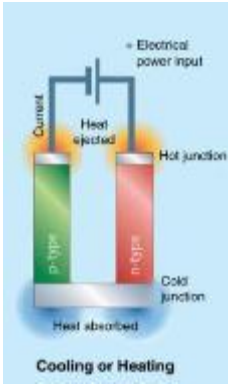
THERMOELECTRIC GENERATOR

Seebeck effect



A thermal gradient produces a voltage

Power generation
Heat flux sensors



Peltier effect

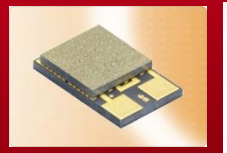
An electrical current induces a heating/cooling at the junctions

Thermal management

comparison of TEG technologies performances.

Technology	Power density	Typical output power	TRL	Life time
Human body TEG	0.1 kW	µW to mW	Low to fair	> 25 years
Hot surface TEG	1 kW/m³	mW to W	Fair to high	> 15 years
Combustion TEG	>1 kW/m³	W to kW	Fair to high	> 15 years

MICROTEG : SOA

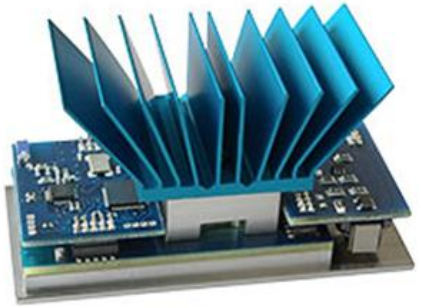


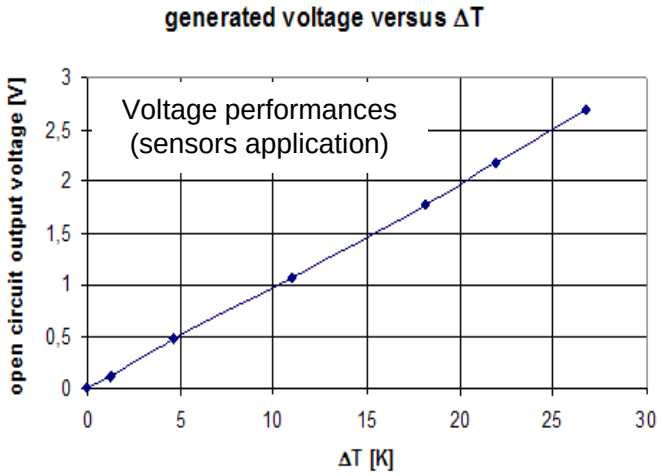
Nextreme THERMAL SOLUTIONS

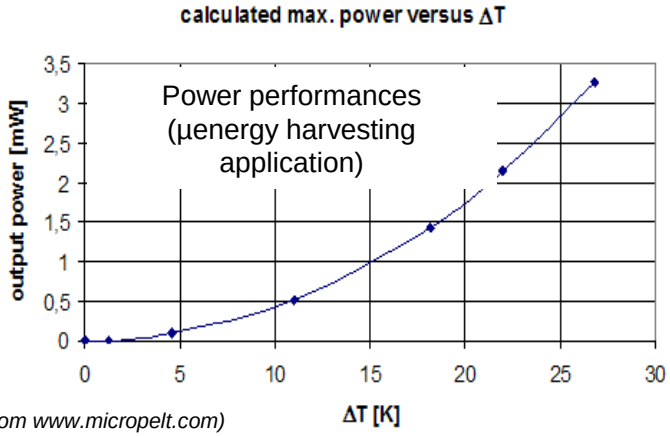
Laird

micropelt Thin Film Thermoelectrics

Bi_2Te_3 TF Technology (Sputtering)







(data from www.micropelt.com)

Micropelt thermoelectric generators				
Device	Foot print x y Total thickness	Electrical resistance at 23 °C Thermal resistance at 85 °C	Net Seebeck Voltage at 23 °C	Features
» MPG-D651 (PDF 1122 KB)	3375 µm 2500 µm 1090 µm	185 Ω 22 K/W	75 mV/K	High output voltage per degree ΔT Very fast response time Ideal for energy harvesting and heat energy sensing
» MPG-D751 (PDF 1122 KB)	4248 µm 3364 µm 1090 µm	300 Ω 12.5 K/W	140 mV/K	High output voltage per degree ΔT Very fast response time Ideal for energy harvesting and heat energy sensing

