

# Industry Session 5: Energy Harvesting



## *IoT sensors powered by solid state batteries and harvested energy*

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Tuesday, March 6, 2018

# OVERVIEW

1. Introduction to Ilika
2. Challenges for Powering IoT Sensors
3. Energy Solutions
4. Charging Solutions and Energy Harvesting
5. Integration

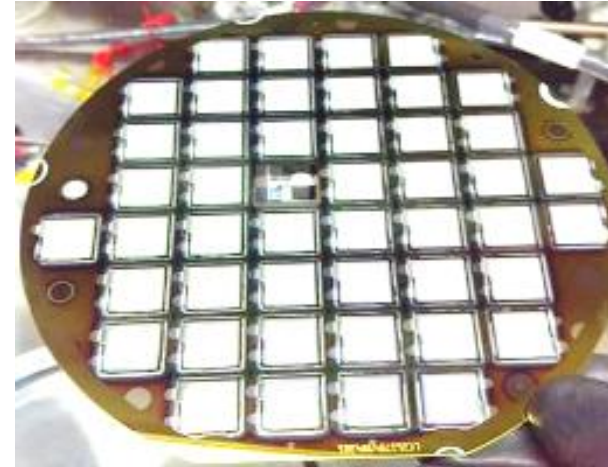
# 1 – Introduction to Ilika

# Introduction to Ilika

Ilika's unique ability to rapidly discover new materials for the energy and electronics sectors



Innovation in Solid State Batteries used in many applications



Medical  
Internet of Things  
Harsh Environments



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# 2 - Challenges for Powering IoT Sensors

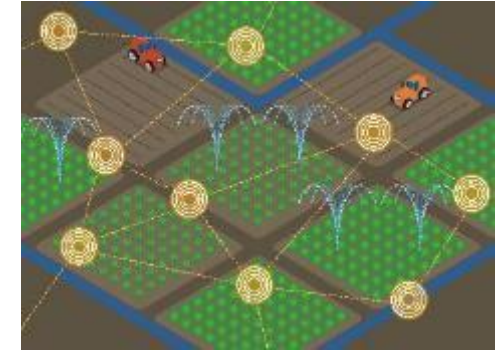
# Challenges for powering IoT sensors

- ▲ Small-size unobtrusive, “invisible”, beacons for hard-to-reach places.
- ▲ Long life
- ▲ Reliability
- ▲ Safety, biocompatibility
- ▲ Low self-discharge for extended storage
- ▲ Changing batteries adds to Total Cost of Ownership

## ▲ Industrial



## ▲ Agriculture



## ▲ Transportation



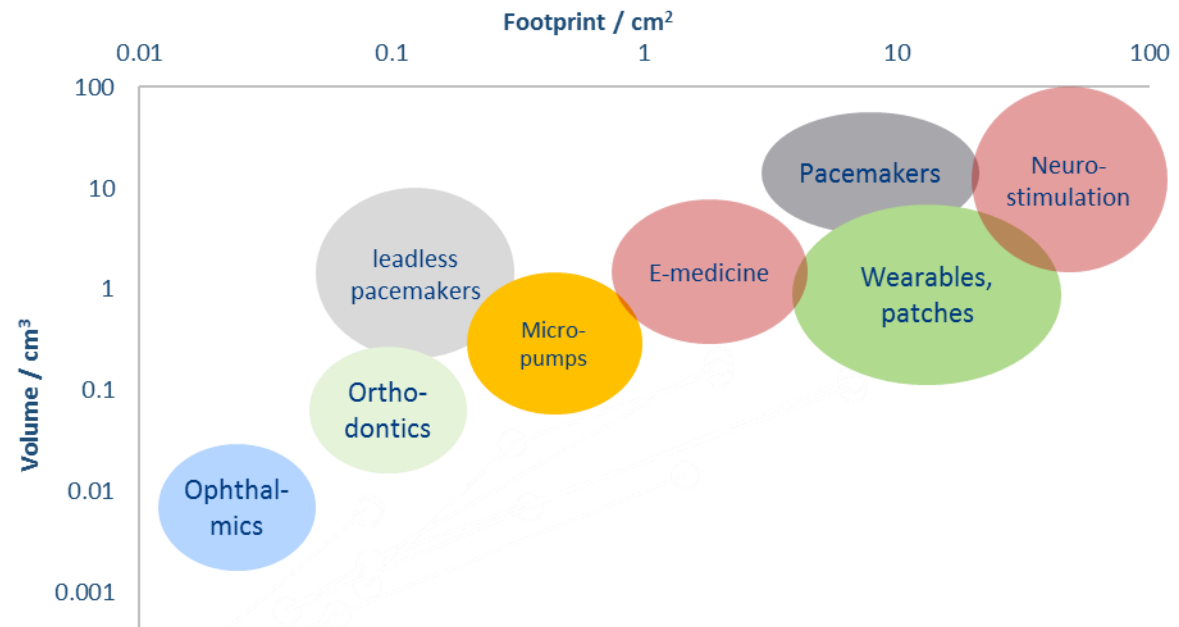
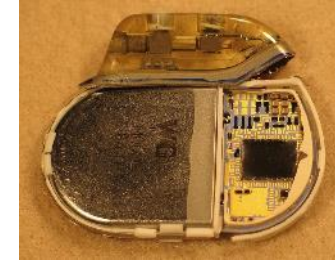
## ▲ Medical



