Sensors Converge

Major Research Collaborations Driving Energy Harvesting TRL progression and Power IoT Ecosystem

Cristina Rusu – RISE, Research Institutes of Sweden
Mike Hayes – Tyndall National Institute

#SensorsConverge

June 20–22, 2023 | Santa Clara, CA

Presentation Outline

Introduction to RISE & Tyndall

EH leverage opportunities

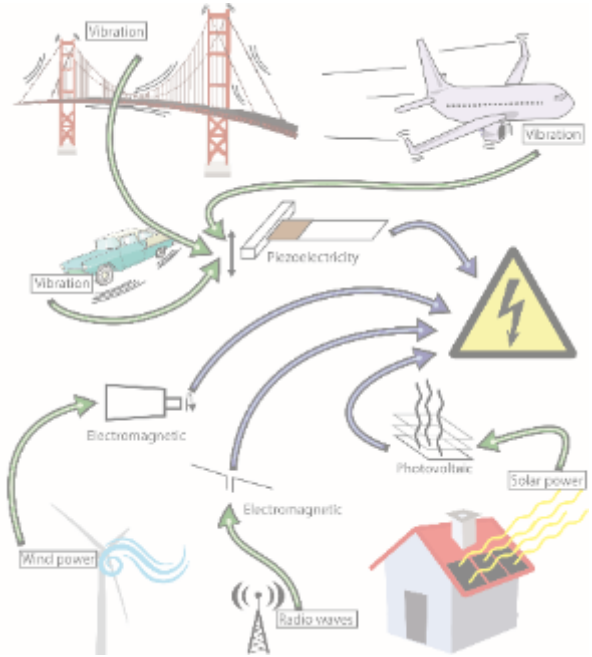
- Sweet spot
- Power IoT Ecosystem

Initiatives 1, EnABLES, Energy ECS, Stargate, Smart Memphis

Initiatives 2 – Technology platform concepts

- PMIC, eSiP
- Simulation model, metrology of real-life applications

Conclusions



Sweden's research institute

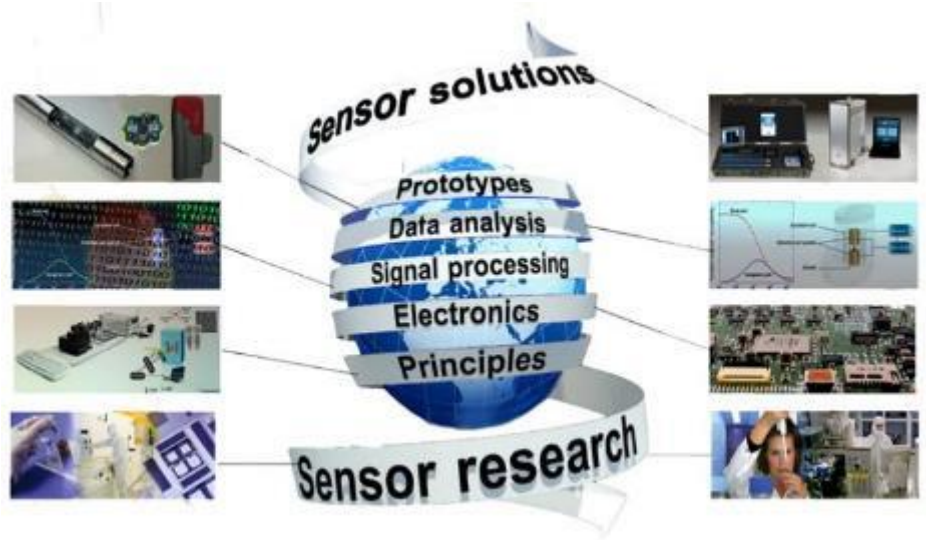
Business and innovation areas

Founded in
2016

3,000
employees

130+
Testbeds and **demonstration environments**

Smart hardware dept.
- **Expertise** -



Tyndall National Institute (Ireland)

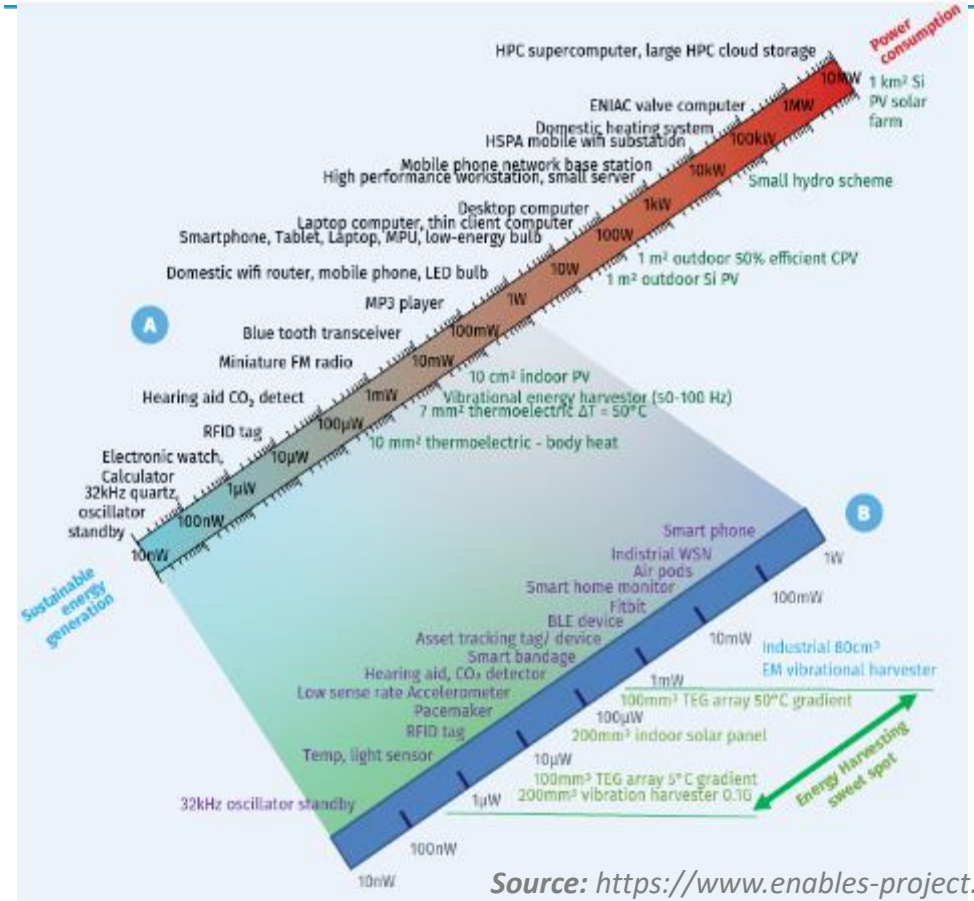
Leading European R&D centre - integrated ICT hardware & systems.

