SYMPHONY
EINE KOSTENEFFIZIENTE UND UMWELTFREUNDLICHE MÖGLICHKEIT, (NANO) ENERGIE ZU GEWINNEN

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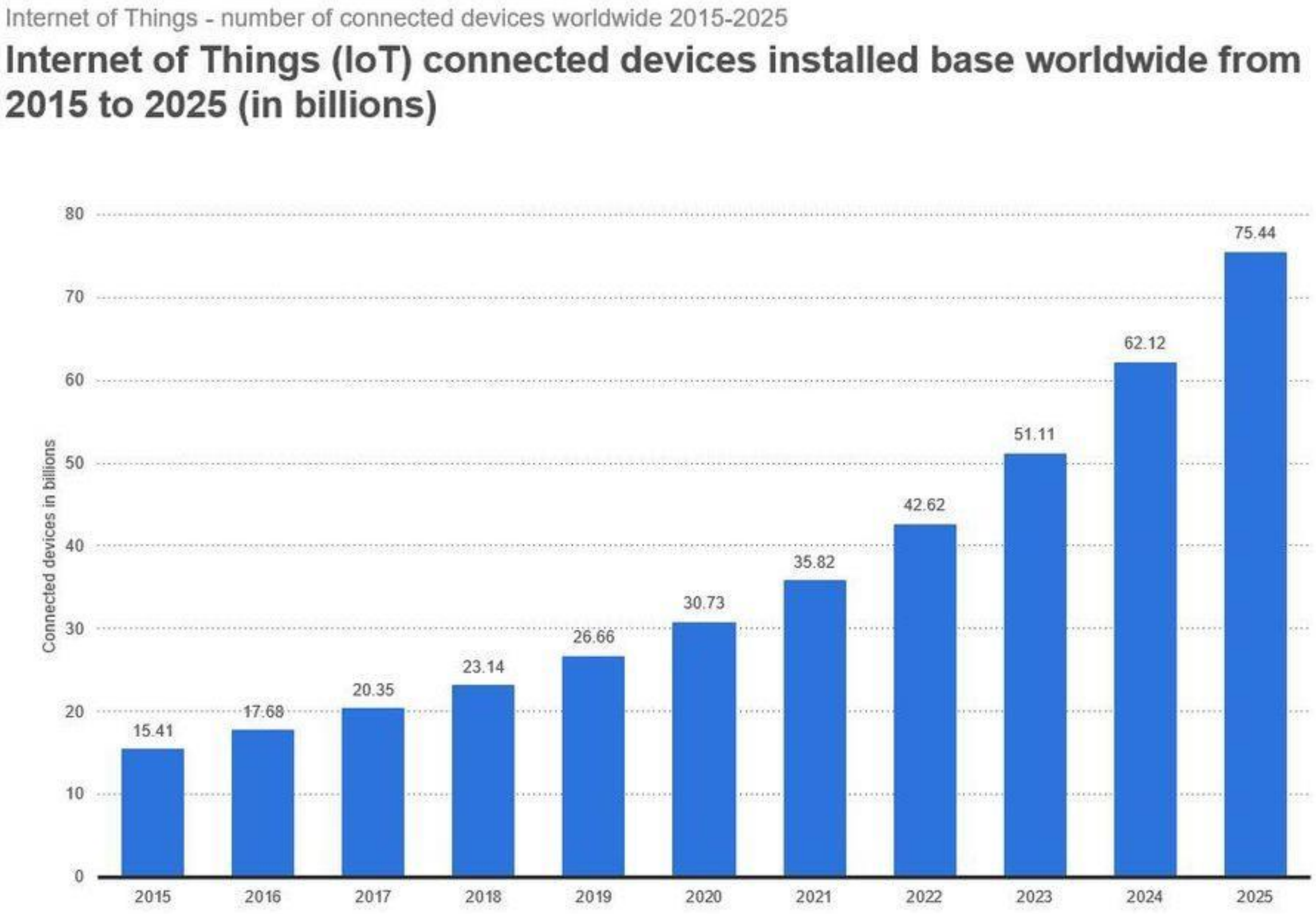
EnInnov 2022 Graz 16. – 18.2.2022

The SYMPHONY problem:

- In the future a lot of sensor will sent wireless data
- 75 billion connected devices by 2025
- Wireless data transmission is possible
- **But:** The sensor nodes need to be powered…



[1]

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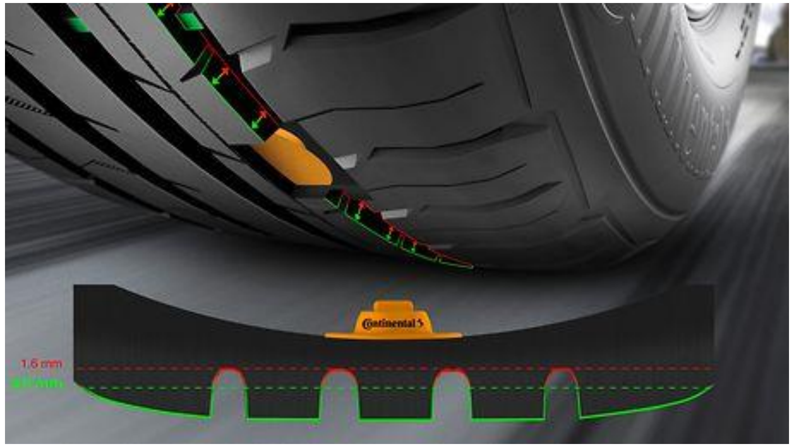
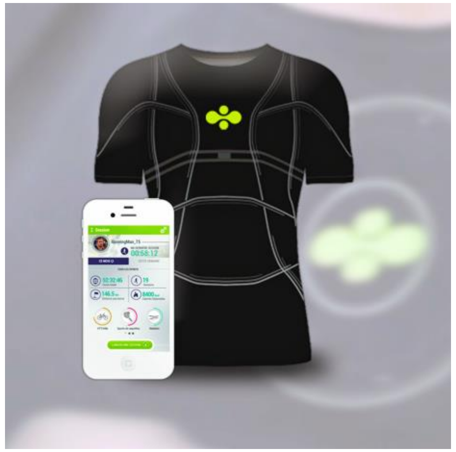
[1] https://objectbox.io/top-5-reasons-why-edge-computing-crucial-for-iot/