▲ Let's discuss these challenges in relation to use cases

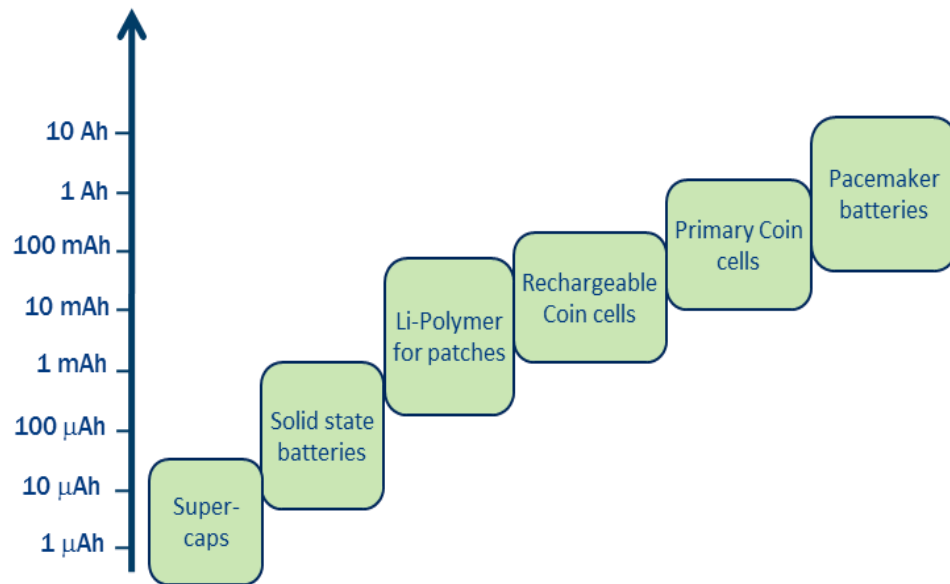
# Specific challenges: Size and form factor

- ▲ Trends towards miniaturisation
- ▲ Unobtrusive devices
- ▲ Device shape & size dominated by battery, or custom solutions



# Specific challenges: Energy

- ▲ Depends on use & available charging source or harvested energy
- ▲ “Accumulated Energy” = Capacity for one cycle x number of cycles



## Primary

- Large size
- Higher cost
- + Large capacity
- + No need for charging



## Secondary

- + Small size (<math>< \text{cm}^3</math>)
- + Lower cost
- Lower capacity
- Need charging or EH

# Specific challenges: Operational life

## ▲ Use case: disposable sensing device

- ▲ Example: lenses, patches
- ▲ Requirements for few days or weeks
- ▲ Or single discharge

Small primary coin ~mAh

Small SSB ~mAh



## ▲ Use case: medical implantable

- ▲ Cost of deplantation
- ▲ Risk of complications, infection or death
- ▲ Life to 15 years and beyond desired
- ▲ Typical power consumption ~ 5-10mW

Large primary  
~Ah

Small secondary +EH  
~mAh 5-10,000 cycles



Study 2017: device  
explantation and  
subsequent re-  
implantation after  
infection clearance was  
USD 75,505<sup>1</sup>