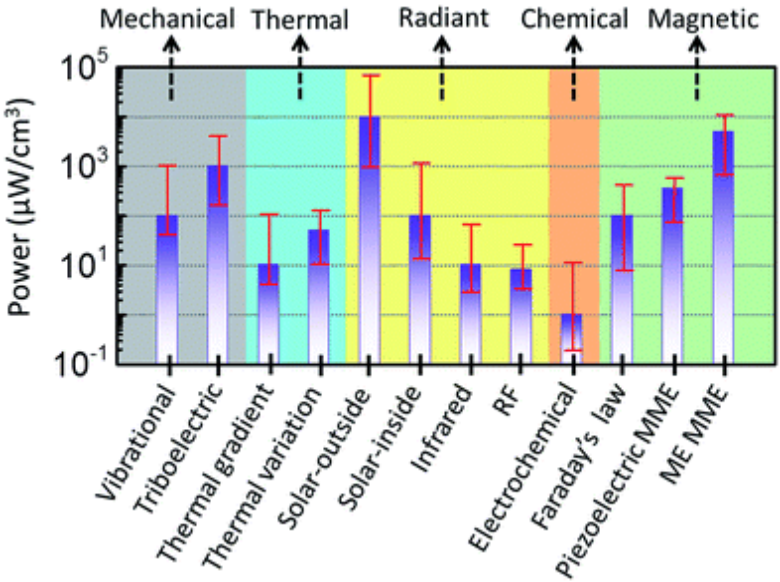
Specializing in:

- Electronics & IC Design
- Photonics
- Materials
- Devices
- Circuits and Systems

- Lead institute for Irish Photonics Integration Centre and European Space Agency Space Solutions Centre Ireland.
- We host industry aligned research centres; Microelectronic Circuits Centre Ireland & International Energy Research Centre
- 600 staff, >200 industry partners
- €45M operating costs, >85% through competitive funding
- >200 publications & 300 publications per annum

