



# Miniaturised Energy Harvesting @ RISE

**Cristina Rusu**
Senior Expert at RISE
cristina.rusu@ri.se

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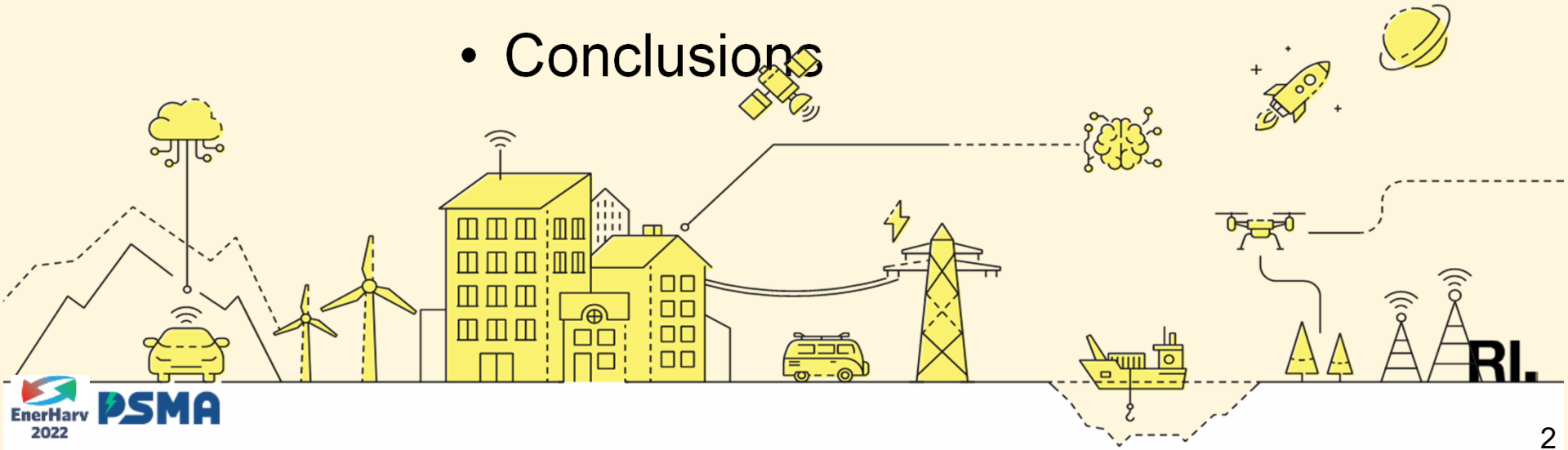
RI. SE

# Miniaturised Energy Harvesting @ RISE

- Introduction
- Examples of applications
- Conclusions



EnerHarv 2022

PSMA

RI.

# Miniaturised Energy Harvesting @ RISE

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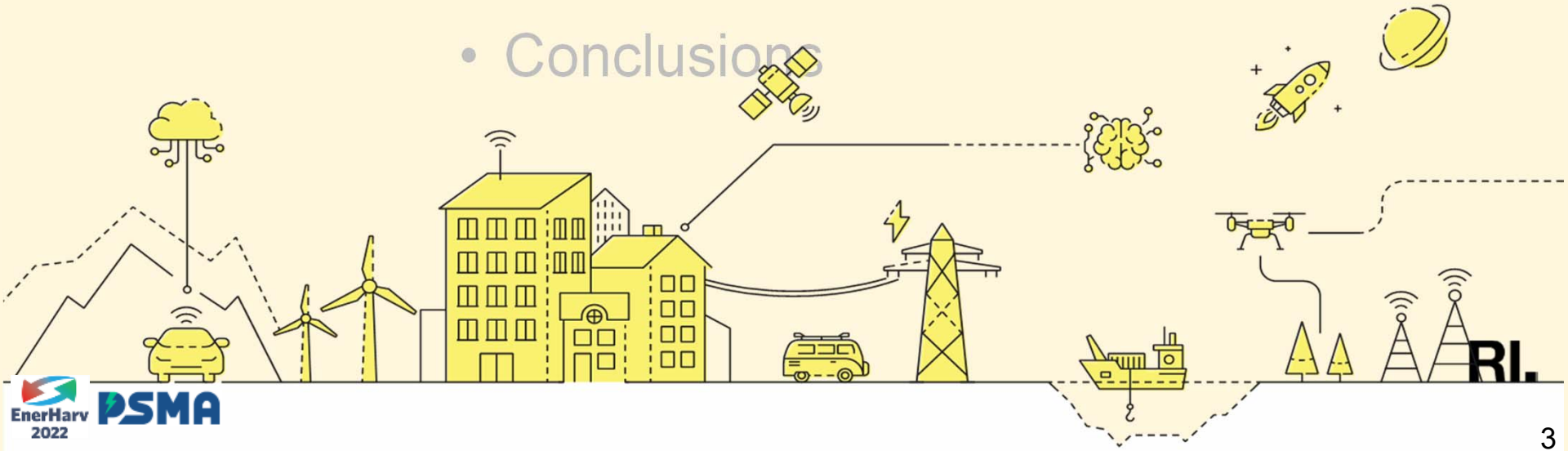
- Examples of applications
- Conclusions