# Specific challenges: Storage

## ▲ Buffer devices lose energy via leakage current

### ▲ In-between intermittent current supply from EH



Indoors :  $20\mu\text{W}/\text{cm}^2$  → SSB: 99.9% efficiency



### ▲ During unused periods in storage



6 months in storage → SSB: lose only  $5\mu\text{Ah}$

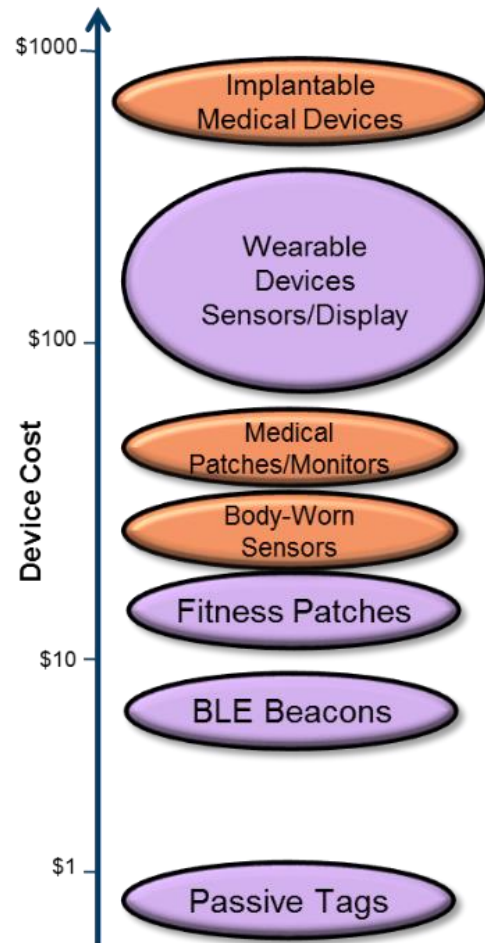
## ▲ Other leakage current contribution:

- ▲ *Communications*
- ▲ *Sensors*
- ▲ *MCU sleep mode*
- ▲ *PMIC*

Leakage current level	Yearly loss	
1nA	10 $\mu\text{Ah}$	← Solid state batteries
10nA	100 $\mu\text{Ah}$	← Pulse caps
100nA	1mAh	← PMIC
1 $\mu\text{A}$	10mAh	← Supercaps, coin cells

# Specific challenges: Cost

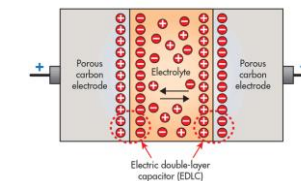
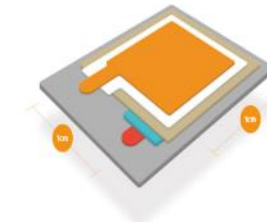
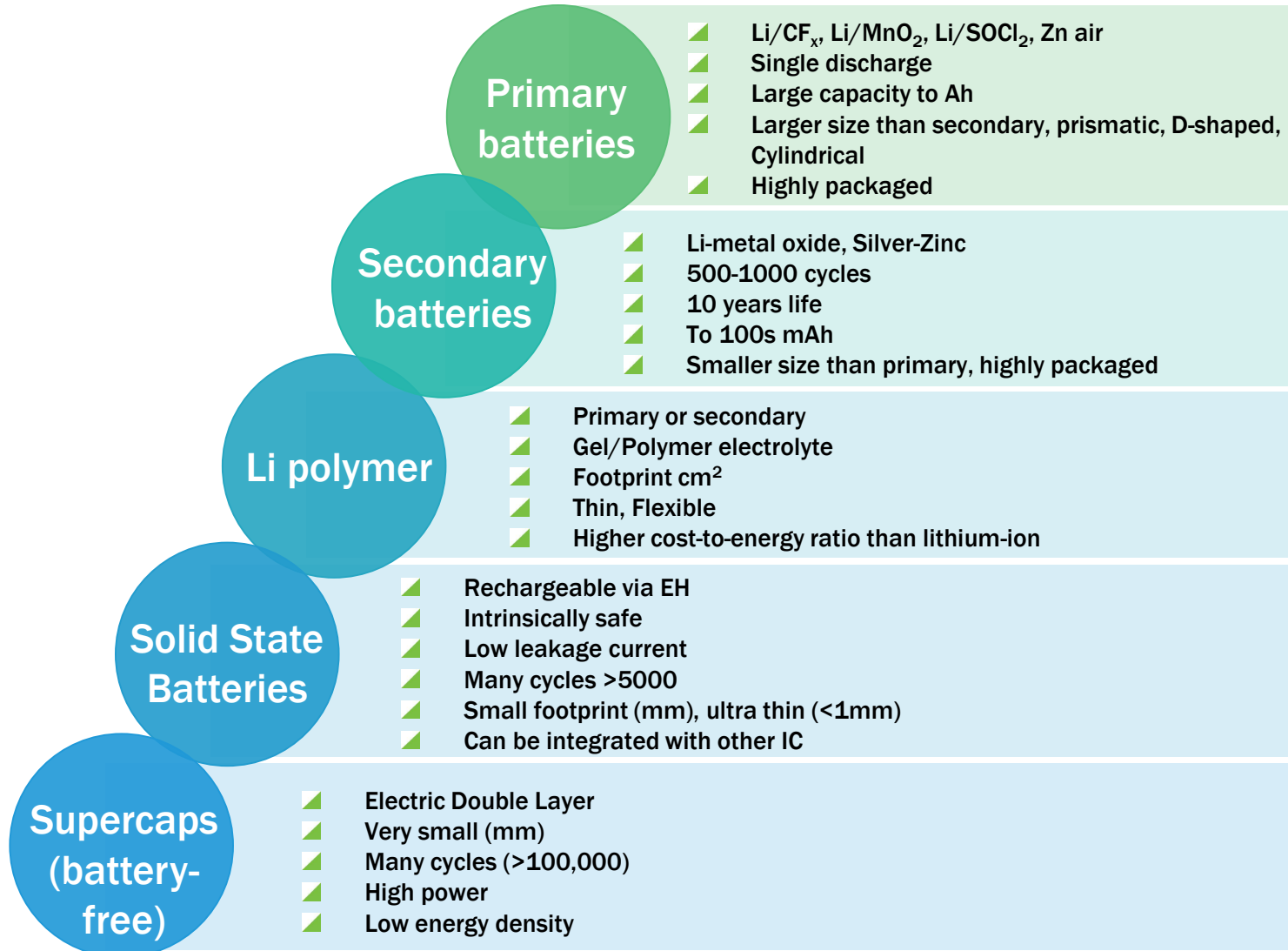
▲ Cost of energy buffer needs to reflect cost of device