Leverage opportunities - 1 Energy Harvesting Sweet Spot



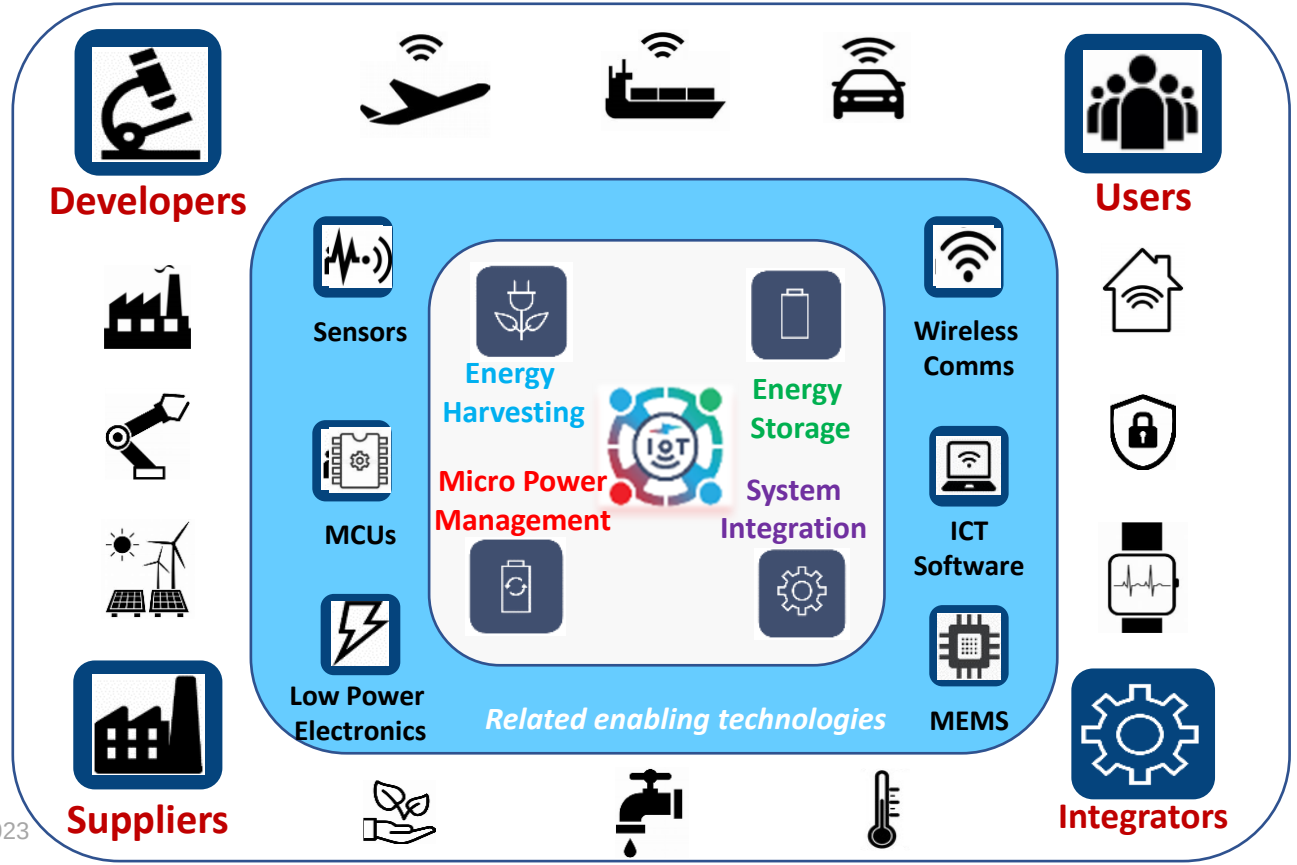


1-200µW sweet spot

Source: *https://www.enables-project.eu/outputs/position-paper/*

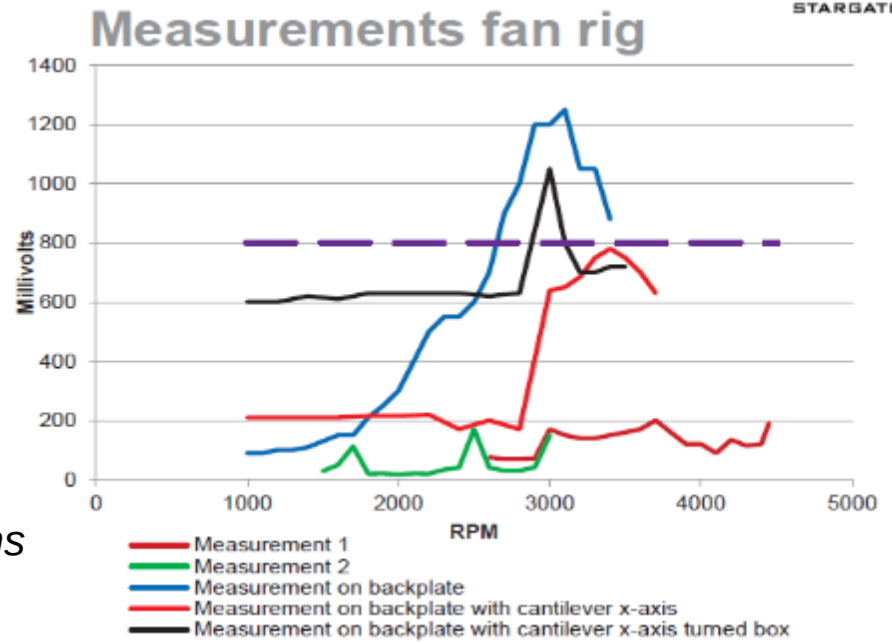
Sensors Converge

Leverage opportunities - 2 The Power IoT ecosystem



INITIATIVES – 1 **Application** driven projects & 2 **Tech** platforms

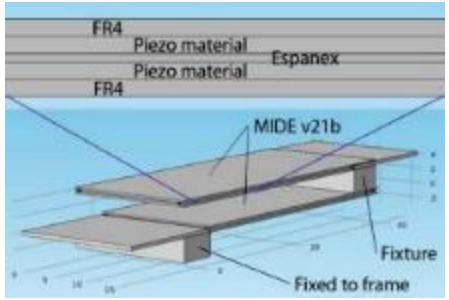
Piezo harvester powering wireless sensor on Gas Turbine



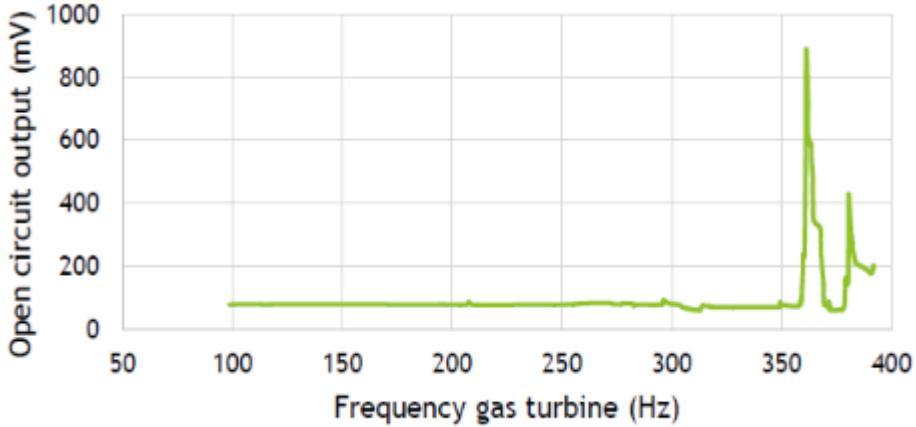
! *Different resonances* in *various directions*

MIDE EH (80 - 175 Hz)

Gas Turbine 2(3) - Developments



Backfolded harvester

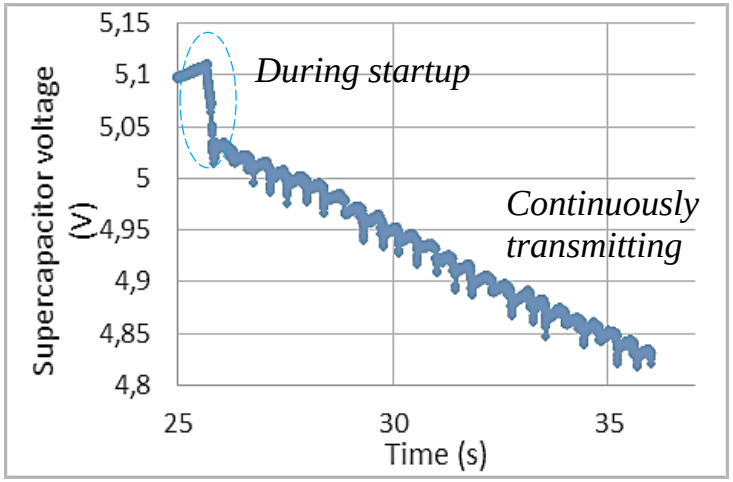


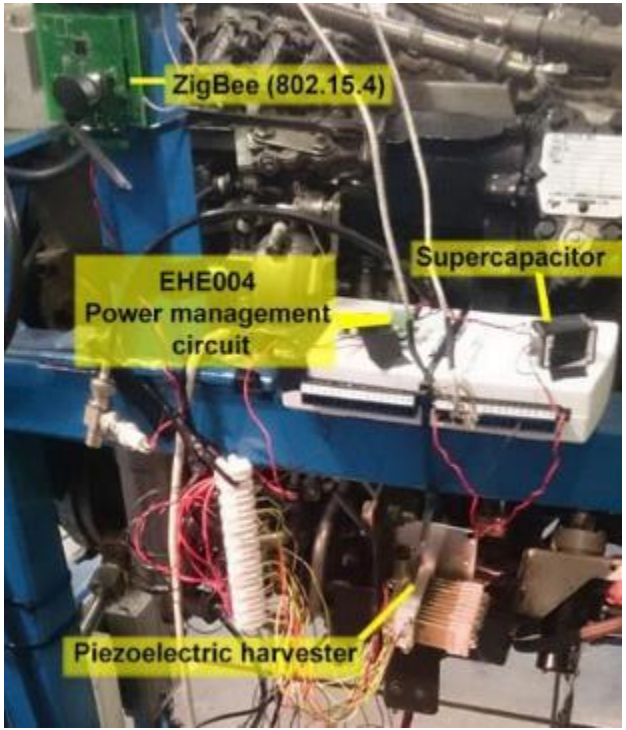
✓ Harvester tested up to 100°C

! Cables → ✓ Multi core (damps vibrations)