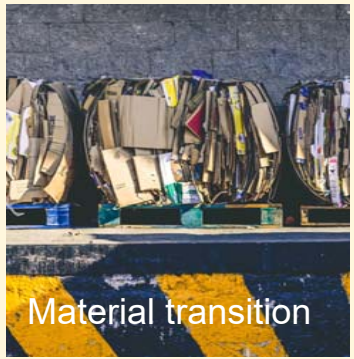


# Sweden's research institute

## Business and innovation areas






**More than 30 research institutes and ca. 130 test beds in one organization**

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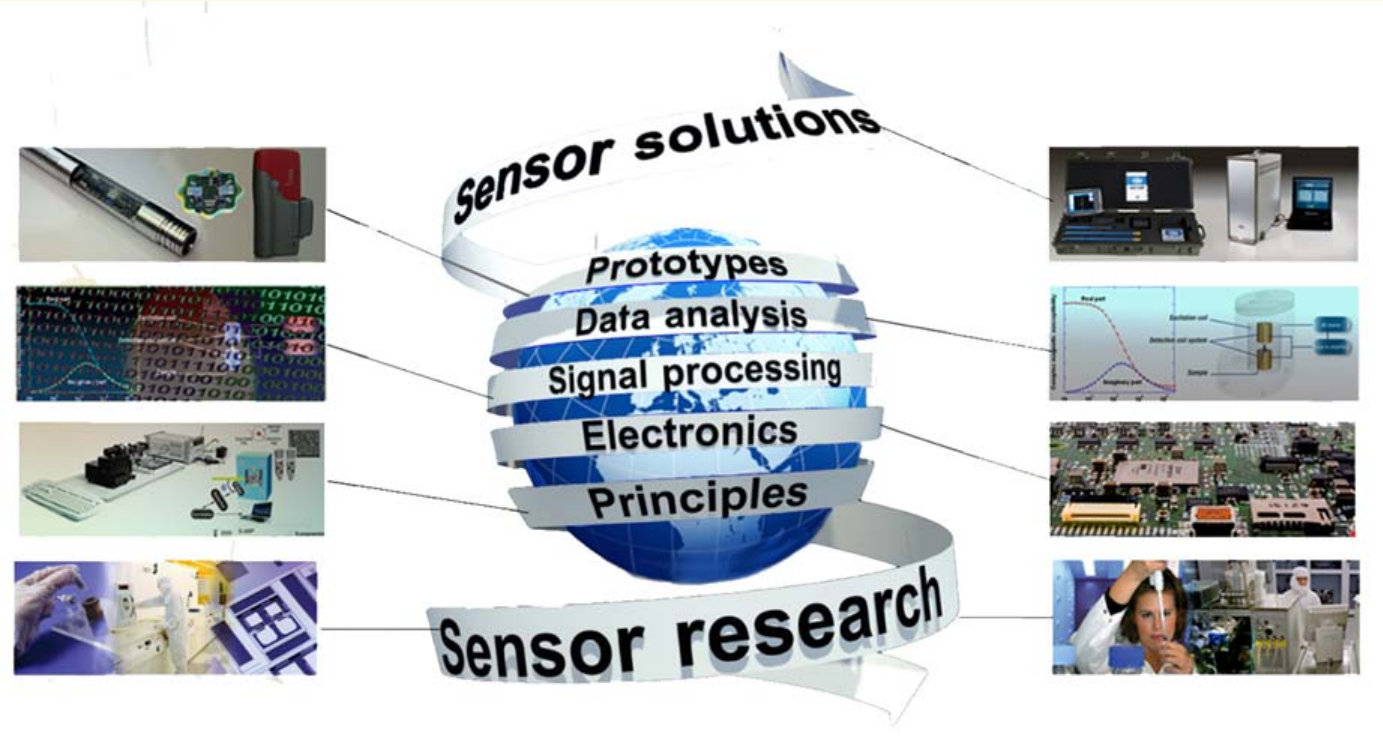
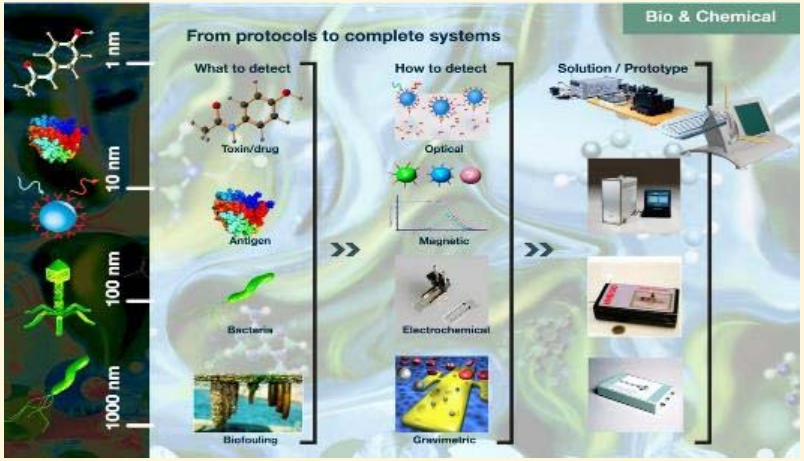
# **Smart hardware** dept. - **Expertise**



# **Smart hardware** dept. - **Expertise**

Magnetic simulation | AC susceptometry | Magnetic Sensor System | Magnetic analysis







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# Energy Harvesting *vs* Cables / Batteries

- Too much weight

- Not easily accessible

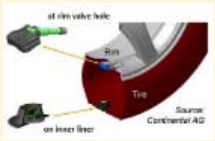
- Inaccessible
- Large quantities

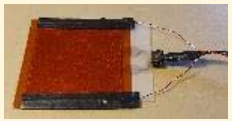
- **Ultra-low power**
- **Low data rate**
- **Low duty cycle**

# Energy Harvesting technologies @ RISE

## Kinetic energy – Piezo, Electromagnetic, Triboelectric

- **Industry**
  - Automotive
  - Mining
  - ….



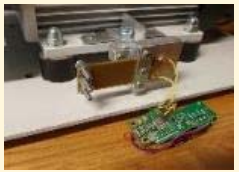


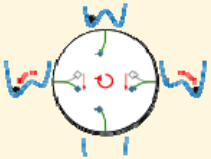
*UDI-2 'Energy Toolkit', Sephmet*

*ECSEL 'Energy ECS'; H2020 'Symphony'*

*Energy harvesting for automotive*

- **Maintenance**
  - Pump, compressor
  - Gas turbine, engine
  - …..





- **Life science**
  - Pacemaker
  - Textile, wearable

*H2020 'Smart Memphis'*

*FP7 'WIISEL'*

# Energy Harvesting technologies @ RISE

## Thermal

- Gas turbine, engine
- Hydraulics
- ….

*FP7 Stargate*

*Digitalisation based on energy harvesting (HSP Gripen)*

## RFID

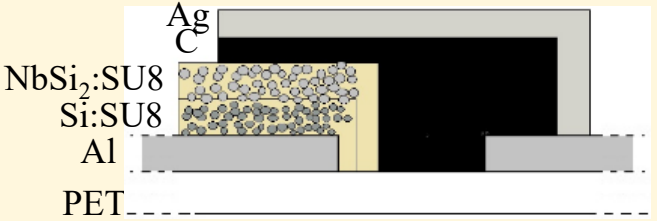
- Recycling, Identification
- Environment
- …

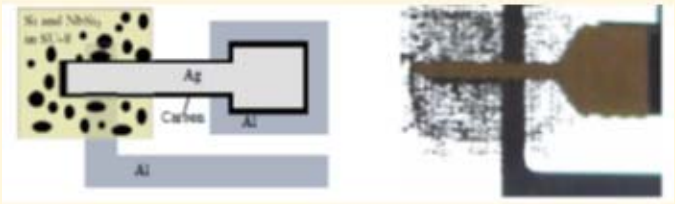
*Robust identification*
*Climate control in greenhouse*