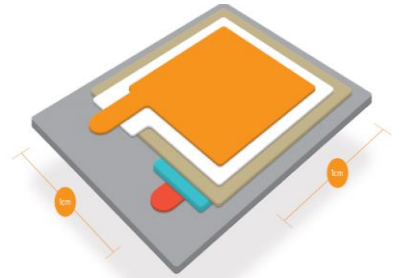
	Typical cost \$
Caps	0.1
Solid state battery	0.2 - 10.0
Coin cells	0.2
External patch battery	0.5
Pace maker battery	40
Cylindrical medical implant battery	150 - 200

# 3 - Energy Solutions

# Energy solutions: Energy storage devices



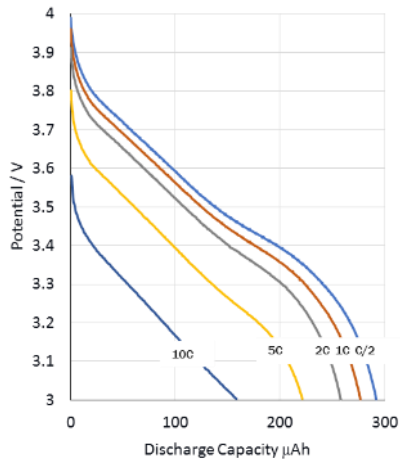
# Stereax<sup>®</sup> M250: Micro-battery for IoT applications



Parameter	Value
Capacity	250 $\mu$ Ah
Operational voltage range	3.0 – 4.0 V
Operational temperature range	-20°C to +100°C
Continuous current	250 $\mu$ A

Parameter	Value
Peak current	5 mA
Dimensions	12 mm x 12 mm (Note 1)
Battery Thickness	10 $\mu$ m (Note 2) + encapsulation
Cycle life (10% DoD)	5,000 cycles (to 80% of initial capacity)

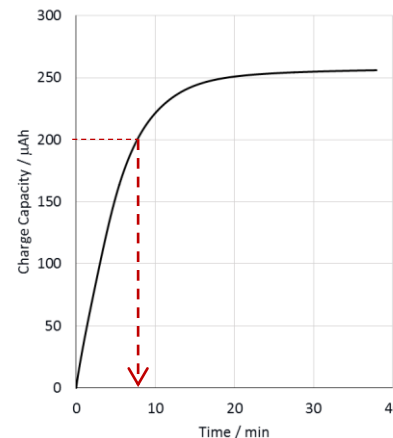
## High rate capability



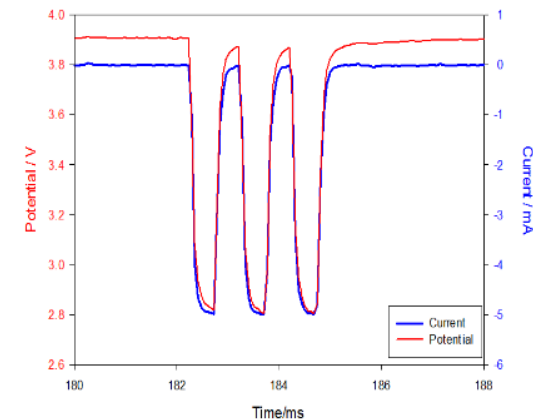
Note 1: Active footprint

Note 2: Battery deposited on substrate (currently 650  $\mu$ m); Thinner substrates in testing (100  $\mu$ m); encapsulation 60  $\mu$ m