→ Sensors

→ Wireless communication

MICROTEG : SOA

Bi_2Te_3 TF Technology (Electrochemistry)

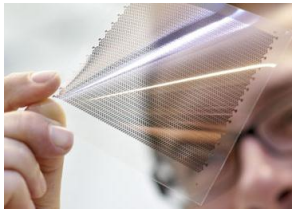


Table 2 — gTEG® Performance in different energy harvesting environments

Open Loop Performance	gTEG®A (Power [µW] / Voltage [mV])	gTEG®B (Power [µW] / Voltage [mV])	gTEG®C (Power [µW] / Voltage [mV])
Body Heat [2]	3.3 / 69 [1]	2.8 / 49	1.4 / 11
Building / Heating [3]	154 / 467	178 / 388 [1]	170 / 116
Industrial / Process [4]	2'180 / 1'755	3'267 / 1'664	12'030 / 2'057 [1]

1 *Best design for this energy harvesting environment*

2 Temperature difference between the body and ambient temperature ΔT = 7°C

3 Temperature difference between hot surface (e.g. radiator) and ambient temperature ΔT = 37°C

Design Examples	gTEG®A	gTEG®B	gTEG®C
Dimensions [mm x mm]	7.1 x 7.1	7.1 x 7.1	15 x 15
Thickness [mm]	1.05	0.63	0.21
Thermal Resistance [K/W]	42	26	2
Electrical Resistance [Ω] at 25° C	353	212	92
Net Seebeck Voltage [mV/K]	24.1	23.5	56.1

(data from http://www.greenteg.com/)

MICROTEG : SOA

Printed technology

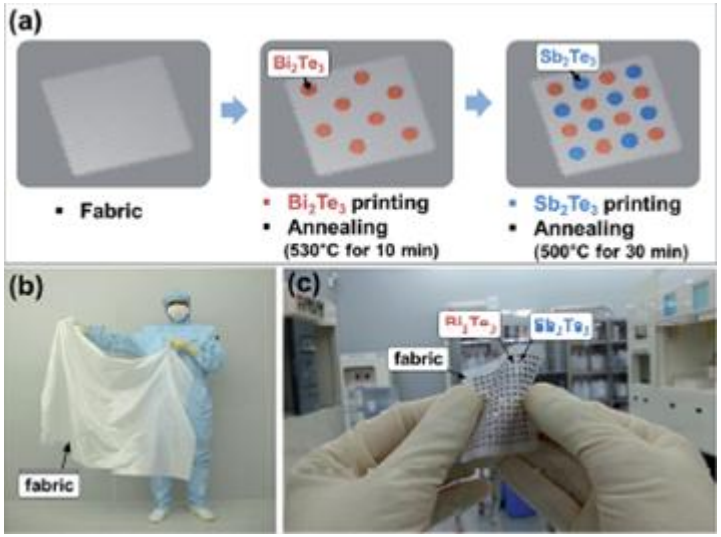


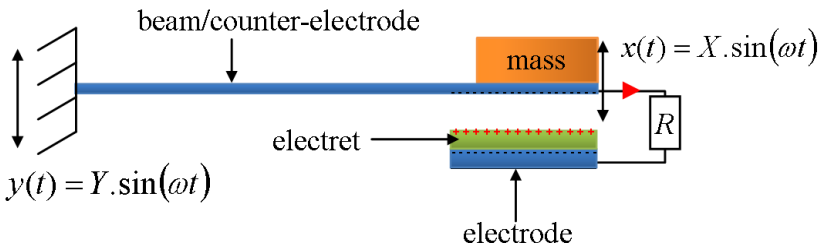
Fig. 6 Demonstration of band-type flexible TE generator for harvesting thermal energy from human skin: (a) photos of band-type flexible TE generator and (b) electricity generation measured on human skin at an air temperature of 15 °C. Scale bar, 1 cm.