*AFarCloud*

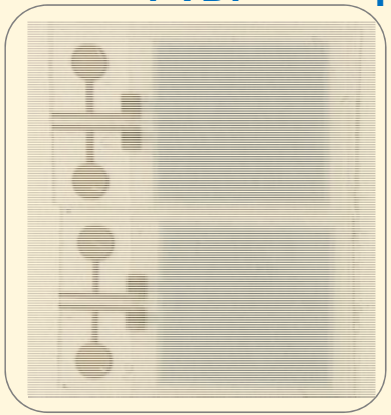
# Printed electronics & sensors

## DIODES

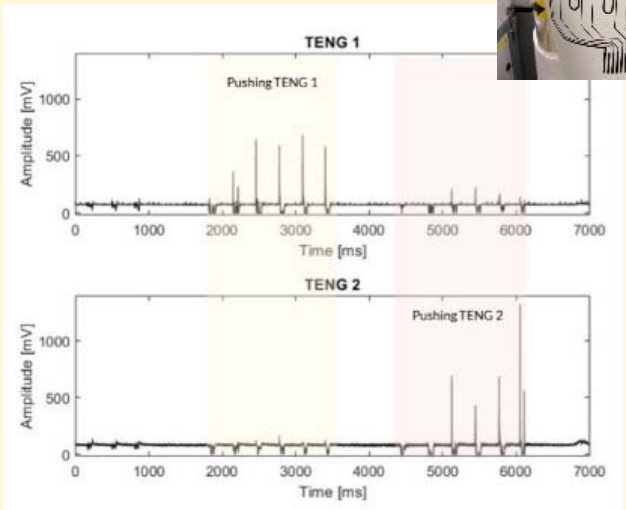



## PVDF

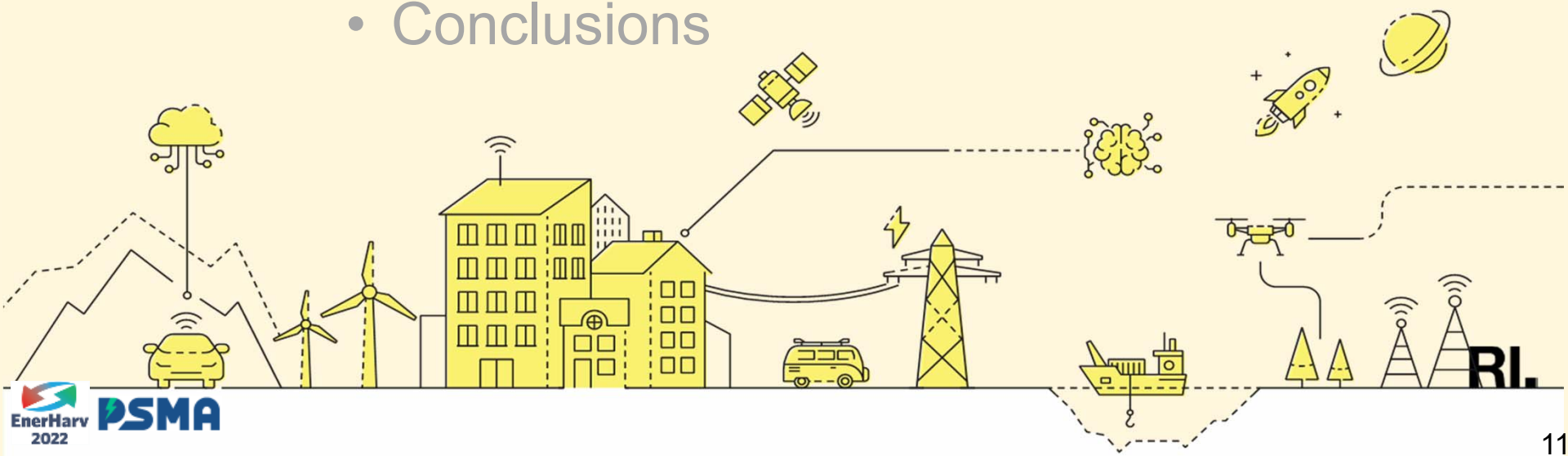


## Triboelectricity in cellulose & lignin

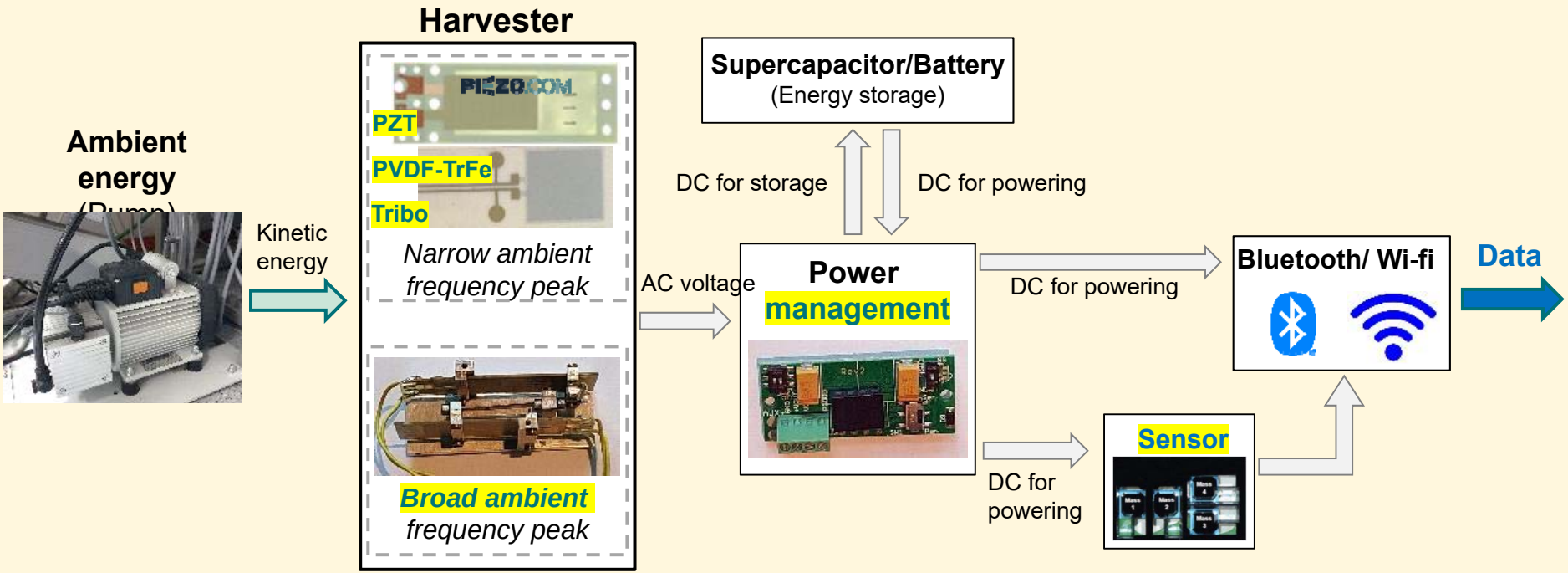



valerio.beni@ri.se

- Introduction
- Applications examples - Piezo
- Conclusions

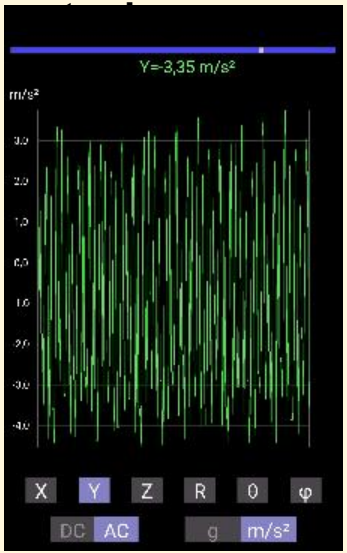


# Our prototypes for Energy Autonomous Sensors

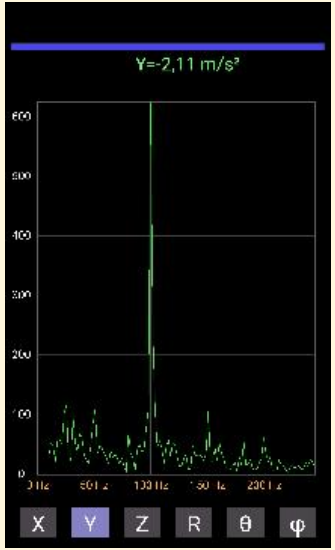


# **Ex #1:** Proof of Concept: **Pump maintenance**

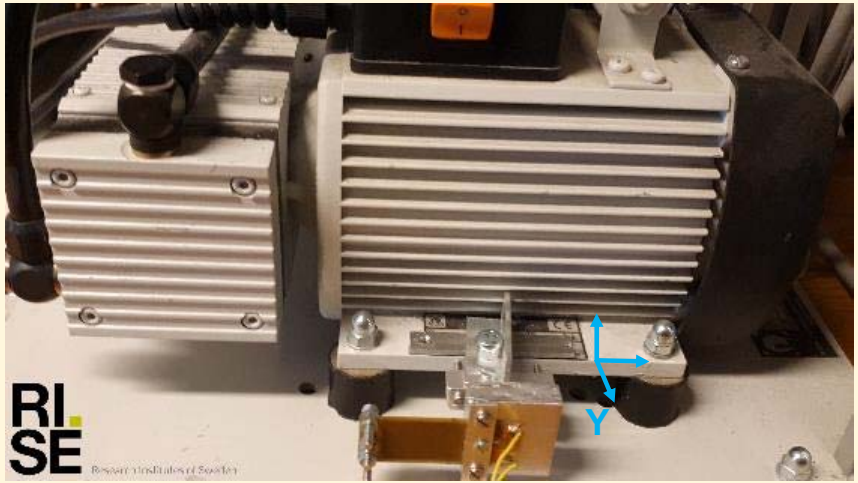
- **Pump characteristics for harvester design and**




*Raw acceleration Y-led on pump*



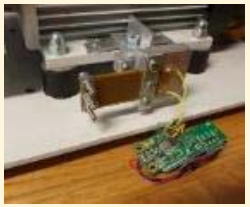

