# ENERGY HARVESTING
# E4IoT

## CLEAN ENERGY FOR IoT AND OTHER ELECTRICAL DEVICES

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Österbottens förbund
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# 1 BACKGROUND

## Participating companies














The main aim of this work was to develope technologies by which it is possible to

**get clean and environmentally friendly electrical energy**

from the changes in the environment without batteries and electrical wires.

This technology is called energy harvesting

This electrical energy is used to power
IoT and other electrical devices

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# 2 NEED OF ENERGY HARVESTING

## Market needs

Dramatical market growth potential for wireless and battery-free IoT

- The market of IoT devices is already forecast to grow dramatically. Few markets go from under  $8 billion to over $121 billion in 2041.
- This market, which is still at an early stage, could quickly take off within a few years and reach $30 billion dollars by 2030.

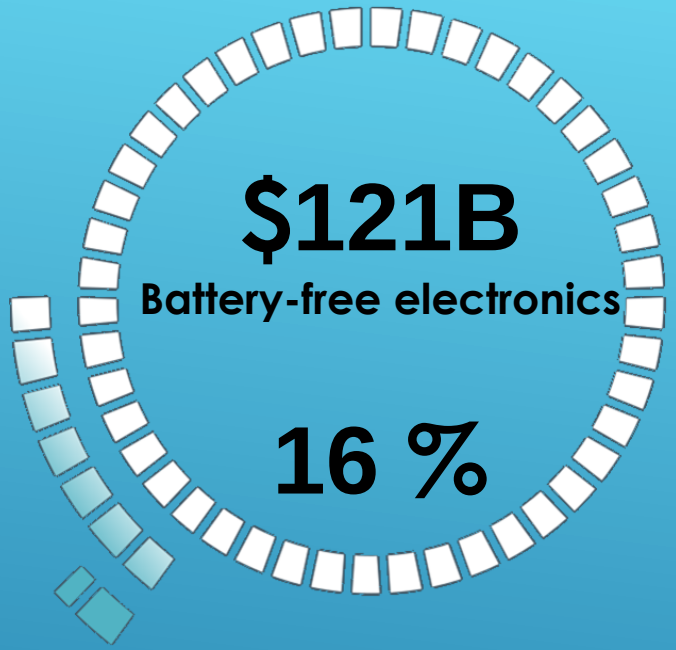


*Fig. 1. Market growth in wireless and battery free IoT.*

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**Forecast by IdTechEx Battery Elimination in Electronics:** Market Impact IoT, 6G, Healthcare, Wearables 2021-2041

# Technology needs

The needs of the participating companies of the project partners.

- Condition monitoring of the electrical power network (low, medium, and high voltage)
- Measurement and condition monitoring of the distribution transformers
- Condition monitoring of electrical devices and electrical machines
  – engines, generators, pumps (temperature, vibration, and electrical quantities)
- Powering of field sensors
- Measurement and monitoring of the temperature of electrical instruments
- New remote monitoring solutions
- measurement and monitoring of operational environments (temperature, humidity, wind)
- Powering of IoT sensors

- Intelligent actuators
- Equipment inside electrical transformers
- Cost-effective, small and low-power data communication sensors
- Measurement of electric discharge
- 3-D acceleration sensors
- Development of reliable and energy-efficient electronics for the harvester modules
- Development of energy storage solutions for the harvester
- New environmental technology
- Following the development of energy harvesting technologies

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# 3 BATTERY POWERED IoT

**ENVIRONMENT**

**Batteries:**
- bad for the environment (lithium extraction, toxic and GHG gases and battery disposal)
- challenging to replace and recycle (1% recycled today)
- insufficient use of energy

**MAINTENANCE**

**Batteries:**
- high maintenance costs
- cannot be accessed for maintenance in military and many civil engineering applications