Examples for wireless sensor nodes:


[2]



[3]


[4]

Predictive maintenance at rails (wired) or in tires (battery)

Wearables


[5]


[6]

[2] https://www.lok-report.de/news/deutschland/industrie/item/4590-deutsche-bahn-sensor-zur-vorausschauenden-instandhaltung-von-weichen.html
[3] https://www.continental.com/de/presse/pressemitteilungen/2014-05-07-tpms-profile-105006
[4] http://sportmondo-sportsportal.blogspot.com/2014/04/e-textiles-electronic-textiles-2014.html
[5] https://alliancesensors.com/blog/bridge-monitoring-systems
[6] https://pingmonitor.co/smarter-wind-turbine-blade-performance.html

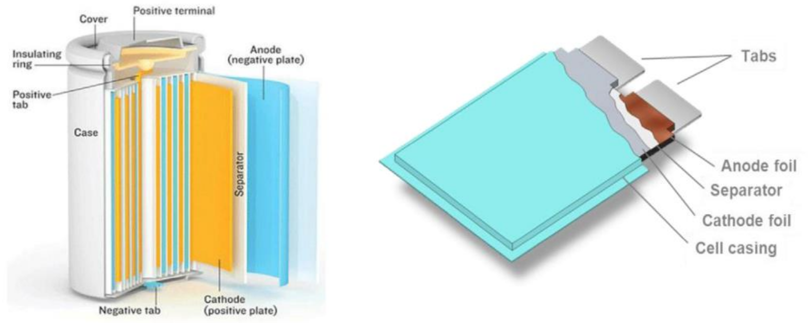
Condition Monitoring of wind turbines (acoustic) or bridges (strain sensor)

Introduction – Current technologies:

- **Wiring of sensor nodes:**
  - Tremendous installation effort
  - Often not possible (rotating parts, remote locations)
- Batteries:
  - Toxic waste
  - Limited lifetime

- **Energy Harvesting (usage of omnipresent energy sources)**

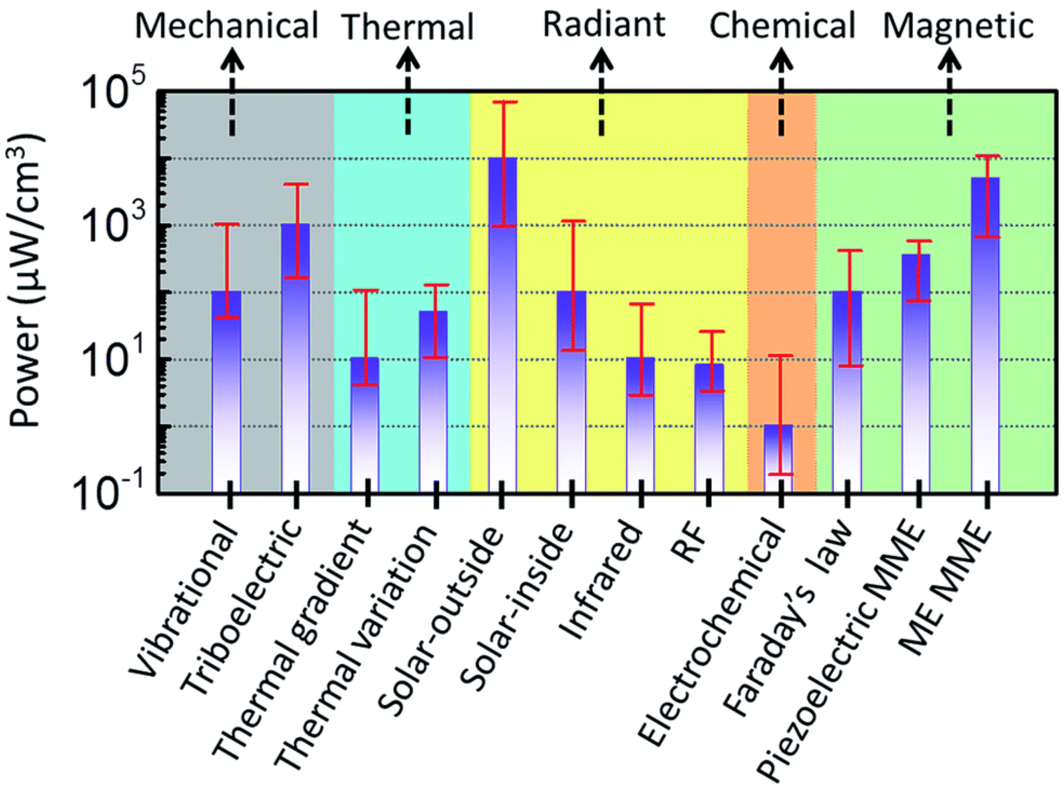
Current Li-ion battery



Zubi, G.; Dufo-López, R.; Carvalho, M.; Pasaoglu, G. The Lithium-Ion Battery: State of the Art and Future Perspectives. Renewable and Sustainable Energy Reviews 2018, 89, 292–308.