## 80% charge achieved in 8 min



## Appropriate for Bluetooth LE transmission



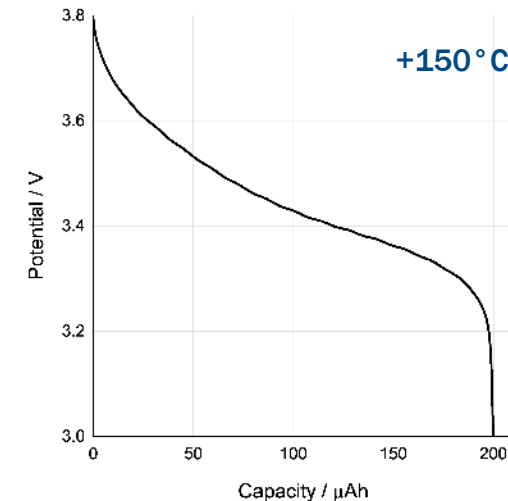
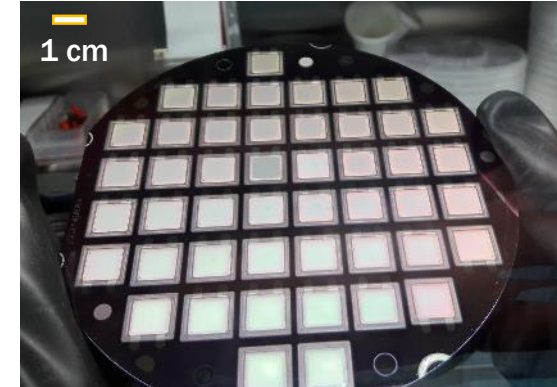
# Stereax<sup>®</sup> P180:

## Extended temperature range solid state battery

▲ Operate between -40 °C and +150 °C

Parameter	Values at +150°C
Capacity	180 μAh
Operational voltage Range	3.0 – 3.8 V
Continuous Current	1.8 mA
Peak Current	3.6 mA
Dimensions	10 mm x 10 mm (Note 1)
Battery Thickness	~1 mm
Cycle Life (5% DoD, to 80% of initial capacity)	4000 cycles
Internal Resistance	15 Ω

Note 1  
Active footprint



# Energy storage comparison

	Conventional Li-ion	Supercapacitors	Solid State Batteries
Trickle-charging/ Low Leakage			
5,000 cycles+			
Ultra-compact			
Safety Profile			
Capacity			
Power			
Biocompatible			

# 4 - Charging Solutions and Energy Harvesting

# Charging solutions: **wireless**

## ▲ Requirements:

- ▲ *Safe to the body*
- ▲ *Fast enough charging time to reduce inconvenience*
- ▲ *High transmitted power*
- ▲ *Size of receiver / coil should be small*