*Amplitude spectrum over frequency*




*Tuned harvester setup attached to pump*

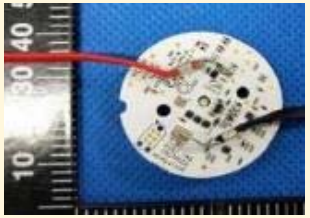
**! Correct mounting of measurement device for vibration spectra**

# **Ex #1:** Proof of Concept: **Pump maintenance**



- **Piezo element**
  - MIDE /Piezo
- **Power management**
  - Analog Devices/Linear Technology **LTC3588**

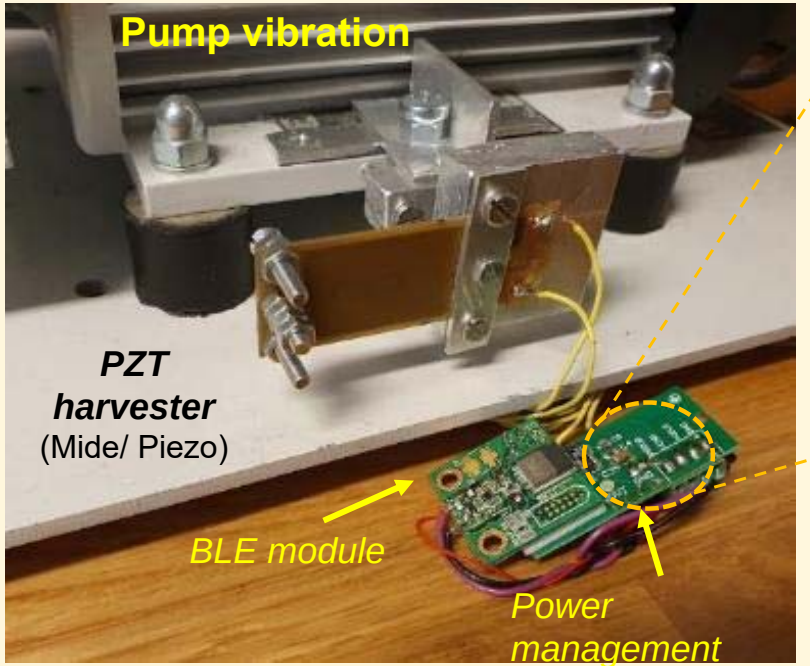
*Bluetooth beacon*



*Pokit multimeter*

- **Communication**
  - LED
  - Bluetooth beacon (RSL10 SIP) + Samsung App
  - Pokit multimeter + Samsung App
  - Modified for harvester application
- **Sensing**
  - Turn on LED
  - Harvested voltage
  - Vibration frequency
  - Vibrations changes