**LIFESPAN**

- **Batteries:** Short lifespan approx. 4 years

*Fig. 2. Challenges of battery-powered IoT.*

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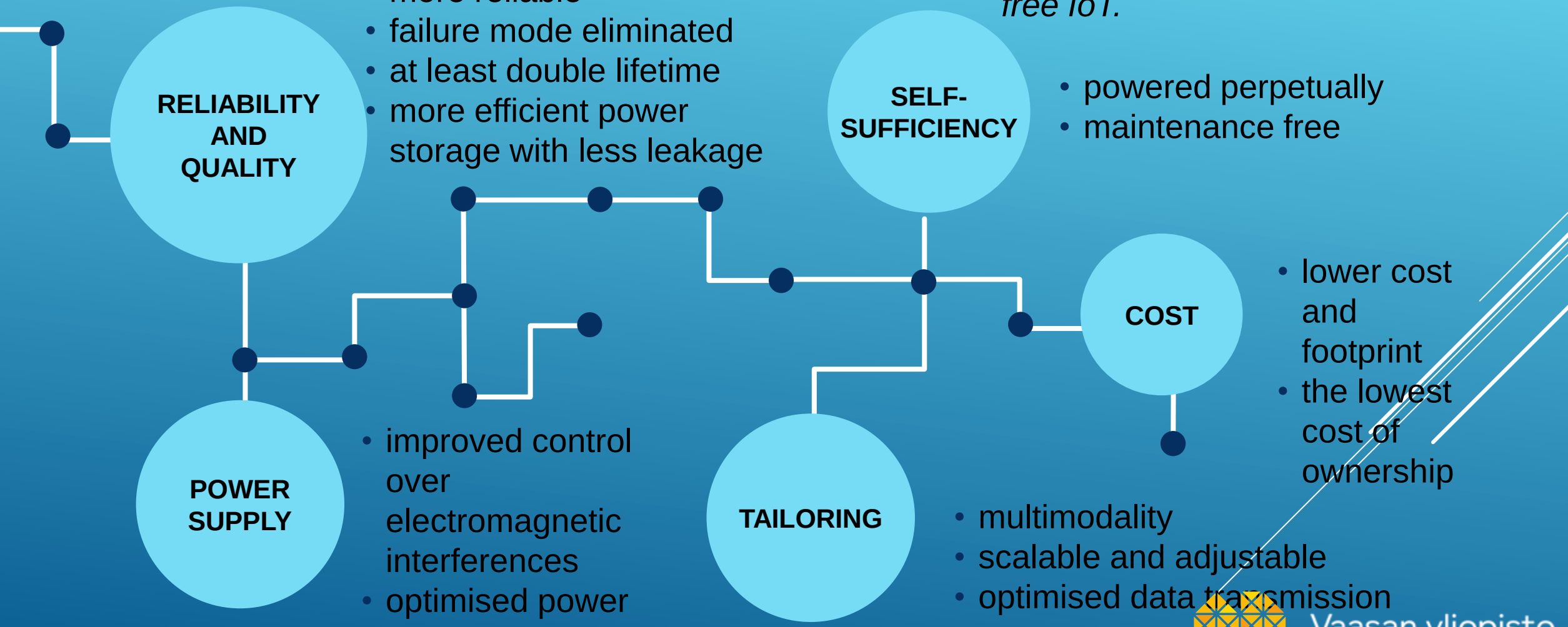
# 4 WIRELESS AND BATTERY - FREE IoT

*Fig. 3. Advantages of energy harvesting and wireless and battery free IoT.*

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# 5 DEVELOPED ENERGY AUTONOMOUS IoT PLATFORM