! Mounting support - eigenfrequency

Gas Turbine 3(3) - Results





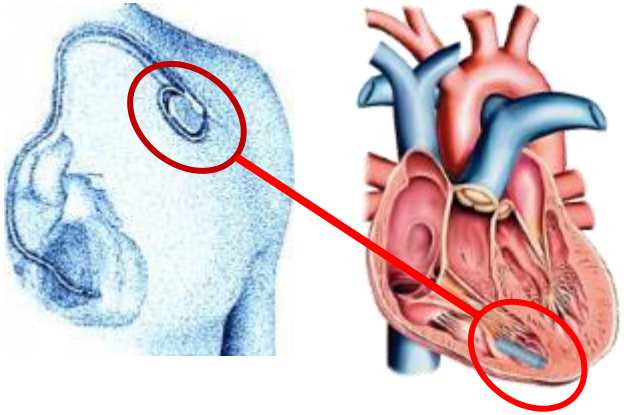
! 4 supercapacitors connected in series

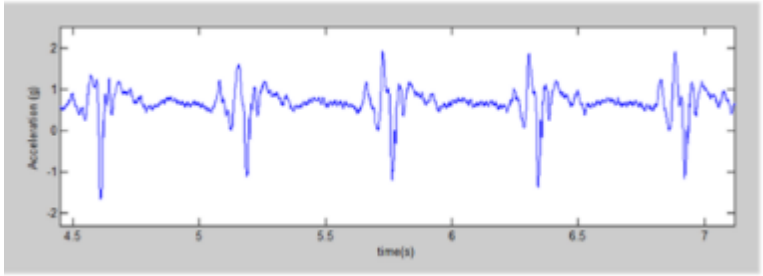
! Discharge while powering Wi-Fi ↔ Rechargeable battery

Pacemaker 1(3) - Requirements

EU H2020 **Smart-Memphis**

Smart MEMs Piezo based energy Harvesting with Integrated Supercapacitor and packaging





Resonance frequency: 10- 30 Hz

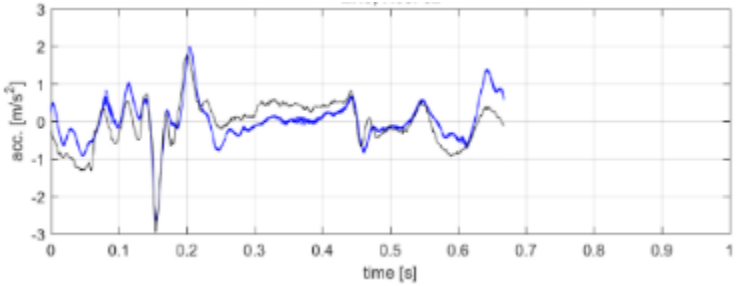
Acceleration: < 1 g

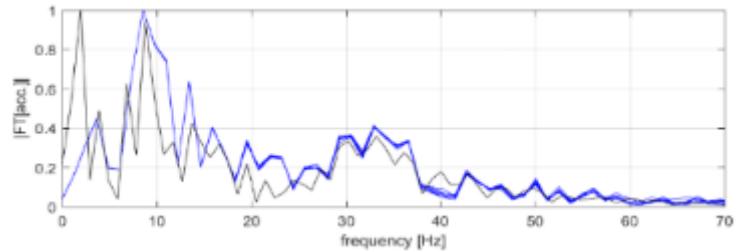
Size: 0.3 - 1 cm^3

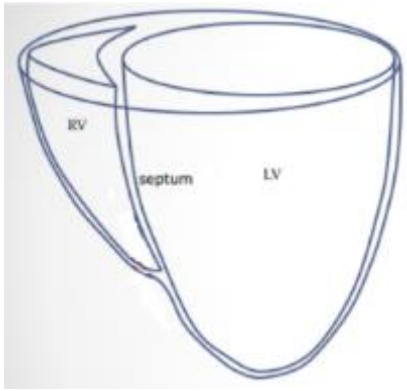
Needed power: 10 – 20 μW

Pacemaker 2(3) - Challenges

- **MEMS design ↔ bulk PZT ↔ low frequency**
- **Resonating structure ↔ damping, pressure encapsulation**
- **Heart measurements ↔ EH position**
- **Excitation data ↔ shaker pre-compensation**