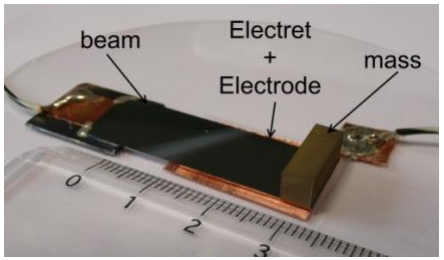
- 3.8 mW.cm^{-2} pour ΔT = 50 K (15 mm x 20 mm x 0.5 mm, 0.13 g.cm^{-2}, 8 jcts (Φ_{plots} = 1.8 mm))
- flexible device 11 jcts, 3 µW (T° air 15 °C)

S. J. Kim et al., Energy Environ. Sci. 7, (2014)

ENERGY HARVESTERS: EFFICIENT STRUCTURES

Electret-based harvesters



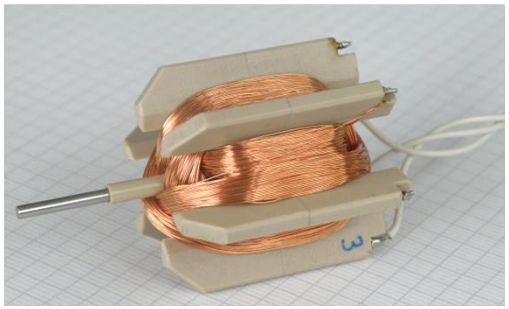


Simple out-of-plane harvester

Low-cost device

Mech. vibrations	Power
0,1G @50Hz (*M*=5g)	50µW

High efficiency alternator



- 30 cm^3 , 60 g / 0,1 – 100 W
- Triphased, "cocon" windings
- No polar part
- Powerfull magnet (NdFeB)
- 1,5 mW / cm^3 @ 350 rpm

Mech. Input power	Efficiency
0,5 - 2 W	90%

ENERGY HARVESTERS: APPLICATIONS

The enerbee concept

Moving magnet + **magnetostrictive** + **piezoelectric** materials

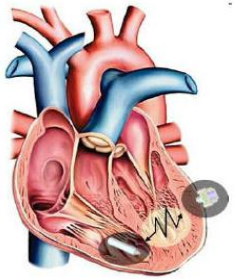
Time independent → from **1 turn /hour** up to **several krpm** (tested @ 3000 rpm)

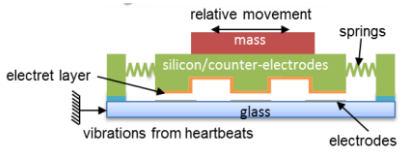
Rotation & translation, short & large movement