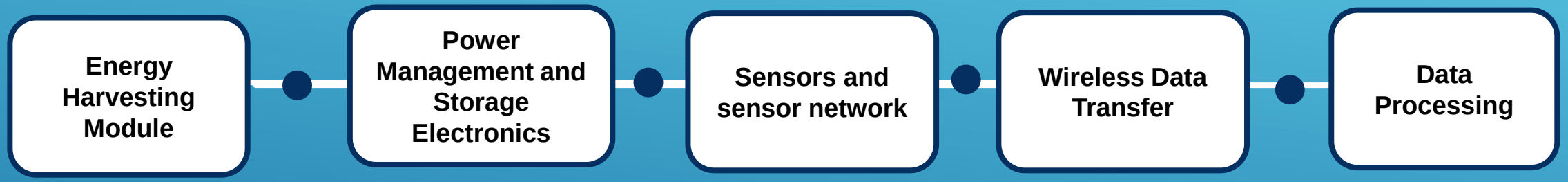


*Fig.4. Energy autonomous IoT platform developed in the project.*

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# Ready for Proof of Concept

We have demonstrated five different energy harvesting technologies and energy harvesting platforms generating sufficient power (5 - 50 mW range) to run various sensors collecting data as well as sending the data using wireless data transfer.

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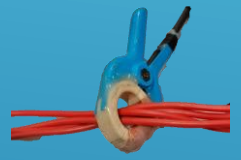
# 6 CHAIN OF ENERGY HARVESTING – FROM SOURCE TO DATA USAGE

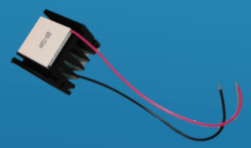
**ELECTRIC FIELD**
- High and medium voltage power lines
- Capacitive

**MAGNETIC FIELD**
- Inductive



**ELECTROCHEMICAL**
- Electrochemical cell

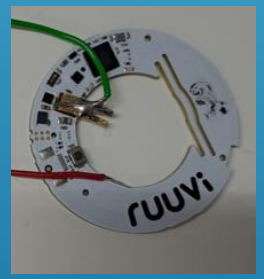
**THERMOELECTRIC**
- Peltier element



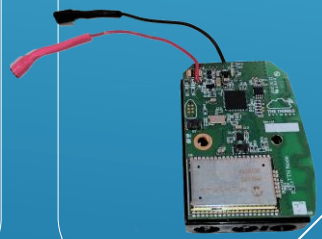
**KINETIC ENERGY**
- Movement and vibration

**POWER MANAGEMENT ELECTRONICS AND ENERGY STORAGE**
- rechargeable battery
- supercapacitor

**SENSORS**
- temperature
- humidity
- air pressure
- vibration
- acceleration
- etc...




**DATA TRANSFER**
- lorawan
- wifi
- bluetooth

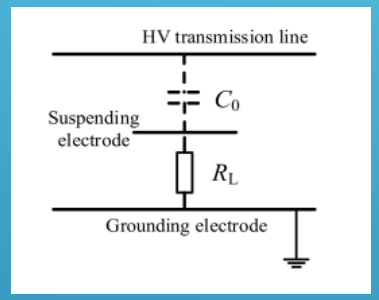


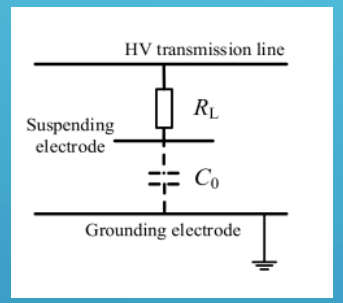
**DATA RECEIVER AND USAGE**
- storage
- procesing
- analysis

*Fig. 5. Chain of energy harvesting: energy source - power management electronics – sensors - data transfer - receiver and usage.*

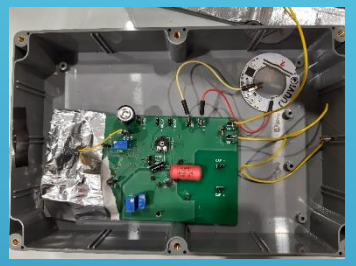
# CAPACITIVE ENERGY HARVESTING

## ➢ Energy from high voltage power lines




- Low potential and high potential energy harvesting under power line.