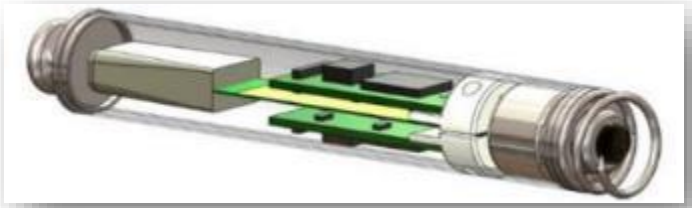






#

Pacemaker 3(3) - Commercialisation



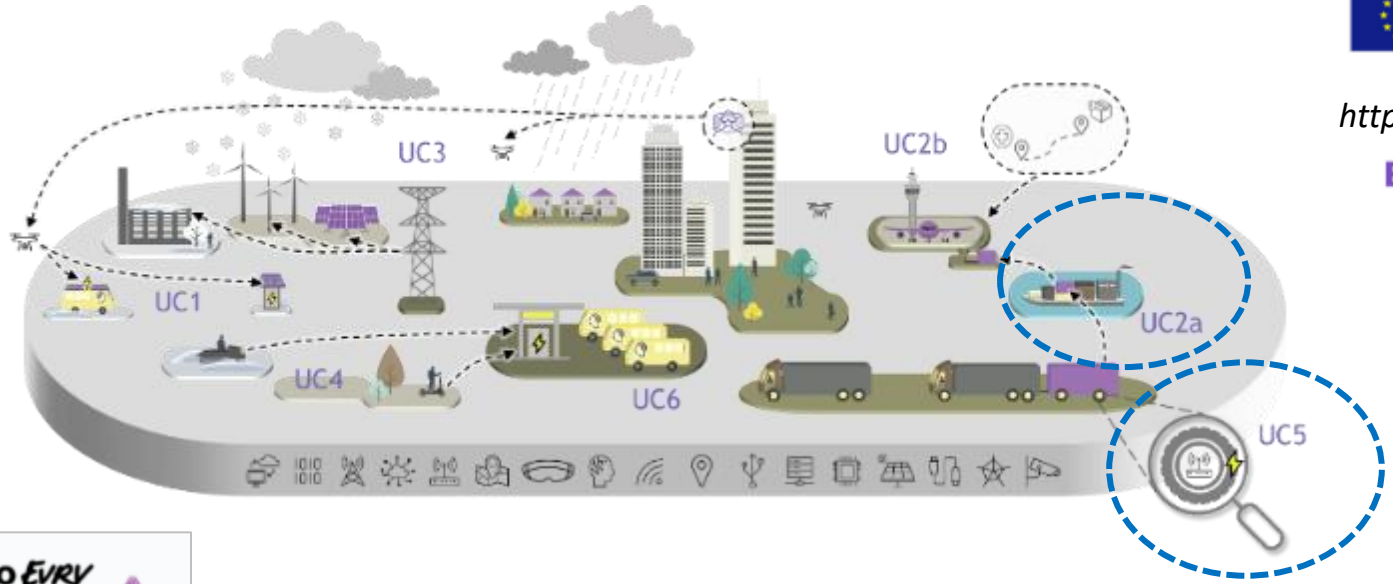
! Investment: prototype → commercialization (many M€)

- Reproducibility
- Reliability

Energy ECS - Smart and secure energy solutions for future mobility

2021 – 2024

https://energyecs.eu



UC2 - Smart transportation demo – port of Cork

Collaboration with Irish SME NetFeasa

Self-powered: >10 years battery life

Tyndall EH PMIC & simulation model
- Minimize device power consumption
- Size the EH & storage components

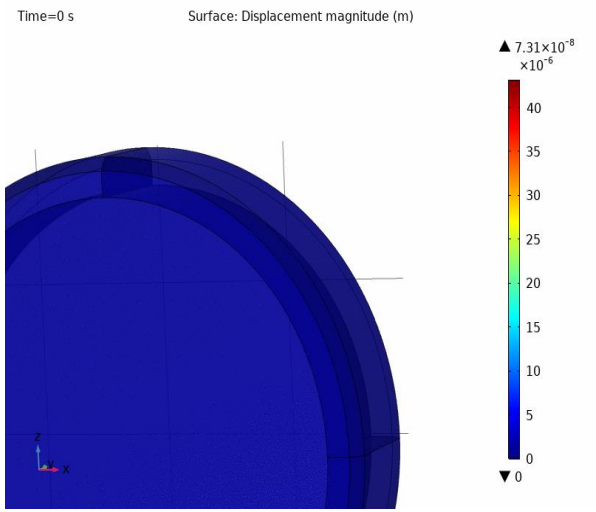
RISE Discrete power management solution

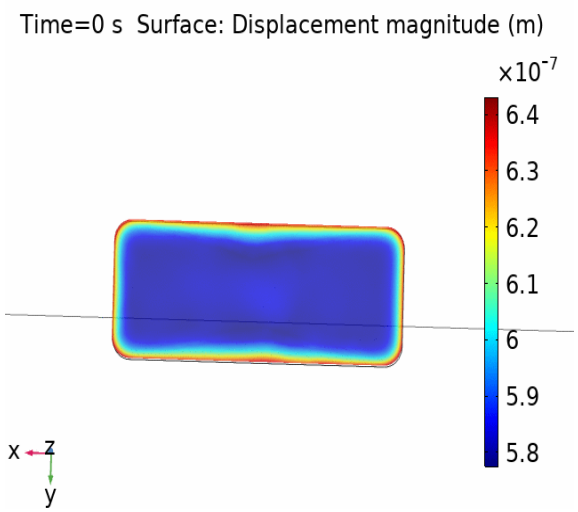
- Associated project with CONNECT - also look at
  - Optimising network energy efficiency & NODE efficiency
  - Optimizing based on Energy available, Criticality, Interference, etc.

IoTPASS™

UC5 – Smart tire 1(2)