conditions	Power
1 turn / s →	1mW
100 turns / s →	100mW

HBS project : SORIN GROUP

Towards an autonomous pacemaker



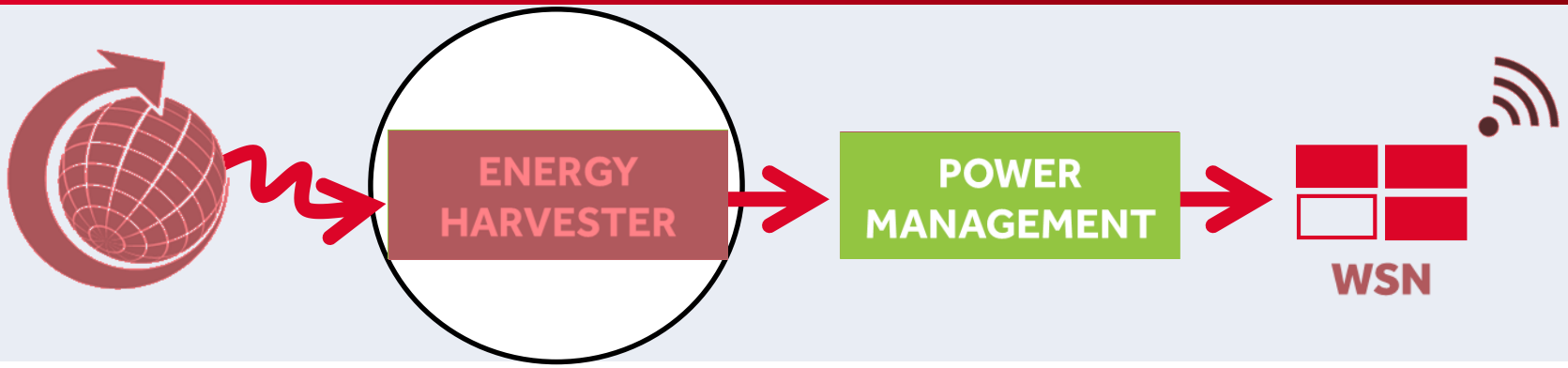


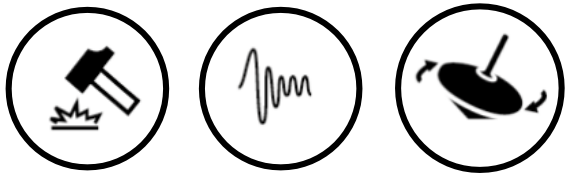
Electret-based harvester

size : **1 cm³**

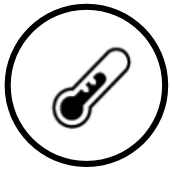
conditions	Power
targeted @ 10 Hz	10µW

POWER MANAGEMENT: WHAT'S THE USE?