# **Ex #1:** Proof of Concept: **Pump maintenance**



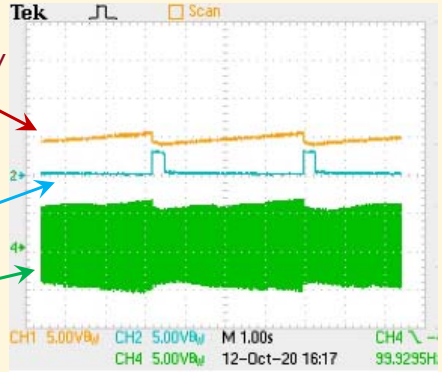

*LED lights when enough energy is harvested*



***Voltage** charging / discharge on supercap*

*Harvester POWER*

*Harvester VOLTAGE*

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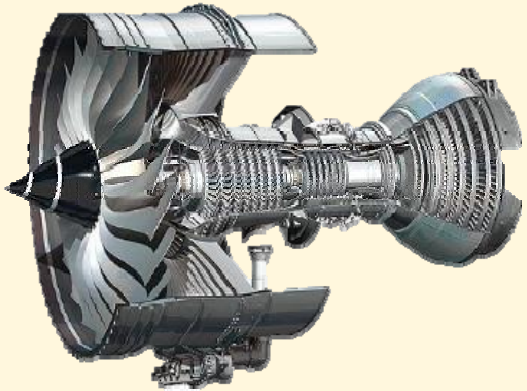
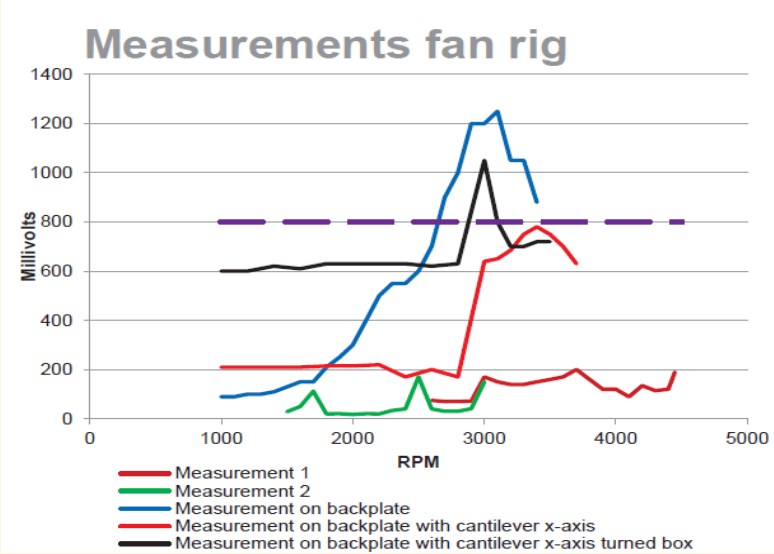
# Ex #2

# Piezo harvester powering wireless sensor on Gas Turbine

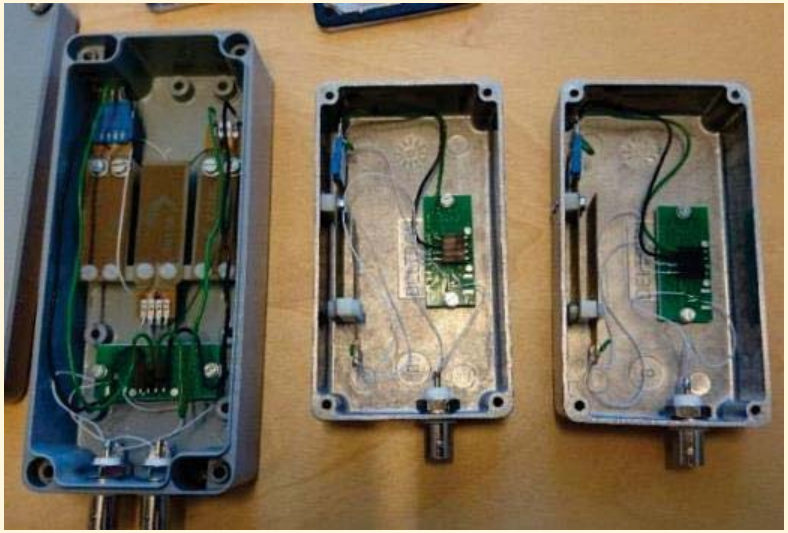


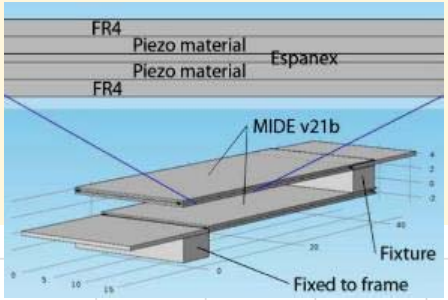



*MIDE EH (80-175 Hz)*

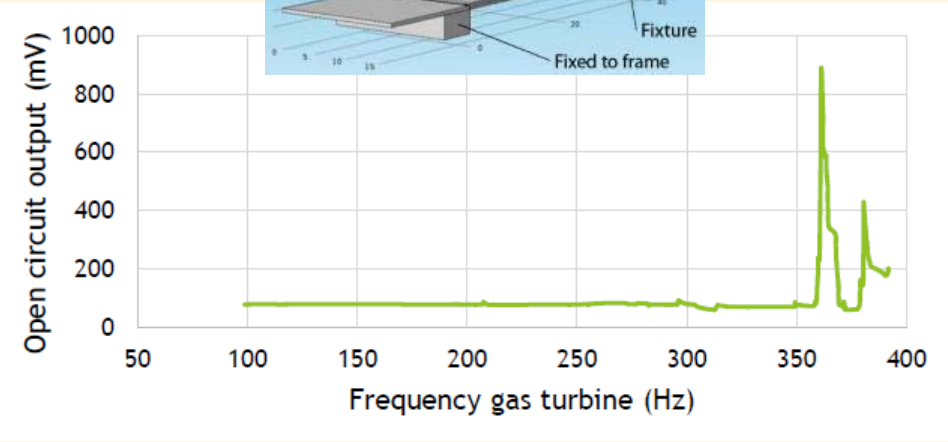
! Many, different resonances and in diverse directions on a gas turbine

# Ex #2 Gas Turbine





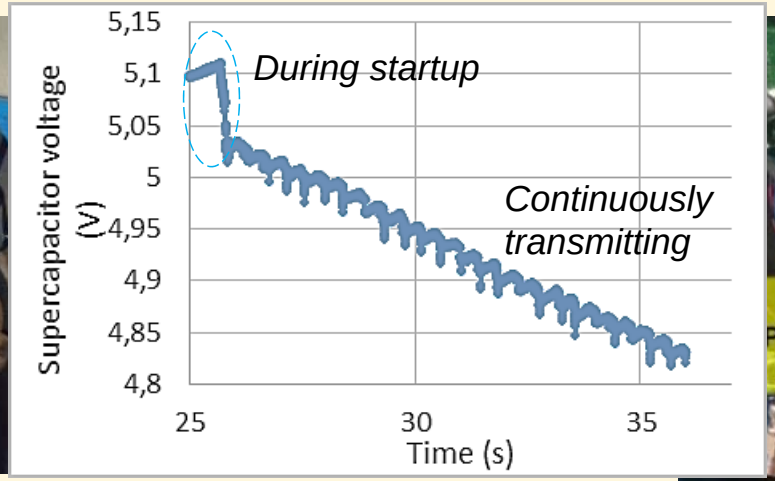

*Backfolded harvester*

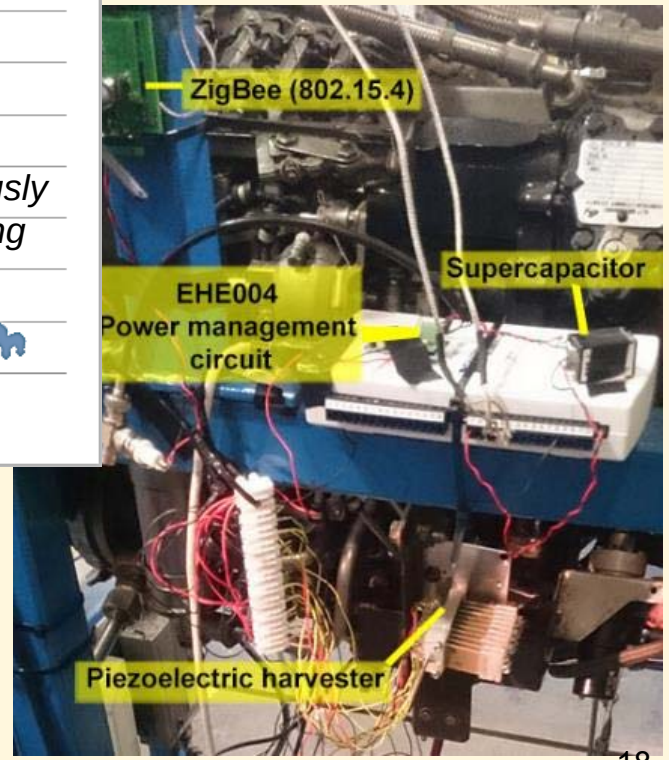



*Open circuit voltage output from a backfolded harvester on ex-service engine*

- ✓ Harvester tested up to 100°C
- ! Cables → ✓ Multi core (damps vibrations)
- ! Mounting support - eigenfrequency