Energy Harvester
- **Piezo PVDF**
- **Tribo**

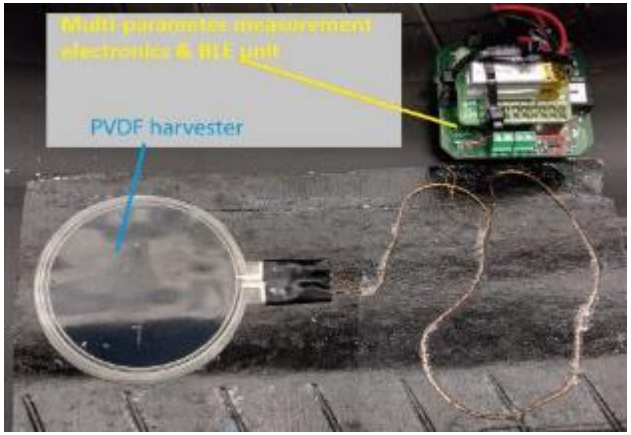


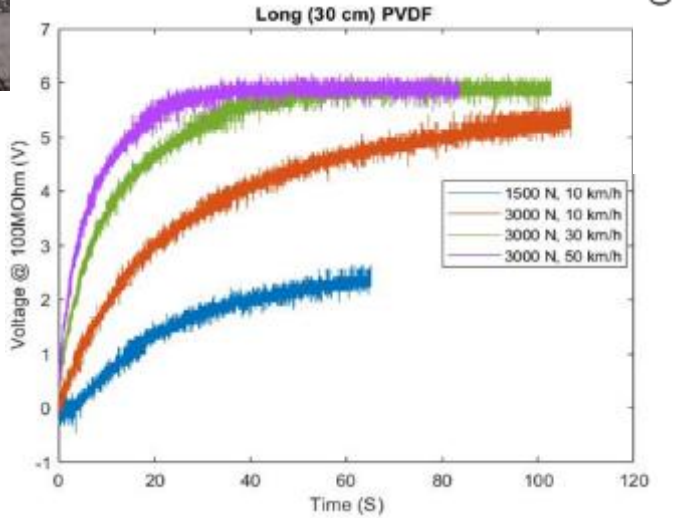


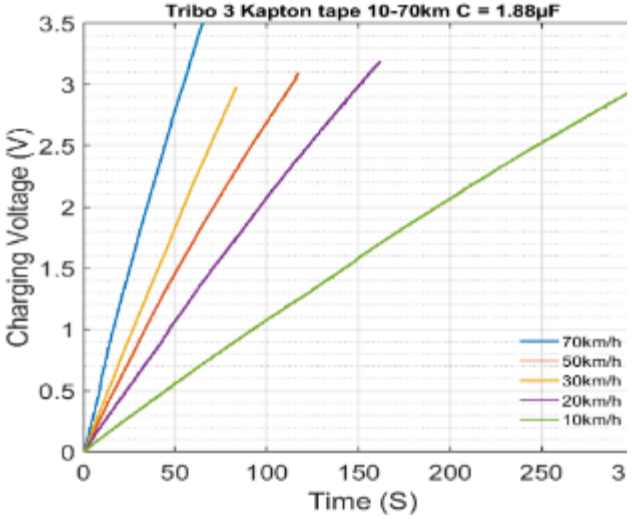
! Simultaneous simulation tire & piezo deformation

! Tire material data

UC5 – Smart tire 2(2)







! Robust integration on tire

! Long-term reliability

> 20 mJ available energy
(after electronics)

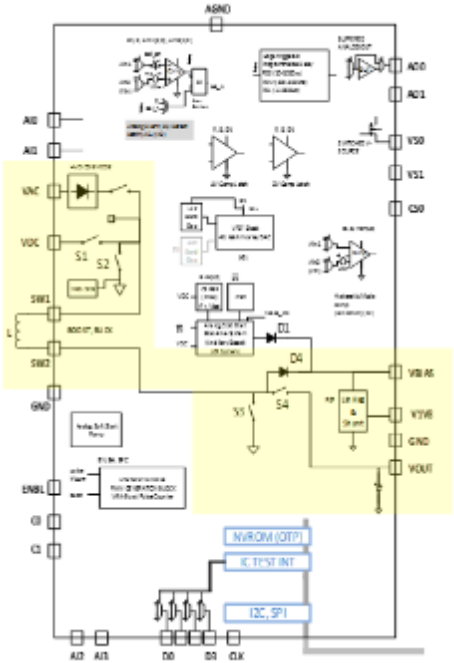
INITIATIVES – 2 **Technology** platform concepts

- **PMIC** (**P**ower **M**anagement **IC**)
- **eSiP** (**e**nergy **S**ource **i**n **P**ackage)
- **Simulation model**
- **Metrology of Real life Applications** (ambient energy & power consumed)

“MISCHIEF” Multi-source energy harvesting **PMIC**

- ***Highest efficiency*** switch-mode, energy harvesting PMIC at 10s of µW point
  - Cold-start and operation over ≈1 µW to 200mW
  - Can convert low level ambient energies that are currently unusable (50mV, 10uW)
- ***Lowest quiescent current*** (I_Q) in low power regulation mode, <200nA
- Highest **end-to-end system** efficiency
- Innovate high frequency ZVS switching ***Buck Boost can handle*** both battery voltage (≈ 3V) and LV (≈ 1V8)
- Potentially can dramatically reduce size of external inductor
- Modular Flexible Mixed Signal blocks - technology Platform proofed for

FAST TRACK LOW RISK development of Next Gen control & features



eSiP - energy Source in Package

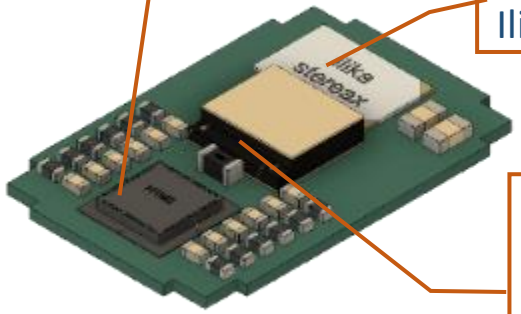
Integration: Ener Harv, Ener Storage, Micro PM

- Progress from COTS to research platforms

Integration Technologies:

- PCB, PCB-embedding, Flexible
- Micro-Transfer Printing (MTP)

Integrate into a SELF POWERED smart patch demo (next slide)

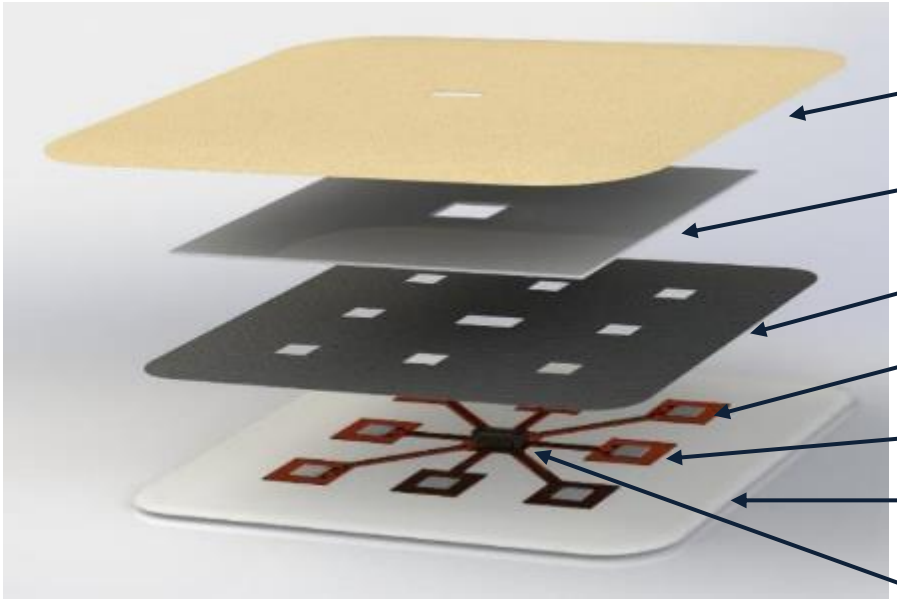


MPM: Power Management IC (PMIC):
COTS then **Tyndall**

ES: MicroBattery: 200-500 µAh
Ilika, Cymbet, iTEN then **Tyndall**

EH: Si-based Thermoelectric Generator:
TEG – (COTS then **Tyndall TEG**)
Wire bond to PCB