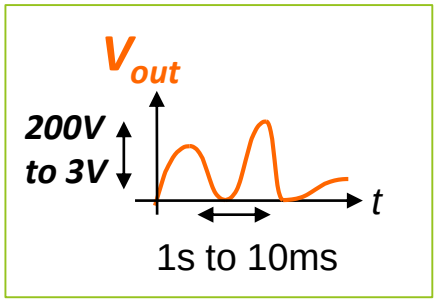


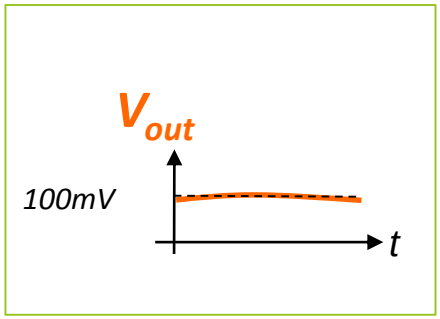


Mechanical energy

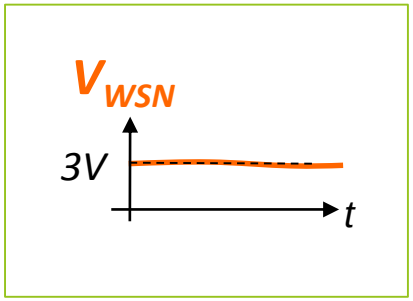


Thermal energy

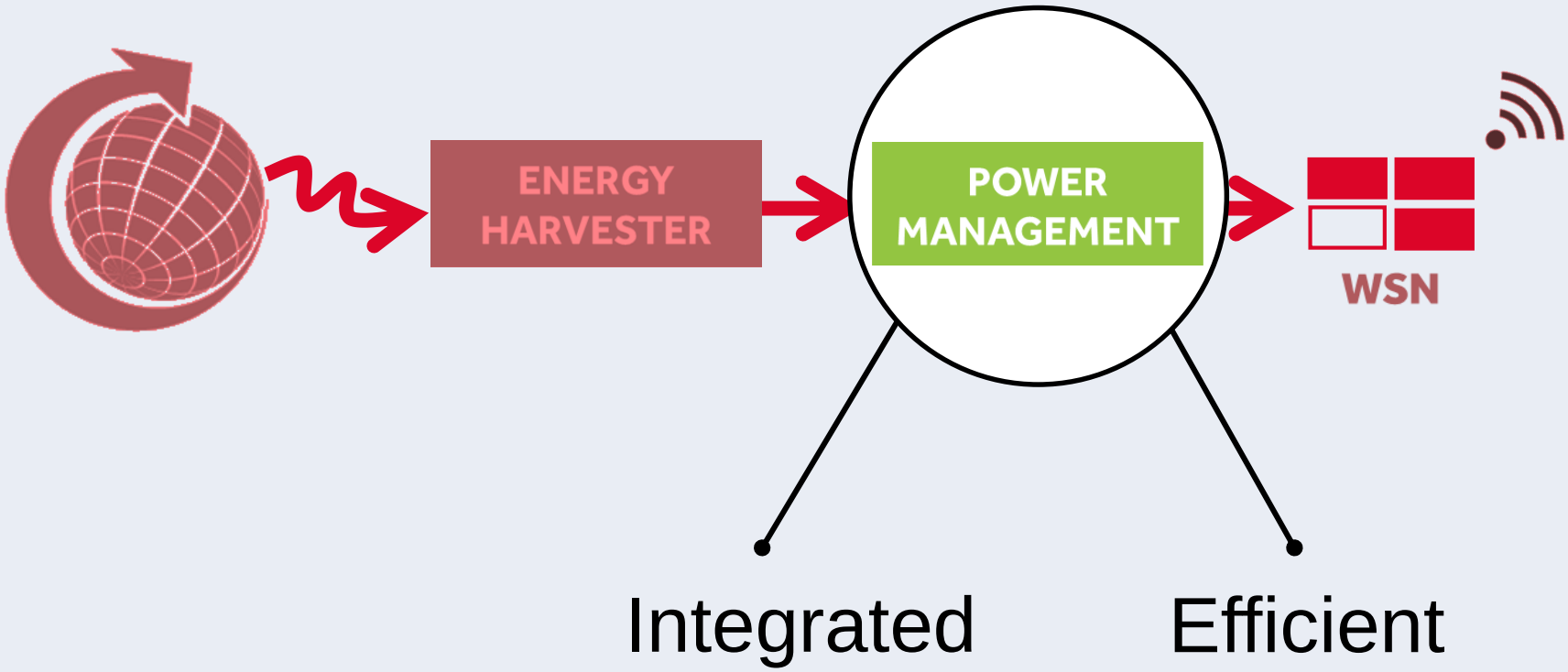




Step down!

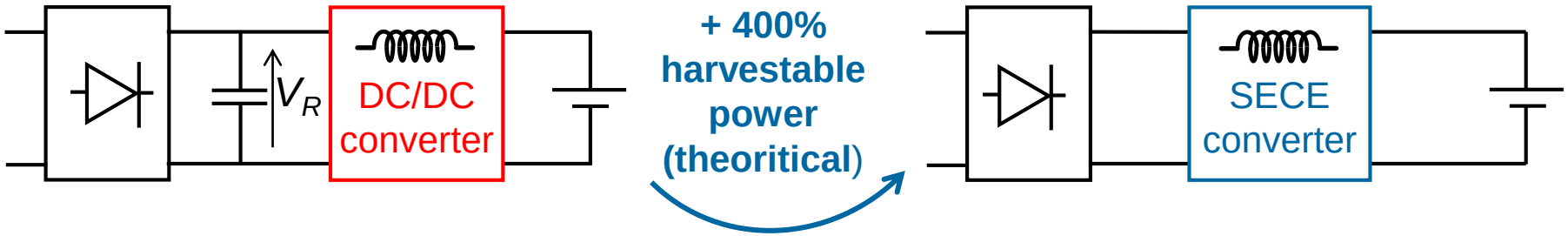


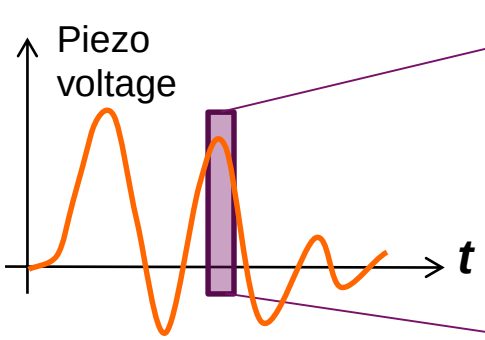
Step up!