# Ex #2 Gas Turbine




! 4 supercapacitors connected in series

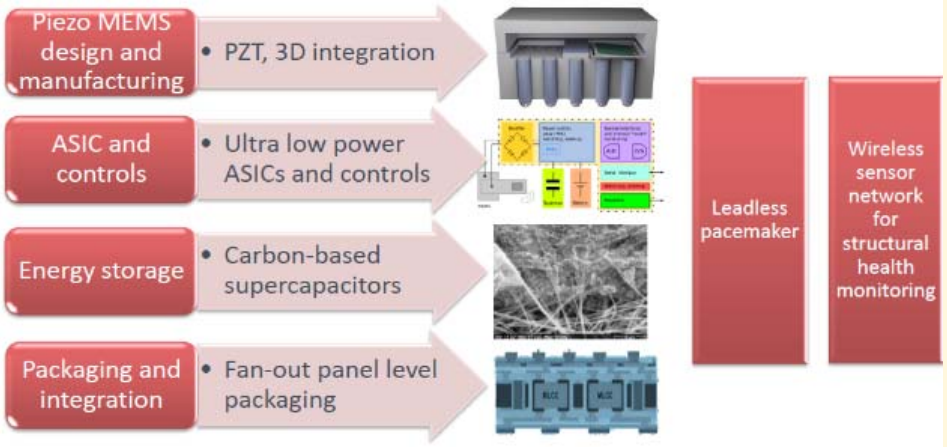
! Discharge while powering Wi-Fi ↔ Rechargeable battery

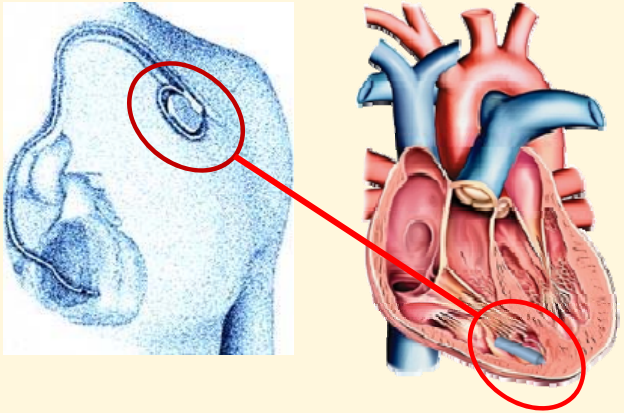
# Ex #3

# EU H2020 **Smart-Memphis**

## Smart MEMs Piezo based energy Harvesting with Integrated Supercapacitor and packaging

2016-2018

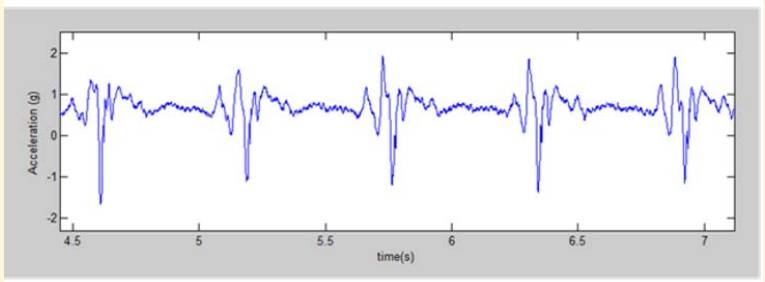


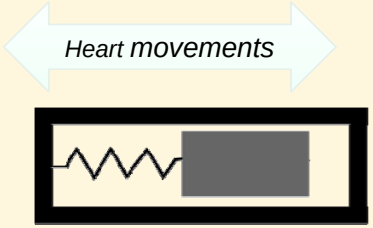



**RISE**

- MEMS-based PZT harvester simulation / design
- Mechanical & electrical harvester characterisation

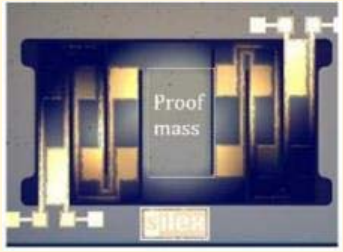
# Ex #3: Pacemaker




**MEMS PZT**

1 – 2 µm




**Bulk PZT**

30 – 60 µm

(Vermon)