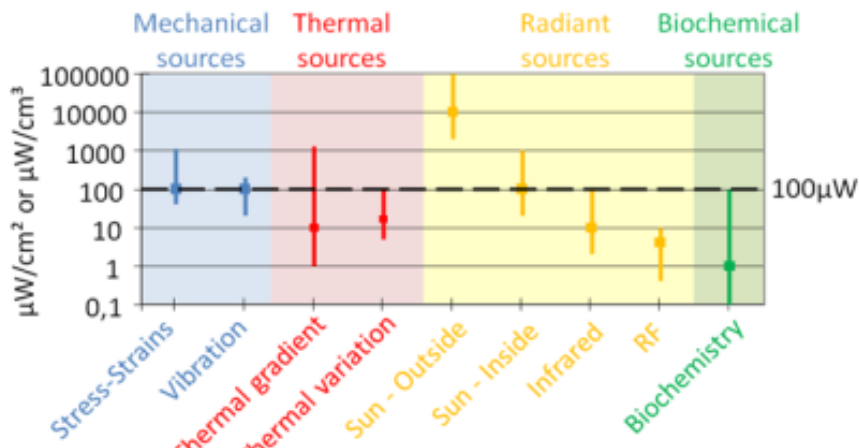
## ▲ Magnetic resonance charging



## ▲ RF Energy harvesting: Drayson Technologies

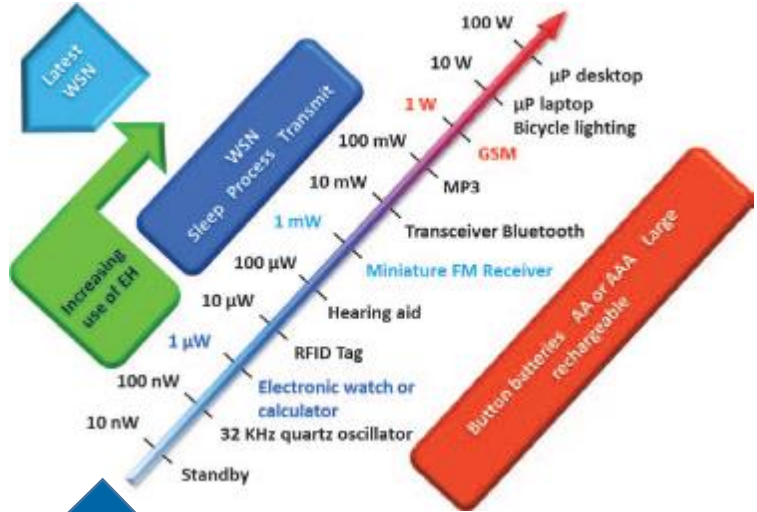
# Perpetual Beacons

## Efficient energy harvesters



Source: Ref 2

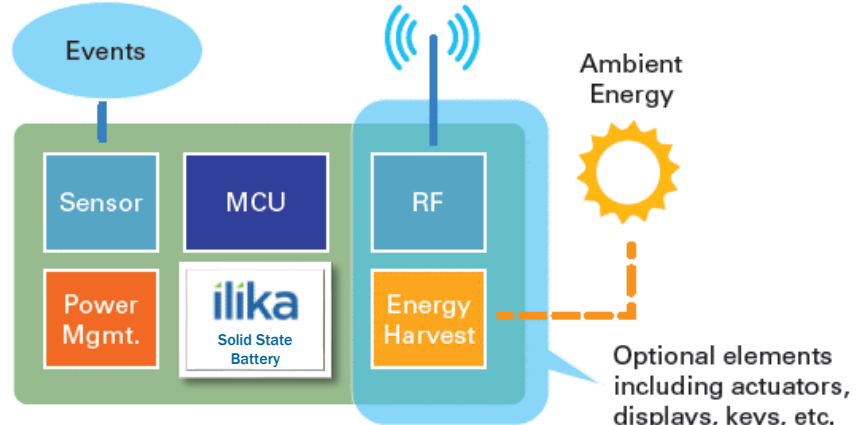
## Ultra low power electronics, e.g. ARM Cortex



Source: Ref 3

## Micro-Batteries enable true "Leave for Life"

Source: Ref 4

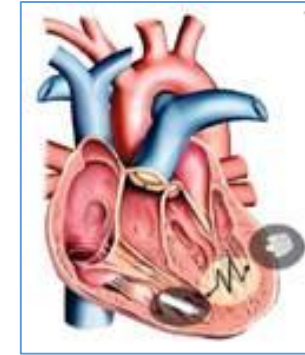


# Charging solutions: energy harvesting

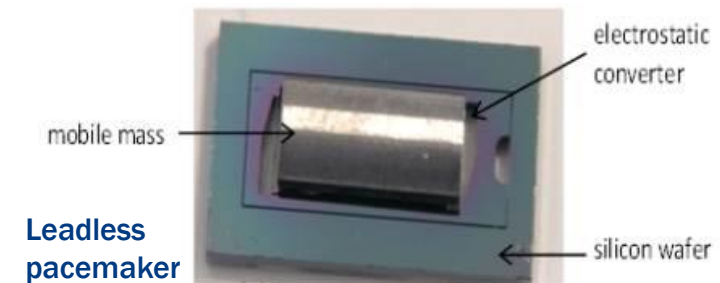
## ▲ Battery-less

### ▲ Cardiac pacemakers powered by piezoelectric energy harvested from heartbeat

- ▲ *CEA-LETI*
- ▲ *Target: Down to 1 cm<sup>3</sup>*
- ▲ *Output power : 10 μW*
- ▲ *Frequency: 1 – 3 Hz*



Source: Ref 5

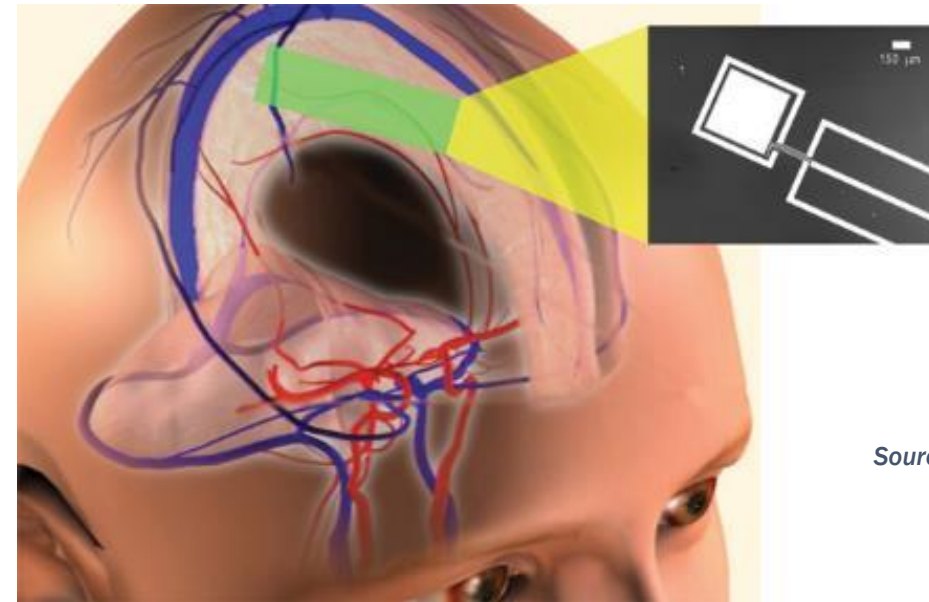


# Charging solutions: energy harvesting

## ▲ Biological batteries

- ▲ MIT: glucose fuel-cell to power neural implants. Fuel cell operates by stripping electrons from glucose molecules to create a small electric current:

- ▲ *Brain implants with spinal cord injuries or strokes*
- ▲ *Pain control (Parkinson's disease)*
- ▲ *1 - 2mm<sup>2</sup>*
- ▲ *180uW/cm<sup>2</sup> peak*
- ▲ *3.4uW/cm<sup>2</sup> steady state*



Source: Ref 6

# Charging solutions: energy harvesting

## ▲ Thermo-electric “Body Pump”

- ▲ Miniature thermoelectric generators (TEGs)
- ▲ Produce energy from the temperature differential between the skin and the outside air – Seebeck effect.
- ▲ **Nextreme Thermal Solutions (Now Laird)\***  
The HV56 is capable of producing 1.5mW of output power and an open circuit voltage of 0.25V at a 10K gradient in a footprint of only 11mm<sup>2</sup>



Source: Ref 7

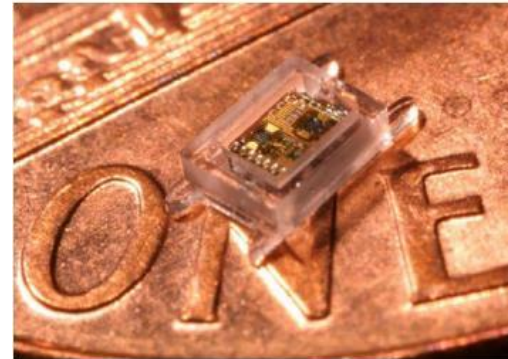
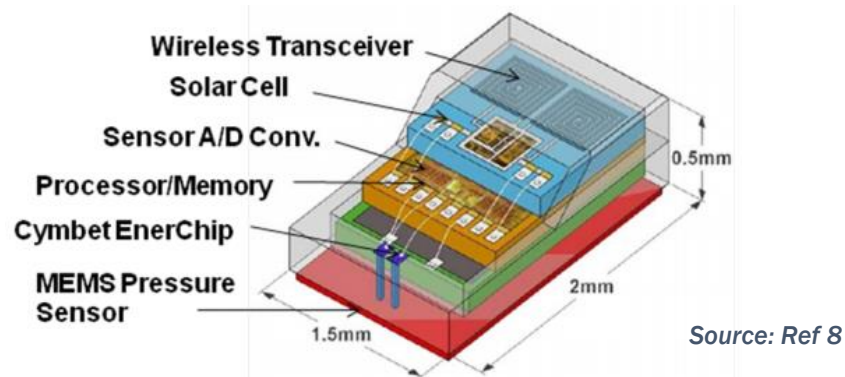
# Charging solutions: energy harvesting

## ▲ Solar energy

### ▲ Cymbet

▲ Non-Cytotoxic Rechargeable Batteries for Medical Devices.

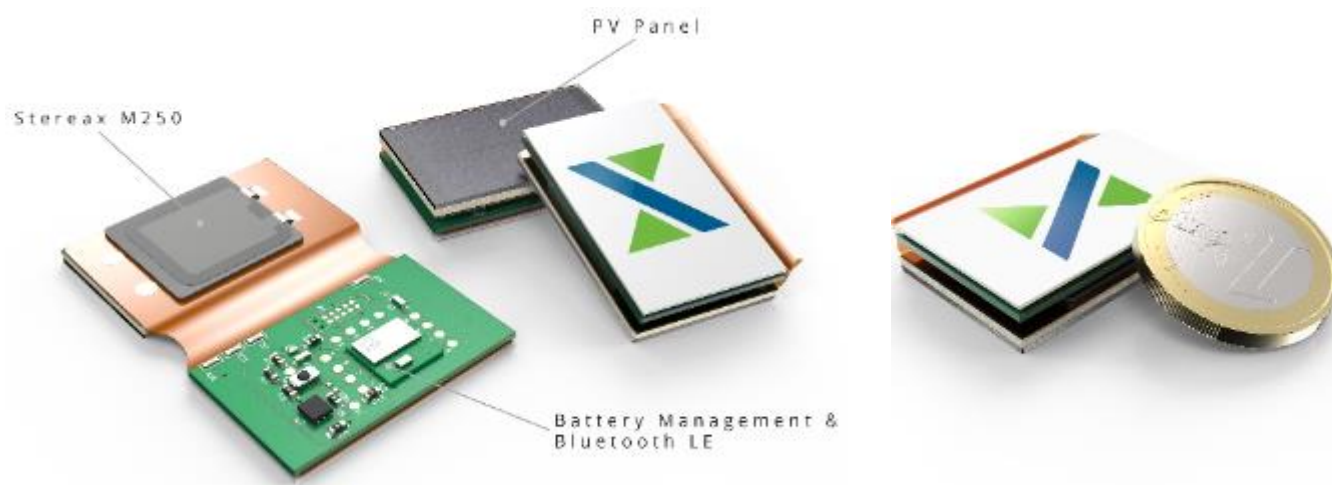
▲ Intra Ocular Pressure Sensor by University of Michigan:  $1\mu\text{Ah}$