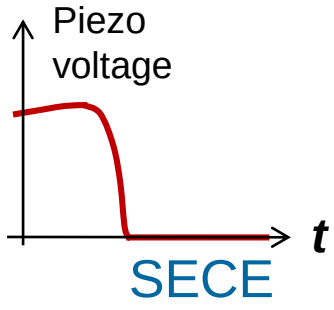

ENERGY HARVESTER
POWER MANAGEMENT
WSN
Integrated
Efficient

POWER MANAGEMENT FOR MECHANICAL ENERGY HARVESTERS

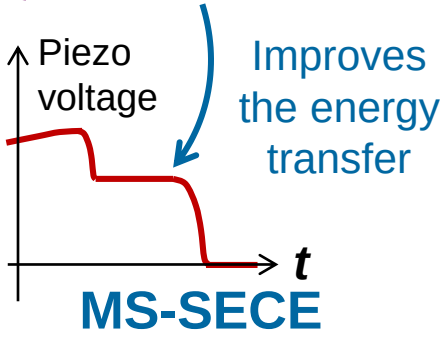
Choice of an **efficient** extraction technique







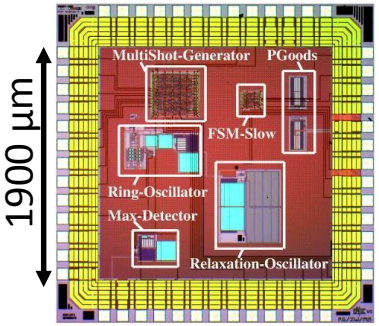
… doing the extraction even more **efficiently**…