Proof-mas: 0.5 – 1 g

**Resonance frequency: 10- 30 Hz**

**Acceleration: < 1 g**

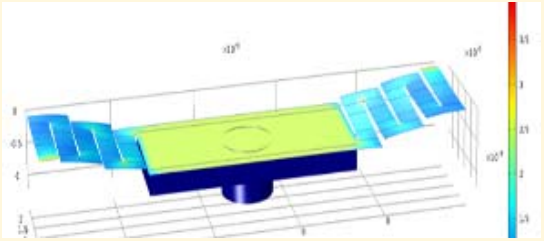
**Size: 0.3 - 1 cm$^3$**

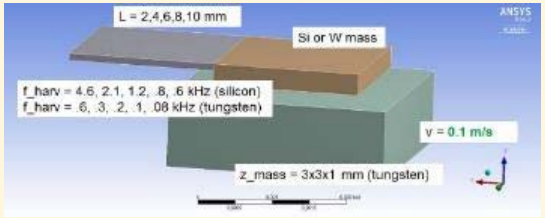
**Needed power: 10 – 20** µW

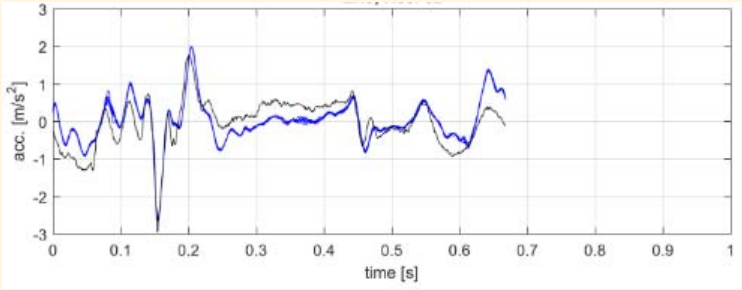
# Ex #3: Pacemaker

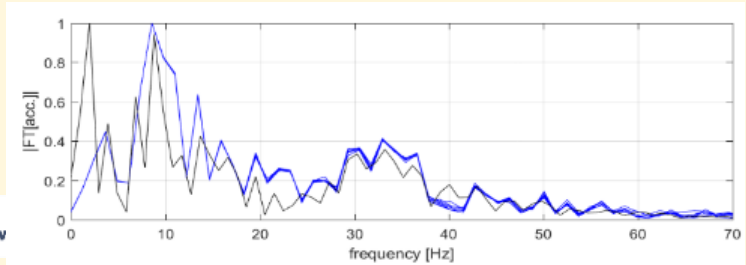
## Challenge

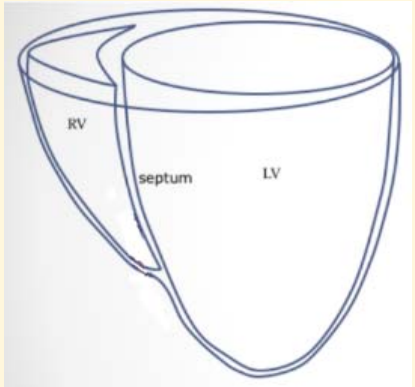
- MEMS design ↔ thin PZT, low frequency
- Damping ↔ pressure encapsulation
- Heart measurements ↔ EH position
- Excitation data ↔ shaker pre-compensation

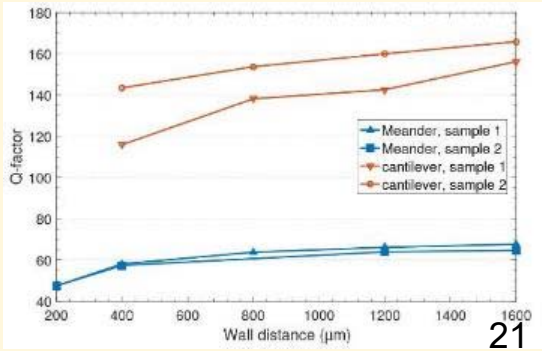




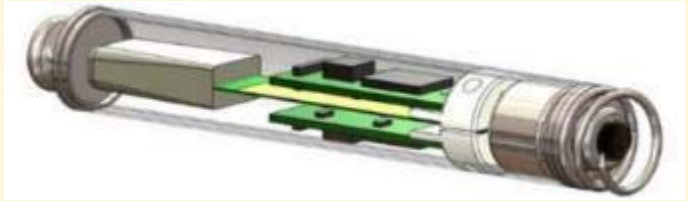



# Ex #3: Pacemaker



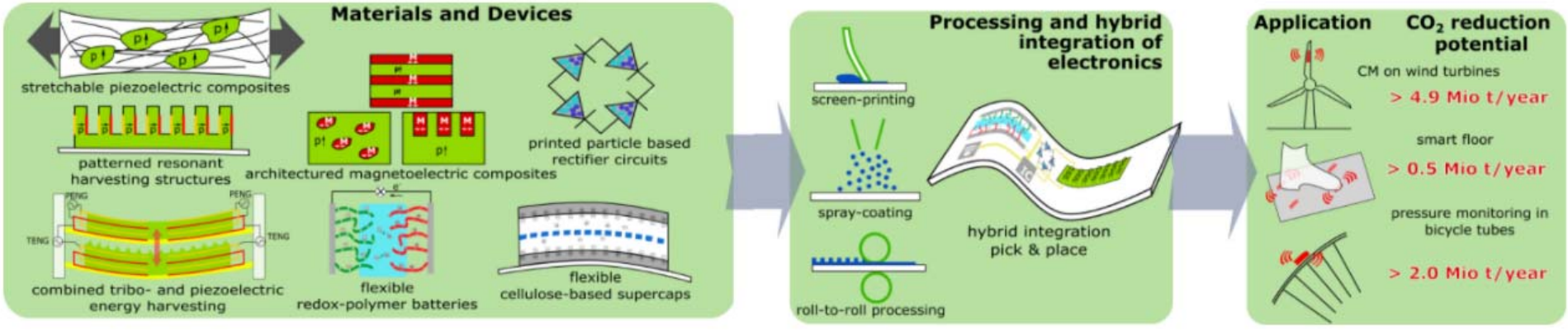

**! Investment: prototype → commercialization**

- Reproducibility
- Reliability

# Ex #4 EU H2020 - **Symphony** -

## Smart Hybrid Multimodal Printed Harvesting of Energy

2020-2024




**RISE:** Magneto electric harvester characterisation

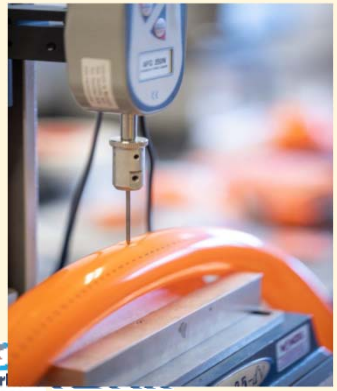
# Ex #4

# EU H2020 - **Symphony** -

## Smart Hybrid Multimodal Printed Harvesting of Energy

**Sensor** skin for wind turbine condition monitoring
*(Copyright: Eologix sensor technology GmbH)*

**Smart floor**
*(Copyright: Joanneum Research–MATERIALS)*



**Automated pressure monitoring of bike tubes**
*(Copyright: Tubolito GmbH)*

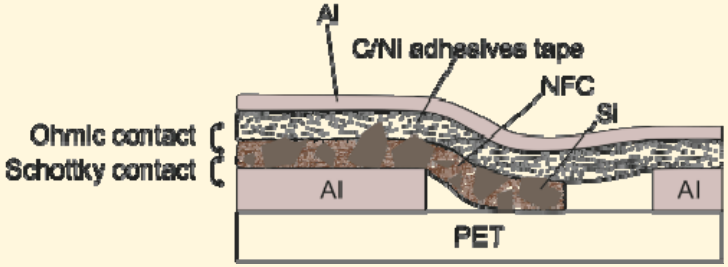
# Ex #4

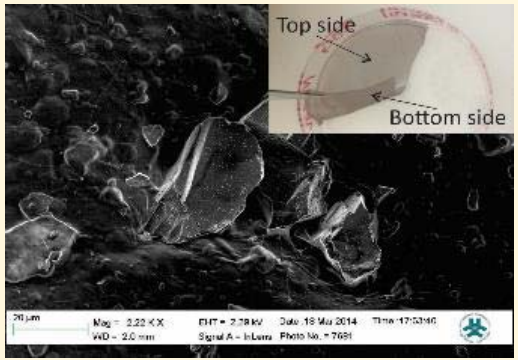
## EU H2020 - **Symphony** -

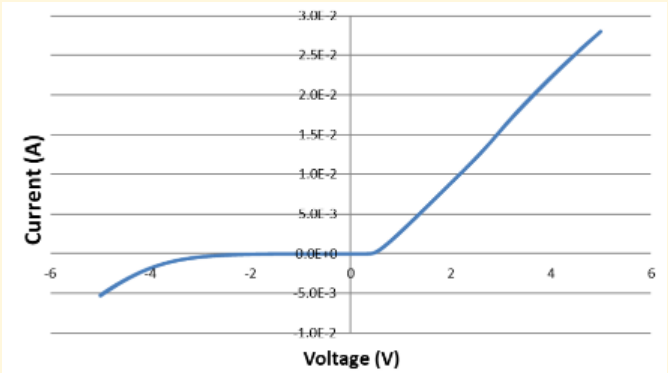
Smart Hybrid Multimodal Printed Harvesting of Energy