Integration eSIP & PMIC into TEG powered patch

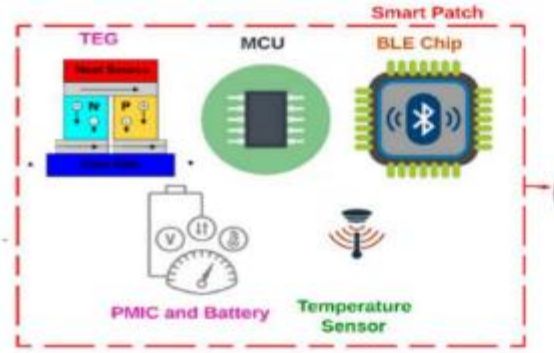


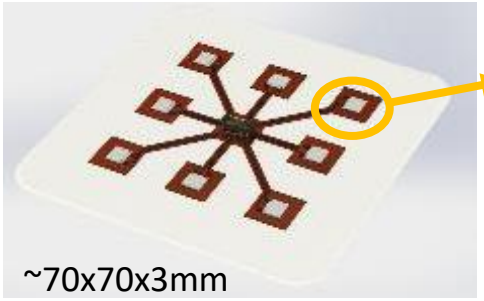
Developing a simulation model to optimise power transfer and component sizing

Initial concept created for Irish DTIF project HOLISTICS

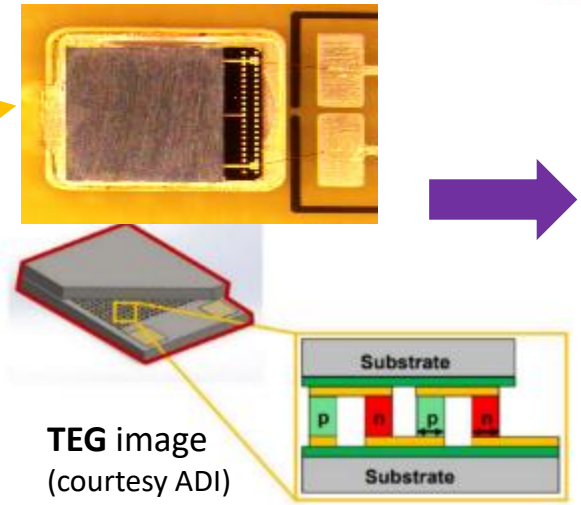
Smart patch - Miniaturised, wearable, self-powered

- Leveraging work done on HOLISTICS (Irish Gov. funded)
- **Self powered (30μW)** with 35°C temp source
- BLE temp reading every 78 sec to mobile app
- **Reconfigurable** (can miniaturize)
- **Simulation models will** optimise for lower airflow and/or increased functionality (e.g. pulse, motion, SPO_2)





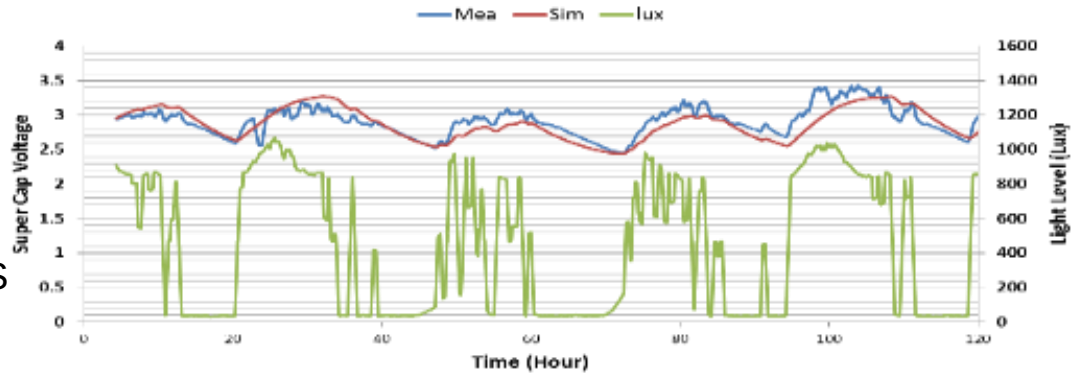
Novel array of TEGs



TEG image
(courtesy ADI)

Simulation model - EH Powered WSN battery life

- Help installers select hardware components for a potential energy harvesting deployment
- No Energy Harvesting or WSN expertise needed
- Can also be used to optimise component sizes



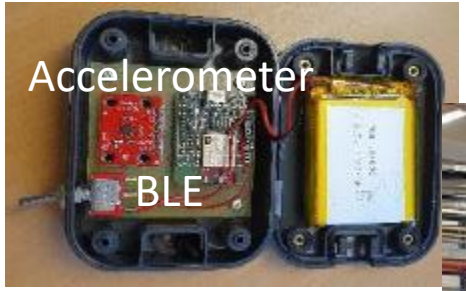
Variant of this being developed for Energy ECS

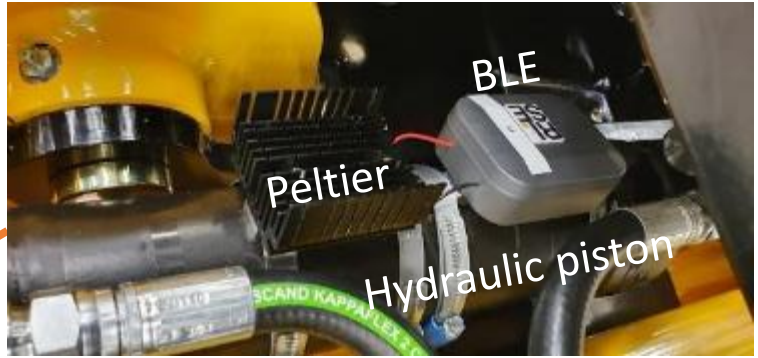
Metrology - EH demo 1(3)