- Capacitive harvester and power managnement electronics.

- Wireless data transfer, bluetooth.

- Technobothnia high voltage laboratory measurements

- Vaasa Electricity transforming station.

*Fig. 6. Capacitive energy harvesting from high voltage power lines.*

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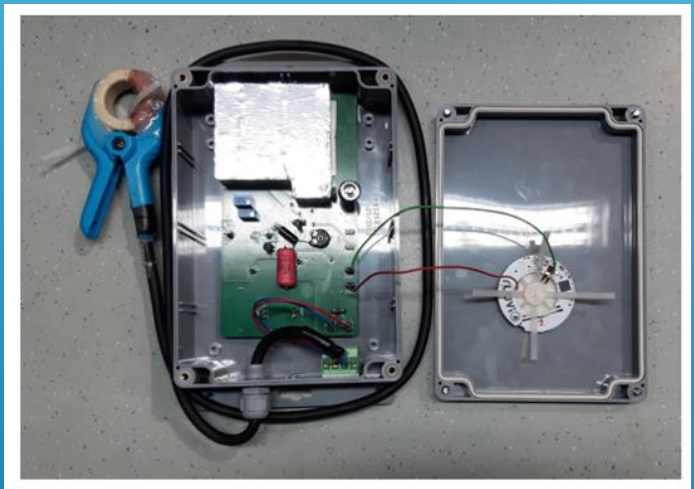
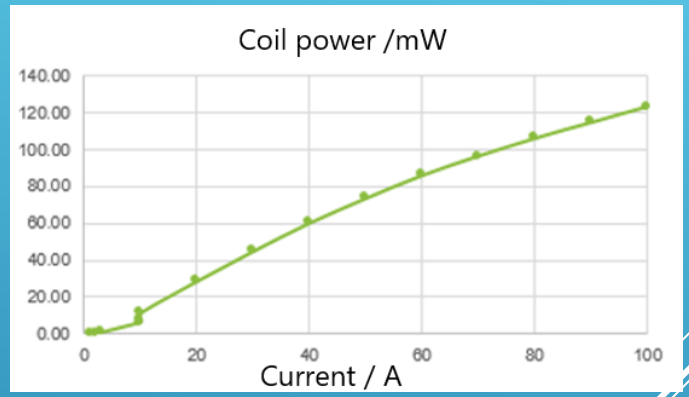
# INDUCTIVE ENERGY HARVESTING

## ➢ Energy from power linens



- Wireless data transfer




- Inductive harvester and power management electronics.
- Power as a fuction of current.

*Fig. 7. Inductive energy harvesting from low voltage power lines.*

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# ELECTROCHEMICAL ENERGY HARVESTING

- Energy from chemical reactions

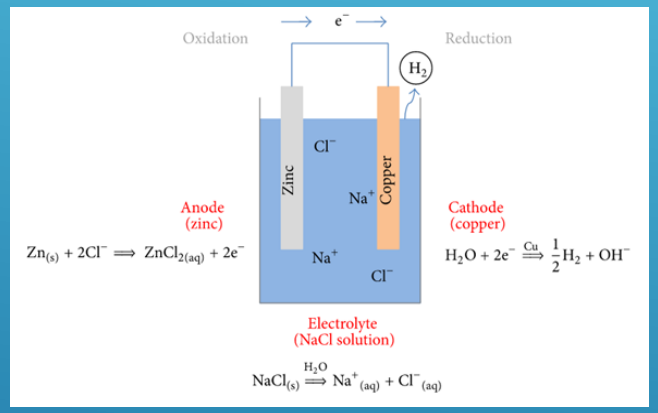


*Fig.8. Electrochemical cell consists of two electrodes, electrolyte and external circuit.*