### DIODES

*Laminated*



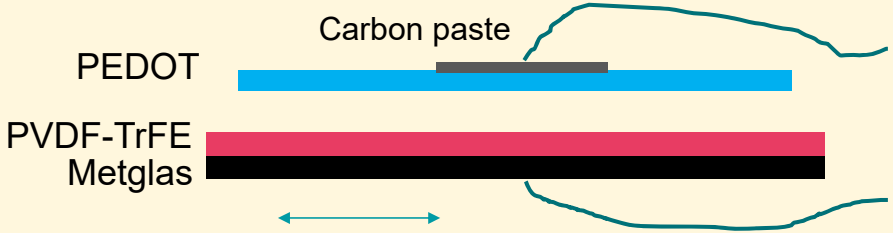
# Ex #4

EU H2020 - **Symphony** -

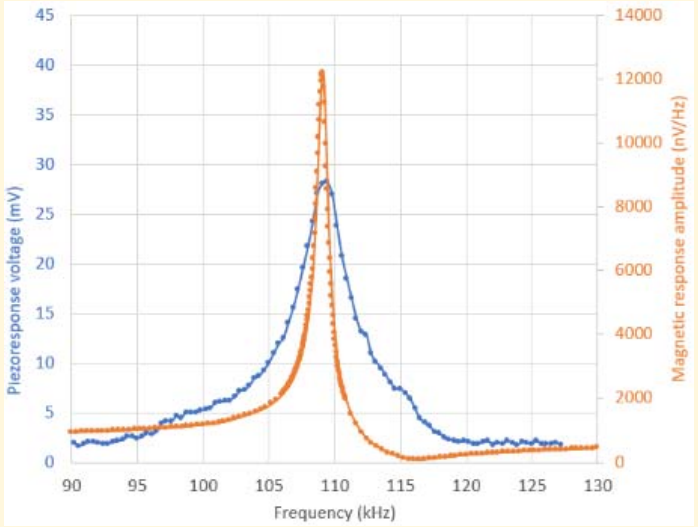
Smart Hybrid Multimodal Printed Harvesting of Energy

## Magnetoelectric coupling

***Non-contact* capacitive coupling electrode**




$$\alpha_{ME} = \frac{dE}{dH} = \frac{V_{piezo}}{tH_{ac}} = 950 \text{ V/(cm.Oe)}$$



# Ex #5 H2020 ECSEL – **Energy ECS -**

## Smart and secure energy solutions for future mobility

https://energyecs.eu

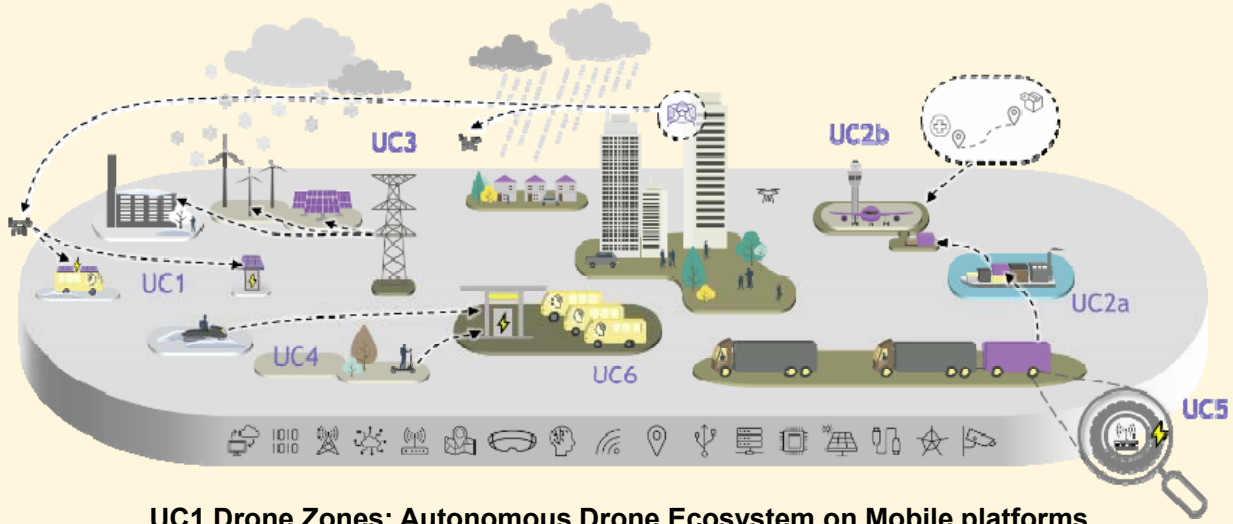
Develop **technologies** to improve **digitalization** of **e-mobility systems** and related **energy solutions**, forming the basis for future businesses and services.


2021 – 2024

# Ex #5

## H2020 ECSEL – Energy ECS -

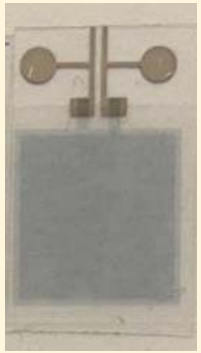
### Smart and secure energy solutions for future mobility




**UC1 Drone Zones: Autonomous Drone Ecosystem on Mobile platforms**
**UC2 Smart containers in intermodal transport**
**UC3 Smart grid with e-mobility**
**UC4 Vehicle to grid**
**UC5 Self-powered system in tyres**
**UC6 Autonomous driving of EV to charging station**

## Harvester system Challenges

- **A component is not a system**
- **Very light & small size**
  - **Flexible energy harvesters (piezo, tribo)**
  - **Enough energy**
- **Robustness**
  - **Electrical contacts**
  - **Mounting**



# Our Conclusions

- **In many applications: energy harvesting won't replace batteries but… there is interest to increase battery lifetime and/or reduce cables.**

- **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**
  - Power density
  - Ultra low power electronics (e.g. high voltage input)
  - Energy storage devices (e.g. current leakages)
  - Wireless communication consumption

- **Collaboration with industry**

# Thank you

# Questions?

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**cristina.rusu@ri.se**