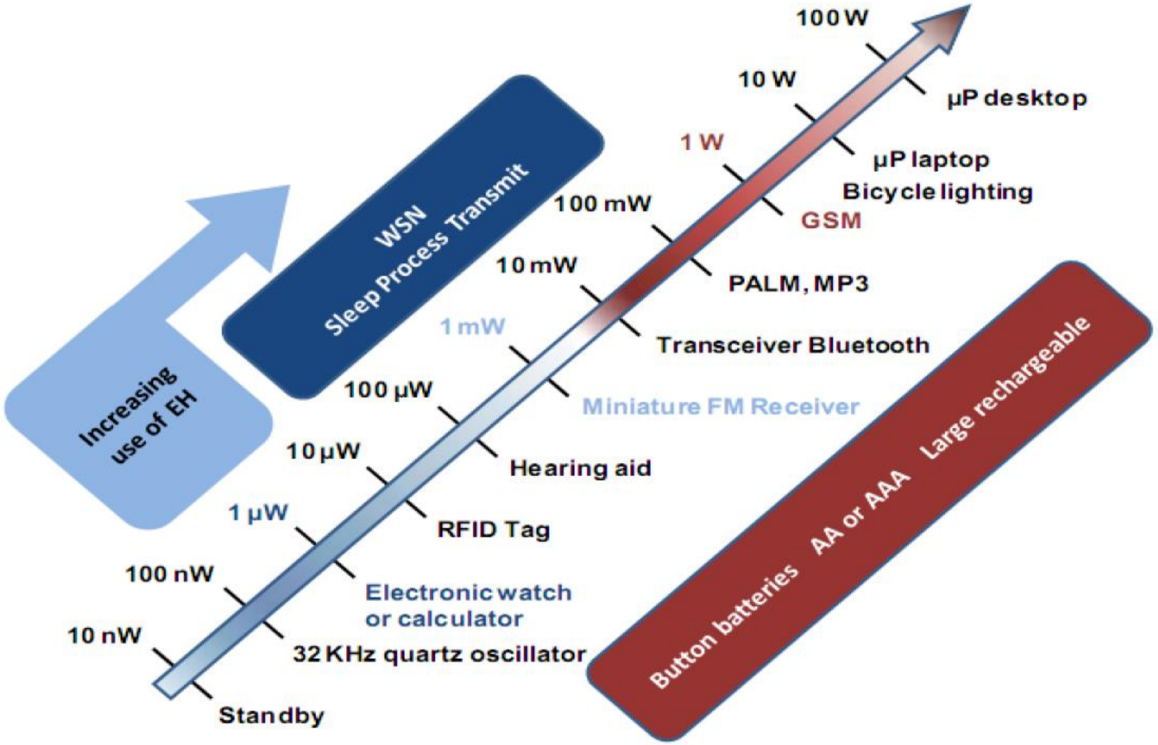
Energy harvesting / energy density

Harvesting energy from vibrational sources:
0,1 – 10 mW / cm³



Sustainable Energy Fuels, 2017,1, 2039-2052

Power requirement for wireless sensor nodes:
1 – 10 mW



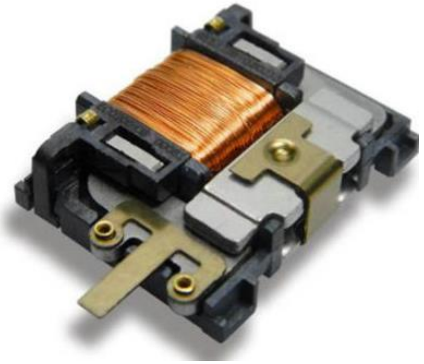
IDTechEx Report:
Energy Harvesting and Storage for electronic Devices 2009-2019

Commercial energy harvesting solutions:

Harvesting energy from vibrational sources:

- Huge amount of material input required
- Large device volume
- High cost Euro per mW

Enocean: ECO 200
Linear electrodynamic
Harvester: 120µJ bis 210µJ bei 2V
~ 400 µWs

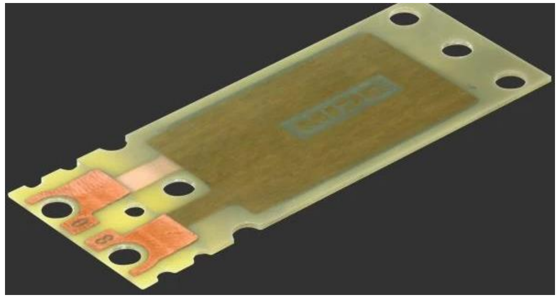


https://www.enocean.com/de/produkt-kategorie/kinetic-harvester-de/

Commercial available piezoelectric energy Harvester:

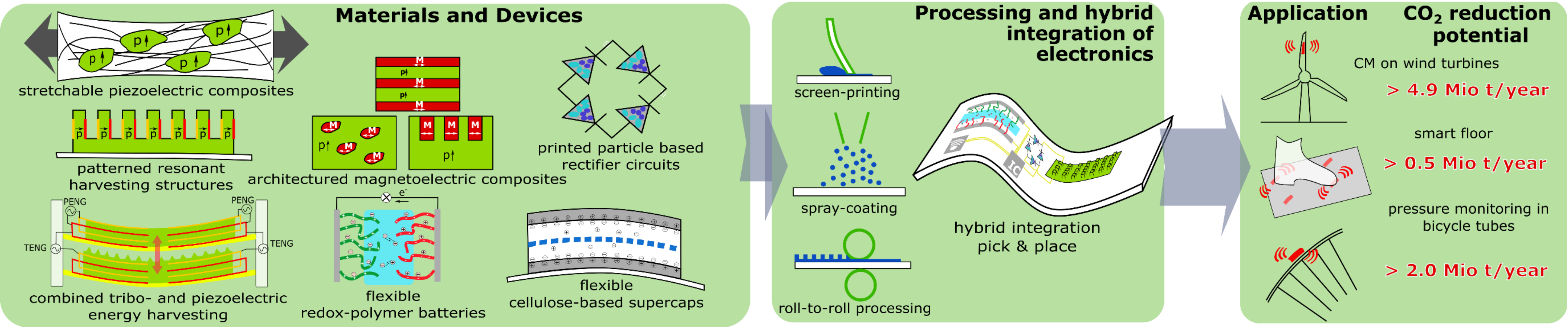
- Hazardous waste (Lead-based harvesters, batteries)
- High cost Euro per mW
- Short term energy storage required