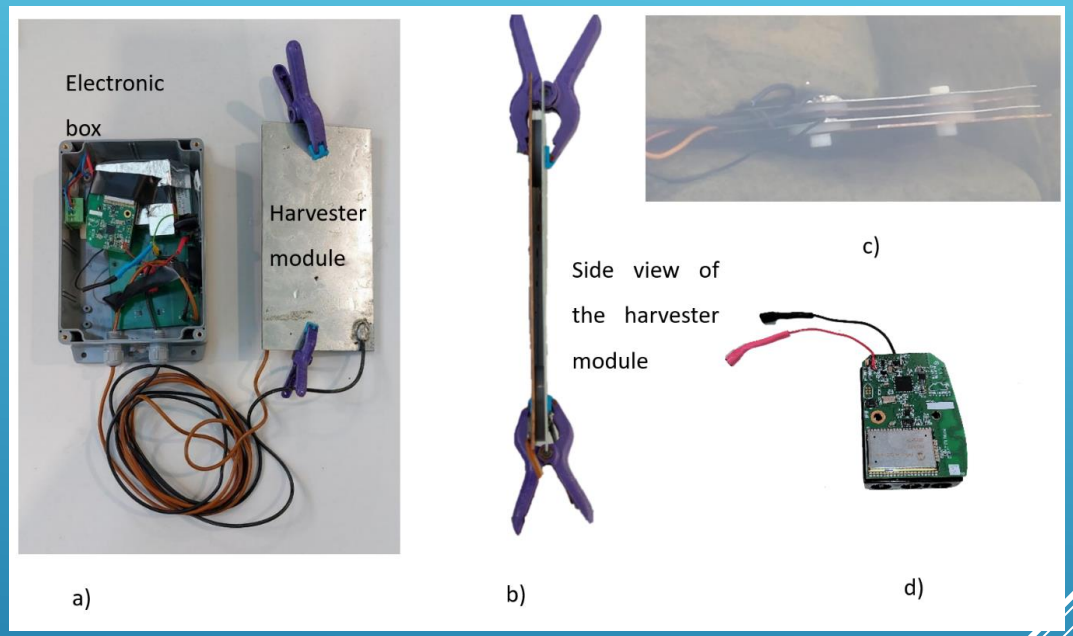


*Fig. 9. Electrochemical energy harvester.*

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(25) Byrne, Aimee & Barry, Shane & Holmes, Niall & Norton, Brian. (2017). Optimising the Performance of Cement-Based Batteries. Advances in Materials Science and Engineering. 2017. 1-14. 10.1155/2017/4724302.

*Fig. 10. Electrochemical harvester tests on the sea side.*

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- One zinc and one copper plate in seawater. Size of the plate is 20 x 10 cm