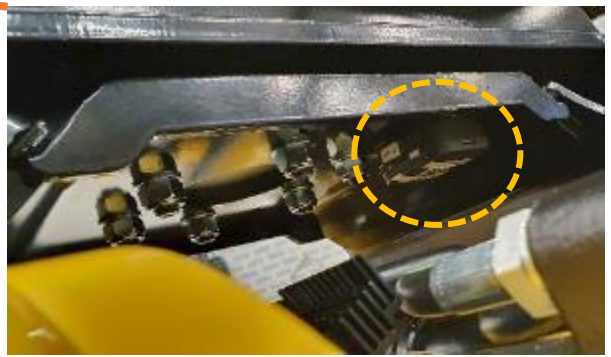
- Max/ min opened/ closed claws
- Gripping logs
- Lifting logs

- Vibrations from shock
- Mechanical vibration
- Heat from hydraulics

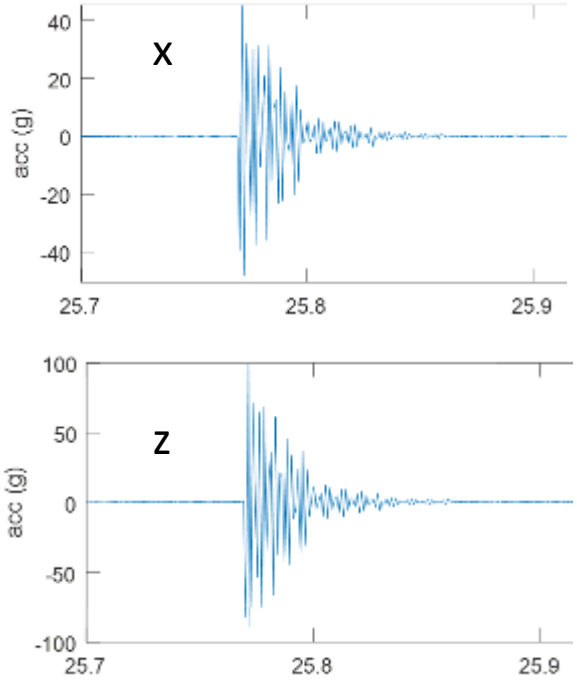
Metrology - EH demo 2(3)







Metrology - EH demo 3(3)

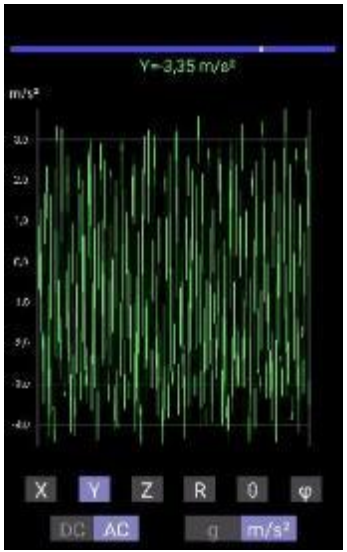


- Accelerations 80 – 200 g but extremely short period
- Temperature gradient ~ 10 – 15°C

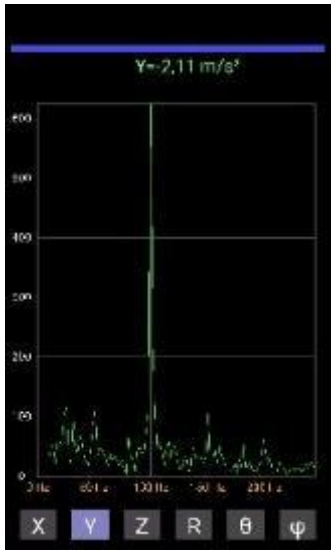
! Correct mounting of measurement device

Metrology - Proof of Concept: Pump maintenance

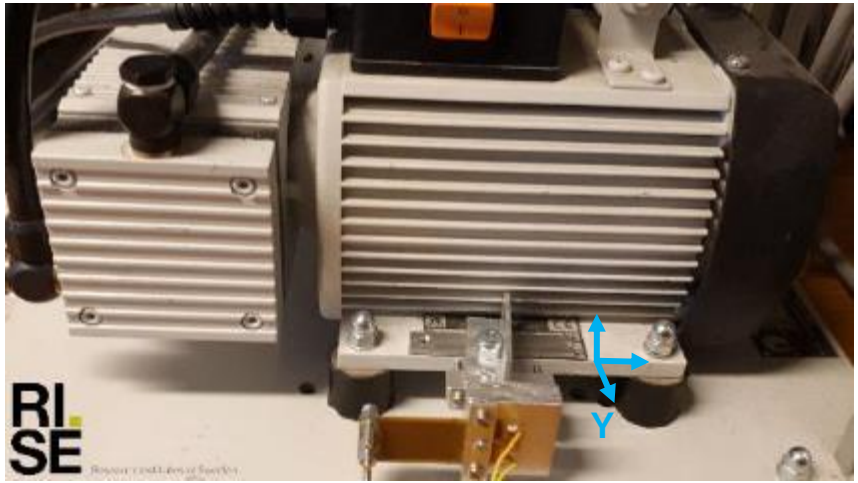
Pump characteristics for harvester design and tuning



Raw acceleration Y-led on pump



Amplitude spectrum over frequency



Tuned harvester setup attached to pump

! Correct mounting of measurement device for vibration spectra

Conclusions

- In many applications: energy harvesting will not replace batteries but… there is interest/need to increase battery lifetime and/or reduce cables.
  - There is a sweet spot where significant extension and in some cases autonomy can be achieved
  - The stakeholders need to collaborate to achieve this

- Market acceptance is very much application dependant:
  - Chosen harvester solution ↔ Energy source
  - Component is not a system
  - Implementation is complex

- Energy Harvesting application is still new & requires significant progress & robustness

- Collaboration with industry is essential

- Use project and tech platforms to drive best practice and learn from real life deployments

Acknowledgements

EU Project 730957

HOLISTICS

Irish government DTIF

EU JU # 101007247

MISCHIEF

Sweden's innovation agency

Contacts

Cristina Rusu
Energy Harvesting system
Sensors & Systems
cristina.rusu@rise.se

Mike Hayes
Energy Harvesting Power
Management & Systems
michael.hayes@tyndall.ie