Piezo.com
PZT based
Harvester:
14 mW
234 $



https://piezo.com/collections/piezoelectric-energy-harvesters/products/piezoelectric-bending-transducer-s233-h5fr-1107xb#&gid=1&pid=1

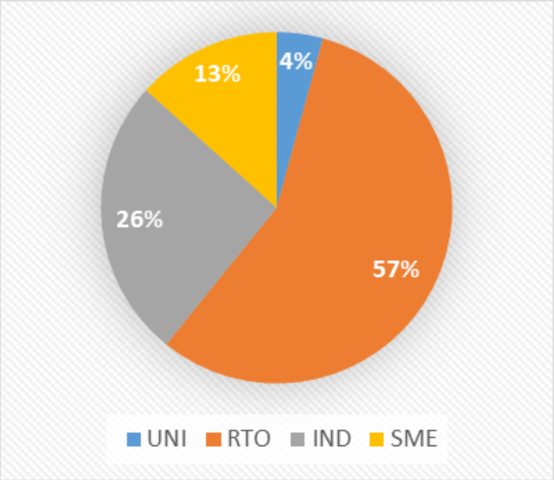
SYMPHONY @ a glance:

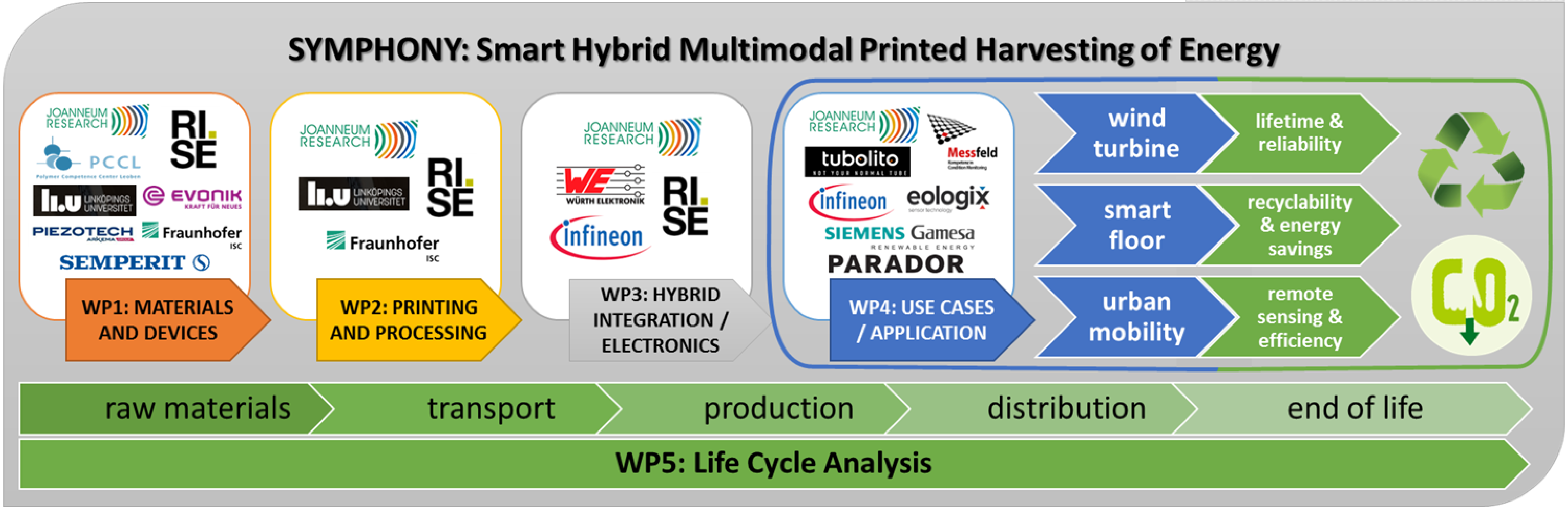


Raw Materials → New Materials → New Devices → Integrated energy autonomous sensor system (EASS) → CO_2 relevant use cases → CO_2 savings and reduction of hazardous waste based on LCA

The SYMPHONY consortium:

- **Project start:** 1/05/2020
- **Project end:** 30/04/2024
- 13 Partners, 4 countries:





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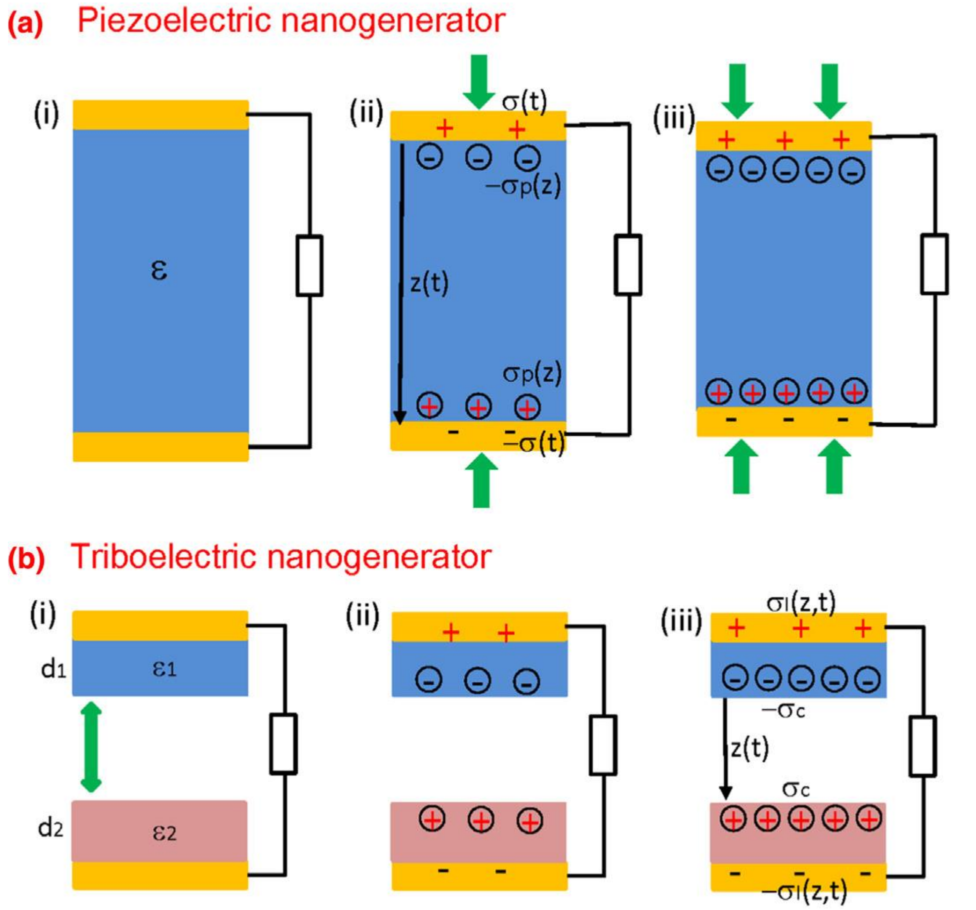
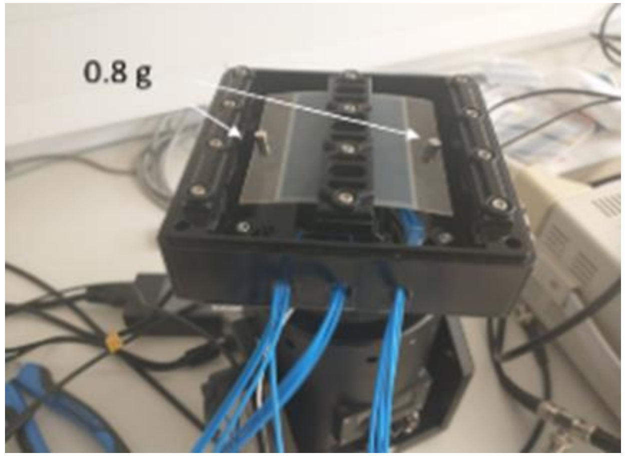
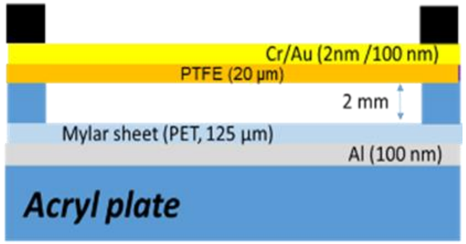
Energy Harvesting concepts:

Piezoelectric Nanogenerators

Triboelectric Nanogenerators







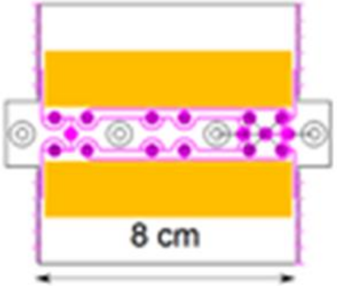
Cross section of TENG

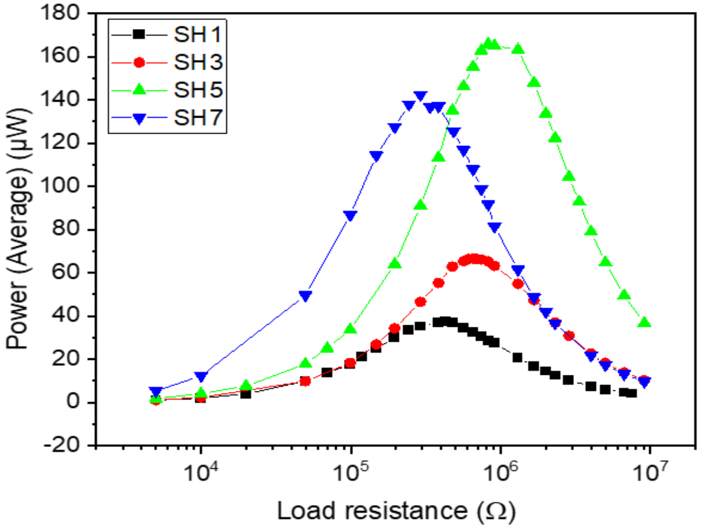
Luo, J., Gao, W., Wang, Z. L., The Triboelectric Nanogenerator as an Innovative Technology toward Intelligent Sports. *Adv. Mater.* 2021, 33, 2004178. https://doi.org/10.1002/adma.202004178

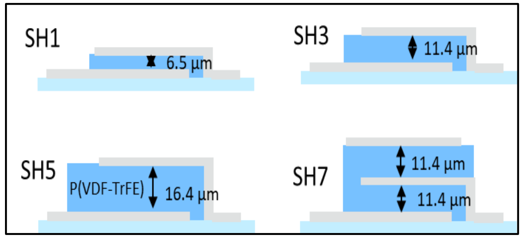
Energy output:

Flexible piezoelectric Nanogenerator

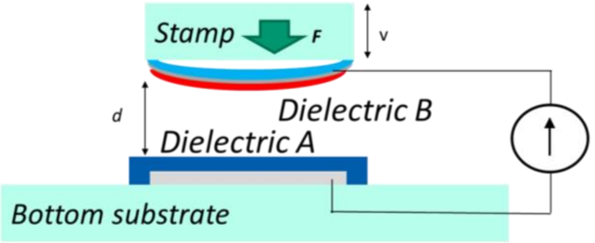
Acceleration 2 m/s^2
Tip mass: 0.85 g
Resonance 28 Hz







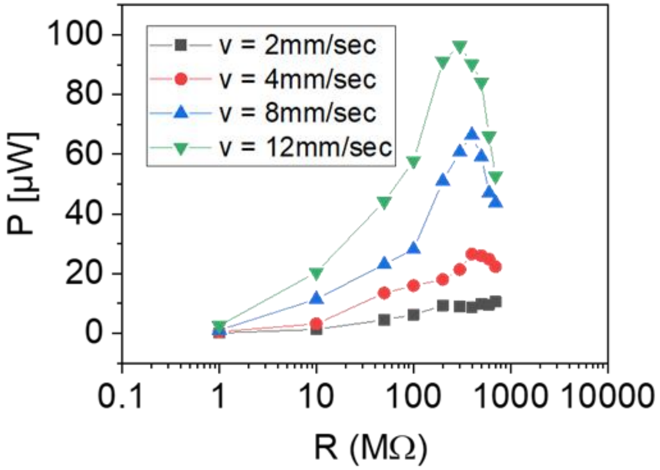
Printed triboelectric Nanogenerator



F ca. 2.1 N; v = 2, 4, 8,12 mm/sec;
controlled over displacement;

Peak Power $P \approx 0.1$ mW

(v ca. 12 mm/sec)



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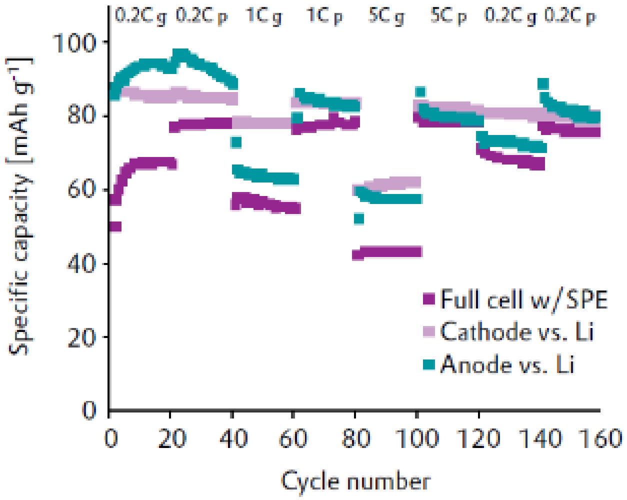
THE SYMPHONY ENERGY STORAGE

Batteries: Redox-polymer batteries

Supercaps: Cellulose based supercaps

Redox-polymer batteries:

- **Design freedom**
- **Flexible use**
- **Seamless integration**
- **Free of toxic substances**
- **Rechargeability**
- **Scalable production**

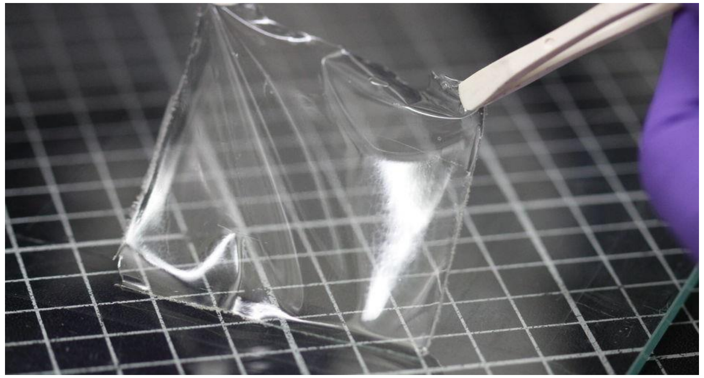


- Voltage of single cell 1–1.3 V
- Capacity retention after 160 cycles 70–90%
- Rate capability (5C/0.2C) 60%

Printed battery

3 functional inks

solid electrolyte



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https://www.taettooz.com

EVONIK Leading Beyond Chemistry

Nanocellulose supercaps:

Energy Density 0.8 Wh/kg

Areal Power Density 10 mW/cm^2

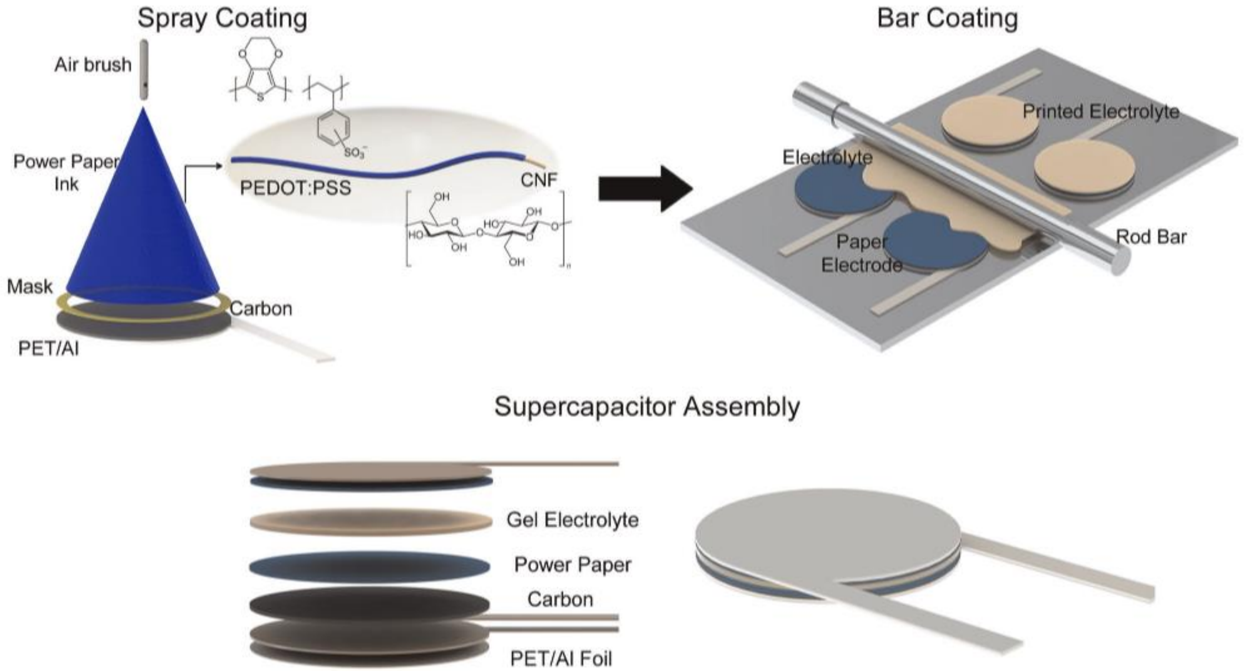
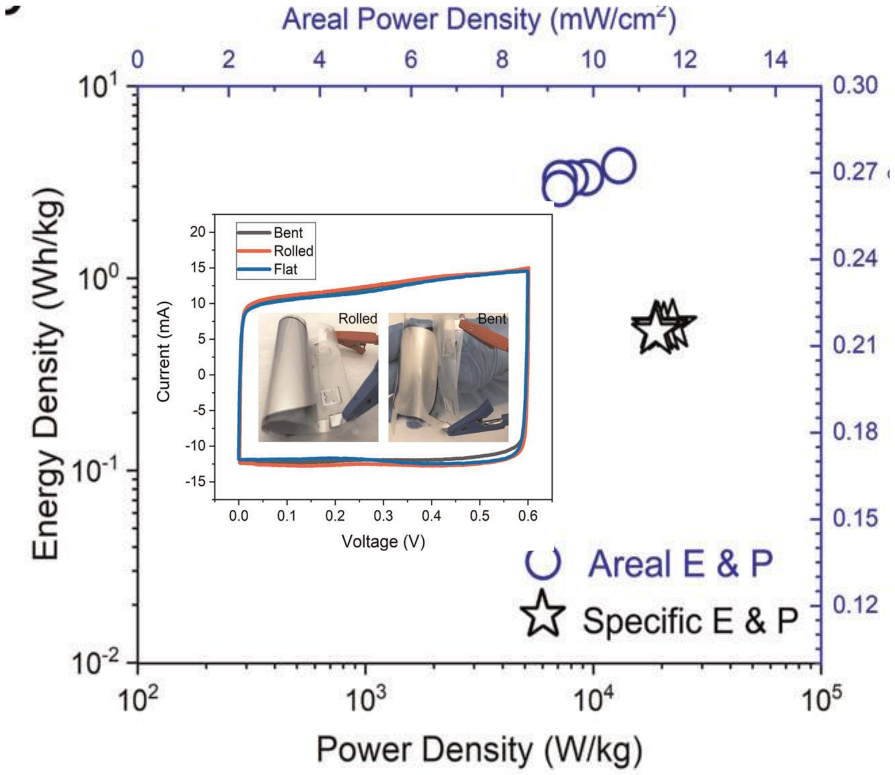


Fig. 1 Fabrication scheme of spray-coated printed paper supercapacitor. Schematics represents the printing steps and components of the paper supercapacitors.



Say, M. G.; Brooke, R.; Edberg, J.; Grimoldi, A.; Belaineh, D.; Engquist, I.; Berggren, M. Spray-Coated Paper Supercapacitors. npj Flex Electron 2020, 4 (1), 14. https://doi.org/10.1038/s41528-020-0079-8.

THE SYMPHONY USE CASES

Enegry production: Wind energy

Room heating and cooling: Smart floor

Urban mobility: Bicycle tubes

Energy production: Condition monitoring on wind turbines

Condition monitoring on wind turbines can

- increase lifetime of wind turbines
- increase uptime
- reduce

SYMPHONY solution:

Generating of energy from **vibrations** and **wind turbulences** using **piezoelectric and triboelectric energy harvesting** also in

- during the night
- long Scandinavian winters
- Reduce energy storage needed (currently 40 coin cells)
- increase the rate of date transfer