*Fig. 11. Electrochemical energy harvesting devices in the laborartory.*

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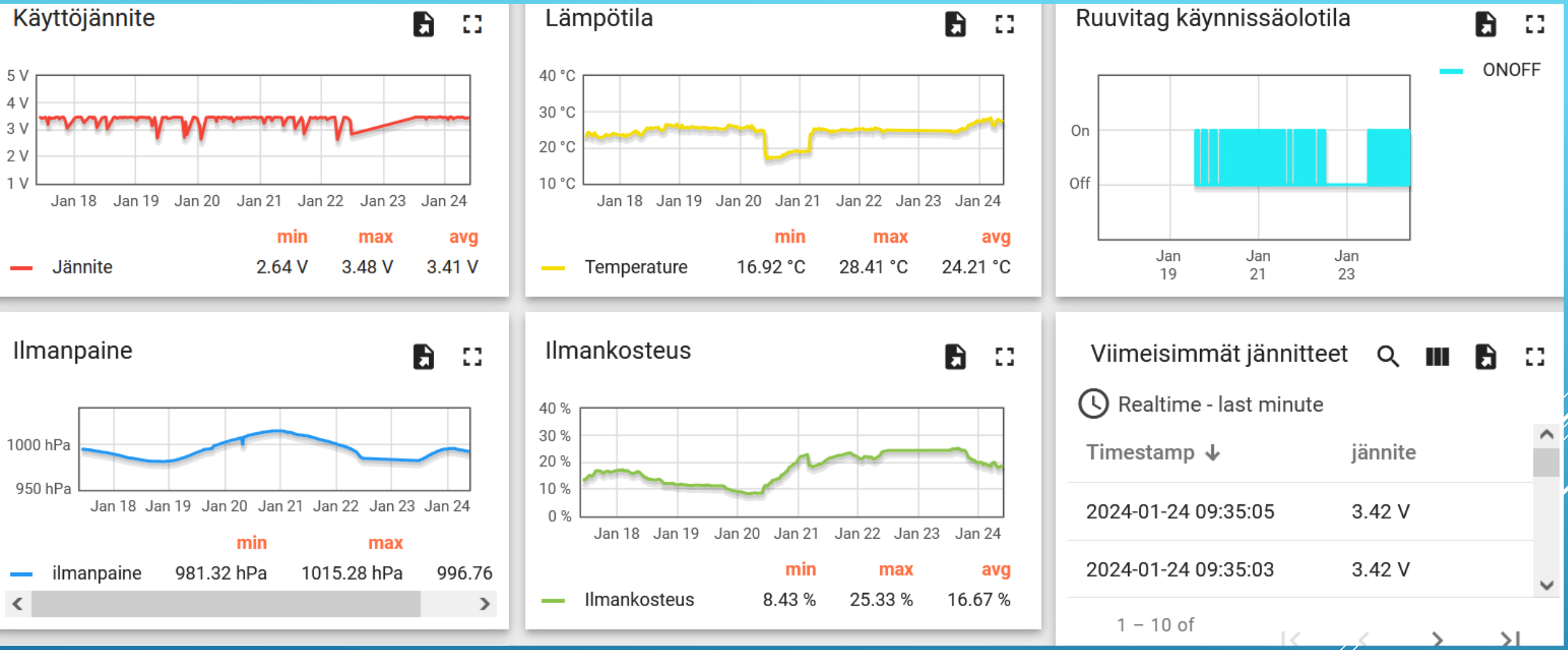


*Fig. 12. Measuring results of the electrochemical energy harvester platform. Voltage of the energy storage capacitor, temperature, air pressure and air humidity.*

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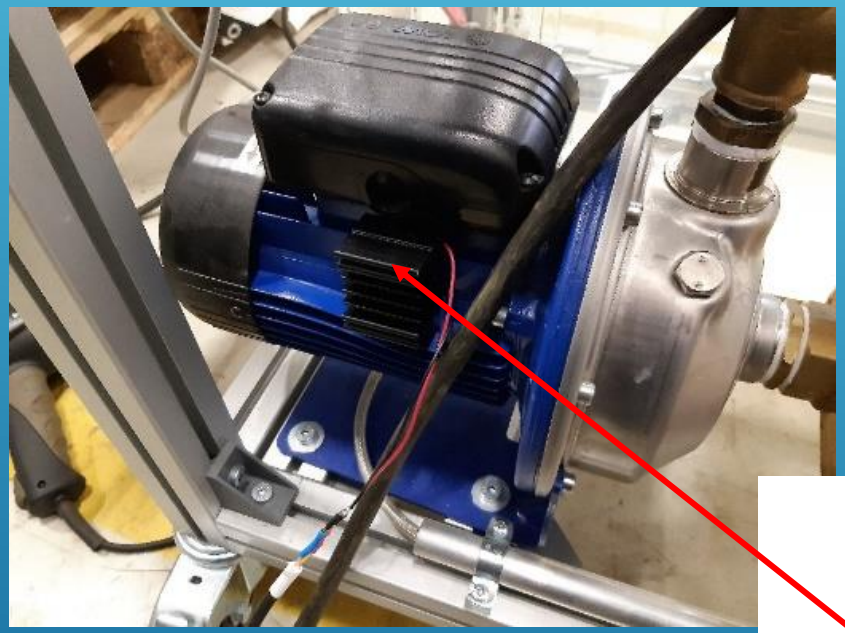
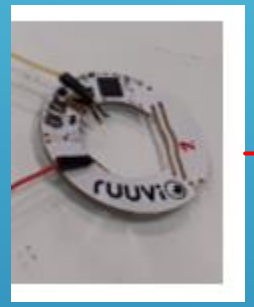
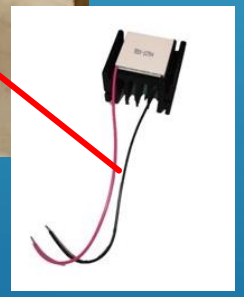
# THERMOELECTRIC ENERGY HARVESTING