# 5 – Integration

# Smart home sensors

- ▲ Perpetual Beacons with temperature, moisture, light level, position sensors powered by Solid State Battery and PV panel



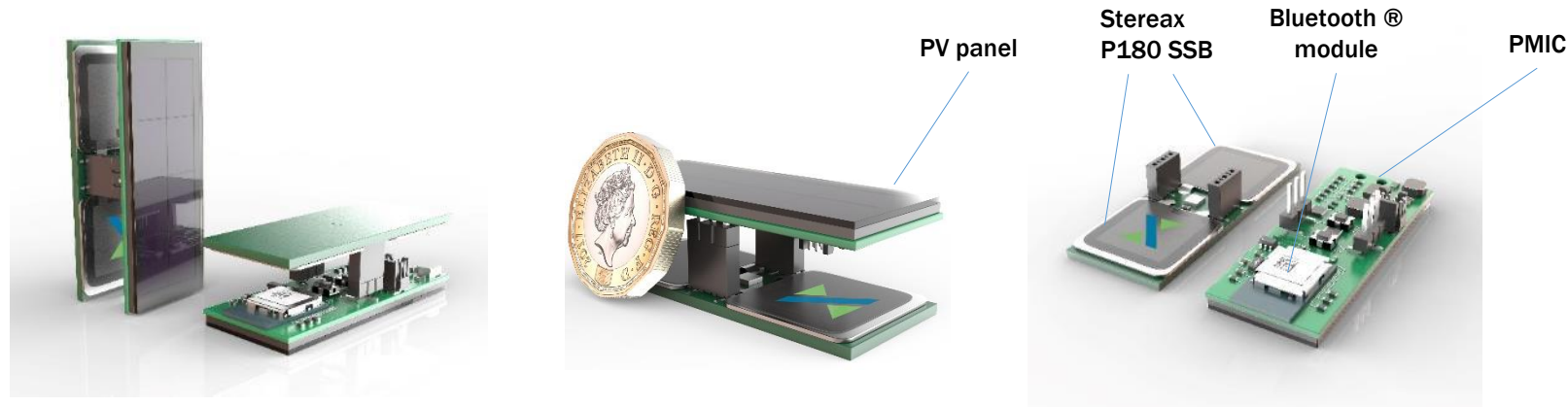
Component	Model	Comment
Battery	Stereax M250	250 $\mu$ Ah solid state battery
PV panel	IXYS SLMD600	35 mm x 22 mm
Battery Management	Texas Instruments	BQ25504
Bluetooth LE	RIGADO BMD-300	Nordic nRF52832 SoC with ARM Cortex M4F CPU



# Industrial IoT sensors

▲ Perpetual Beacons with **temperature sensor** powered by Solid State Battery and PV panel

▲ Operates > 100 °C



Component	Company	Model / Comment
Battery	Ilika	2 x 180 mAh Stereax P180 solid state batteries
PV panel	Lightricity	20 mm x 50 mm
Battery Management	Texas Instruments	BQ25570
Bluetooth® LE	Rigado	R41Z, incl. NXP KW41Z SoC with ARM Cortex M0+ CPU
Temperature	Texas Instruments	HDC 1080



# Call to action

- ▲ Ilika is looking to cooperate with:
  - ▲ System and component suppliers
  - ▲ Manufacturers
- ▲ To enable volume production for Stereax solid state batteries



# Conclusions

- ▲ IoT sensors require adapted power sources based on
  - ▲ Size
  - ▲ Power and energy requirements
  - ▲ Cost
  - ▲ Expected life
  - ▲ Operating temperature
- ▲ Various solutions exist for primary or secondary use cases
  - ▲ Conventional batteries (Lithium ion, button cells)
  - ▲ Supercaps
  - ▲ Solid state batteries
- ▲ Solid state batteries offer a small, size, long life, energy dense solution for wide operating temperature range

# Keep in touch!

Thanks a lot for your time and attention!

Any questions and/or comments?

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