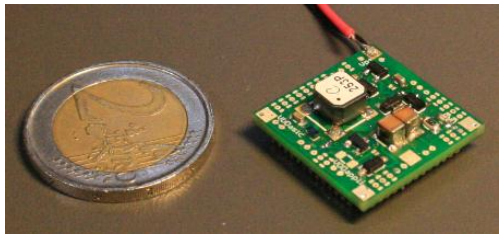


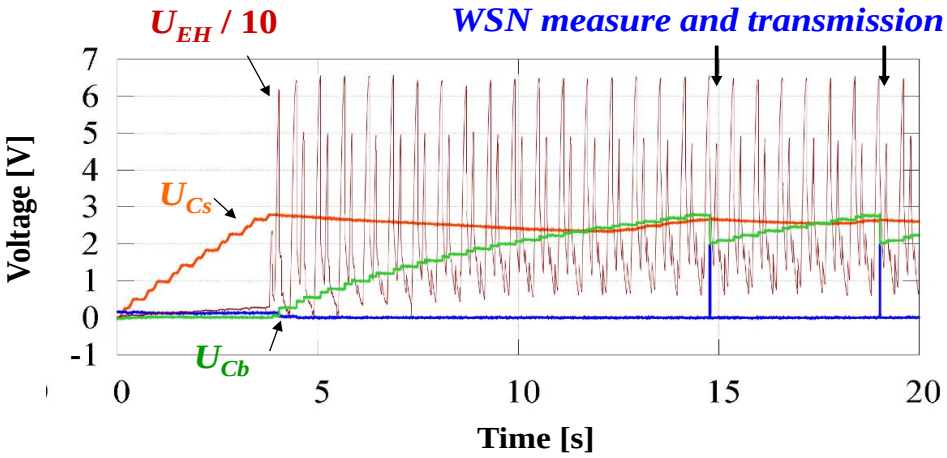
→ **MS-SECE technique** improves SECE

POWER MANAGEMENT FOR MECHANICAL ENERGY HARVESTERS

ASIC implemented in AMS 0,35 µm technology





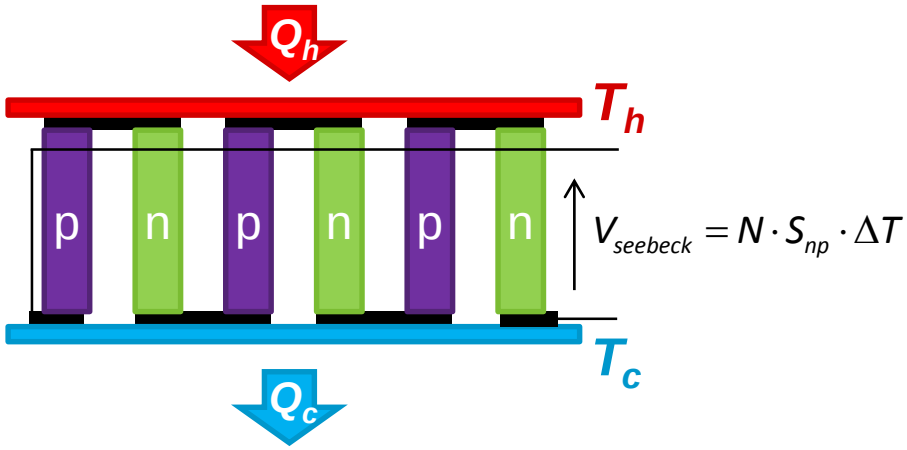


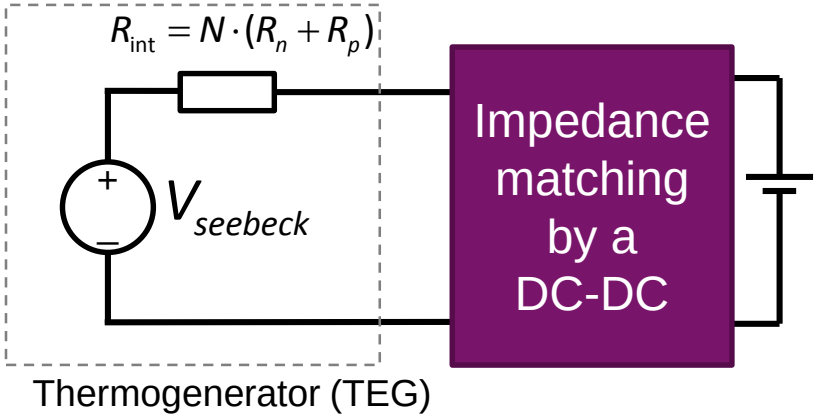
- IC's Features :
  - Power consumption: 1 µW @ 5 Hz and 5 µW @ 100 Hz
  - Low voltage technology (3,3 V)
- System's feature
  - MS-SECE ↗ overall efficiency from +15% to +25% compared to SECE
  - Battery-less (capacitor powered)

Conditions	Results
10 - 500µW with a < **1 cm³** power mngt circuit	Global efficiency = **61%**

POWER MANAGEMENT FOR THERMOELECTRIC GENERATORS (TEG)

TEG: principle





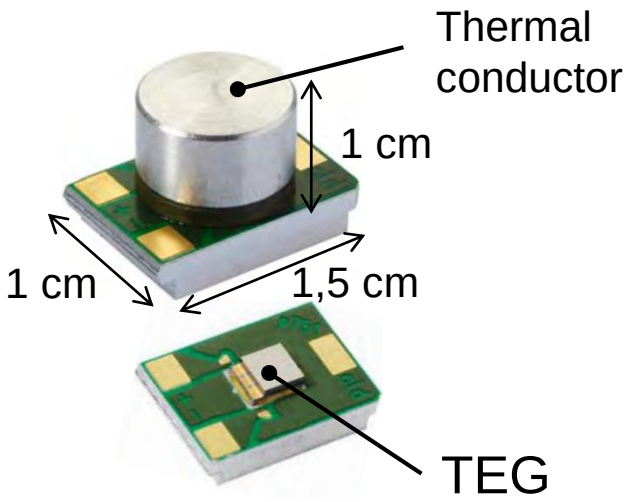
Selected TEG:

540 junctions of thermoelectic elements

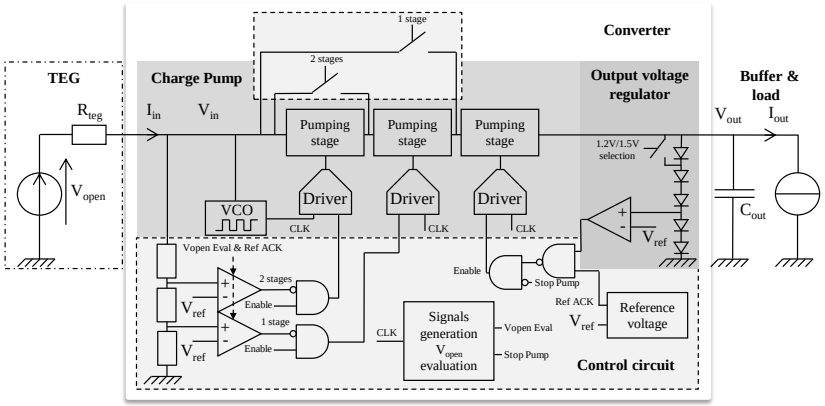
S = 140 mV/°C

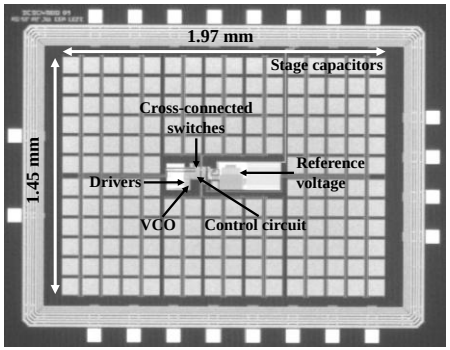
R_{TEG} = 300 Ω

For ΔT=3 K, V_{open}= 420mV



POWER MANAGEMENT FOR THERMOELECTRIC GENERATORS (TEG)





Techno UMC 180 nm

Fully integrated DC/DC converter

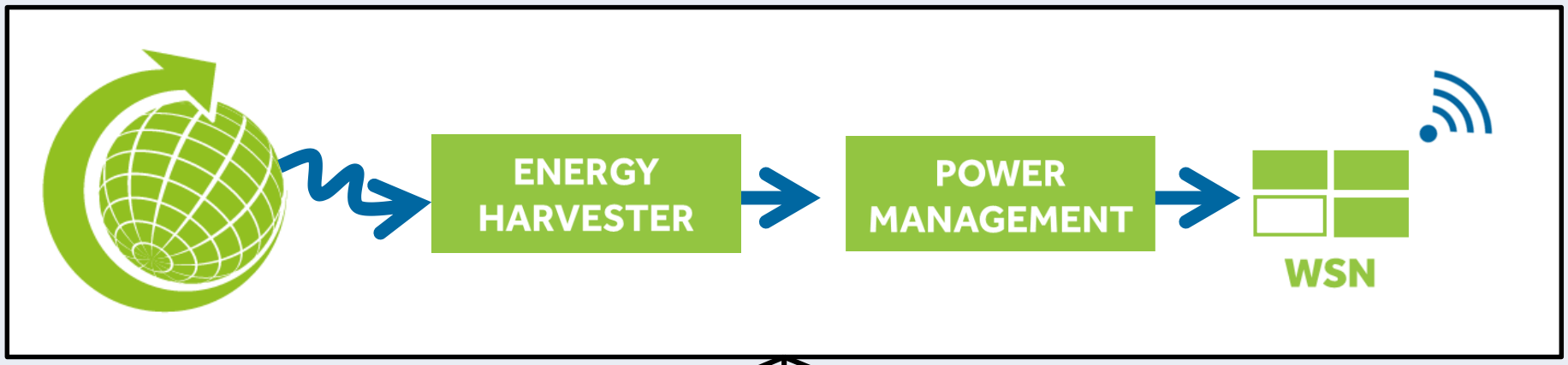
- Charge pump based

Features

- Regulated output
- Low self-start voltage (>VTEG = 250 mV)
- ΔT = [3°C to 12°C] and Pin = [10 µW to 1,6 mW]

Conditions	Results
ΔT=10°C (Pout=1,3 mW)	DC/DC efficiency = **80%** Global efficiency = **77%**

CONCLUSION



Dedicated

Energy harvesting today is for dedicated applications

→ what about tomorrow?

Efficient

- … materials
- … structures
- … power mngt circuits
- … extraction techniques

Integrated

- … technologies reduce cost and size
- and battery-less architecture

DE LA RECHERCHE À L'INDUSTRIE

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Thank you