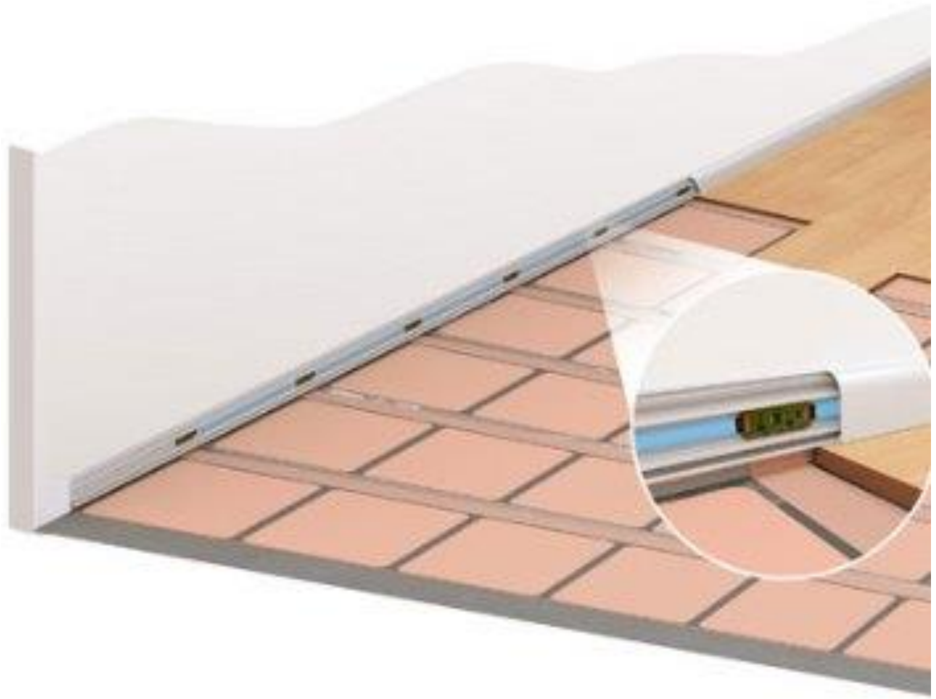
Installation possible on existing wind turbines

eologix
sensor technology

Self powered activity tracking in smart floors:

Smart floor:

- Self-powered activity sensing
- Regulate room temperature, ventilation and cooling with respect to activity in public buildings
- Usage-monitoring in public buildings
- Improved privacy detection compared to cameras
- Ambient assisted living
    - Fall detection



https://at-aust.org/items/12660

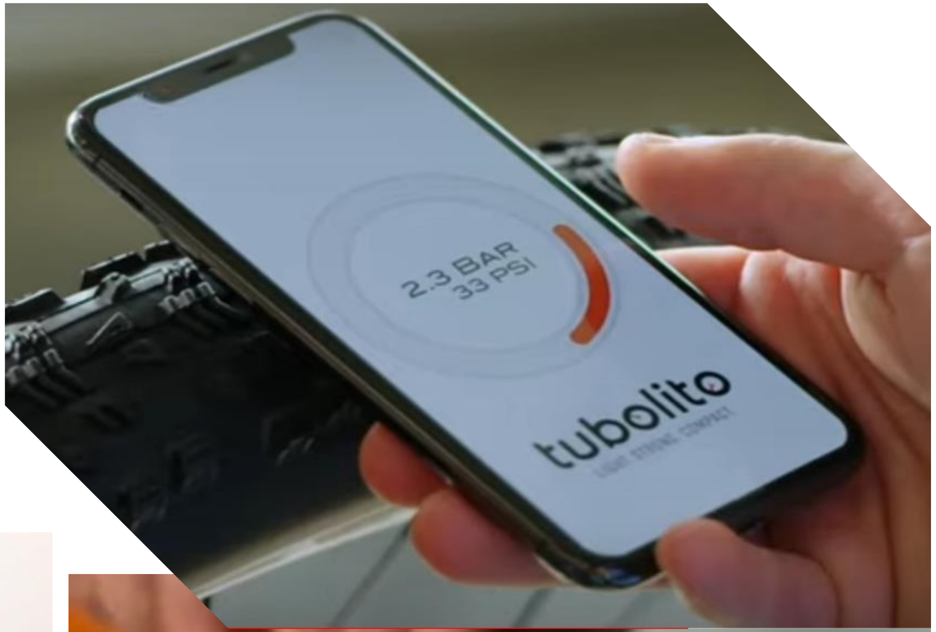
PARADOR

Pressure monitoring in bicycle tubes:

tubolito
LIGHT WEIGHT TUBES

Urban mobility:

- Self-powered wireless tube pressure data.
- Reducing rolling resistance
- Increase cycling comfort
- Switching from NFC to BLE communication
- Improve maintenance of bike rental systems



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Life cycle analysis (LCA):

1st level Materials
- Lead-free piezoelectric harvesters
- Cellulose based supercaps
- Non-toxic redox polymers for batteries

2nd level Processing
- Energy efficient low temperature processes
- Efficient material use in additive Processes
- Energy efficient electronics

3rd level Application
- Increasing the lifetime of wind turbines
- Reduced energy consumption in buildings
- Reduced energy consumption in e-Bikes

Reduction of **hazardous waste** and **CO_2 emissions** in the LCA based specific application scenarios

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Conclusions:

Energy harvesting

- **Can not** be used for large scale power generation
  - High amount of material input needed per mWh
  - High amount of electronic components needed per mWh

Energy Harvesting

- **Can** power wireless sensors where wiring is not possible
- **Can** prevent the usage of toxic battery waste
- **Can** lift energy efficiency potentials using sensor data

SYMPHONY develops Energy harvesting:

- From nontoxic materials
- Processed with resource efficient printing techniques
- Applied to lift efficiency in CO_2 relevant use cases (power generation, urban mobility, room heating and cooling)

Infineon

EVONIK
Leading Beyond Chemistry

eologix
sensor technology

RI.
SE

Messfeld
Kompetenz in
Condition Monitoring

SYMPHONY

PCCL
Polymer Competence Center Leoben

LINKÖPING
UNIVERSITY

WÜRTH ELEKTRONIK

ARKEMA
INNOVATIVE CHEMISTRY

tubolito
LIGHT WEIGHT TUBES

Fraunhofer
ISC

SEMPERIT

JOANNEUM
RESEARCH
MATERIALS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862095.

www.joanneum.at/materials

THANK YOU FOR YOUR ATTENTION!

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