- Energy from temperature differences







- Peltier element placed to the surface of electric engine.

- Wireless data transfer with Bluetooth.

*Fig. 14. Testing of the thermoelectric harvester on the field.*

*Fig.13. Thermoelectric energy harvesting from the surface of electric engine.*

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# KINETIC ENERGY HARVESTING

- Energy from vibration and movement

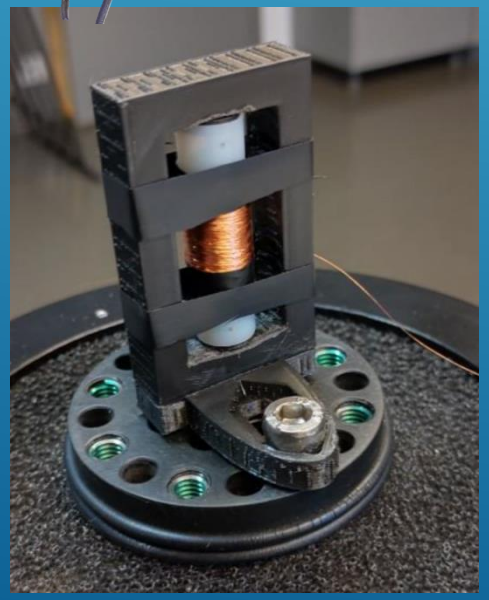

*Fig. 15. Kinetic energy harvesters.*

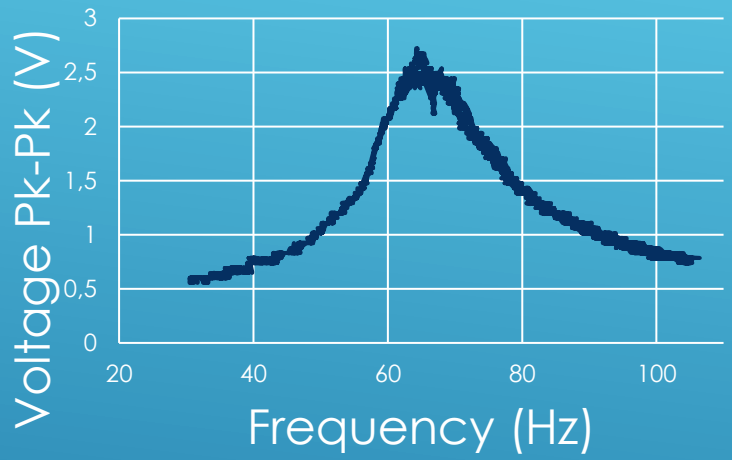


*Fig. 16. Pk-Pk voltage from the kinetic energy harvester as a function of frequency.*

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# 7 CONCLUSIONS

## Ready for Proof of Concept

- Five different energy harvesting technologies and energy harvesting platforms were demonstrated.
- These platforms generates sufficient power (5 - 50 mW range) to run various sensors collecting data as well as sending the data using wireless data transfer.

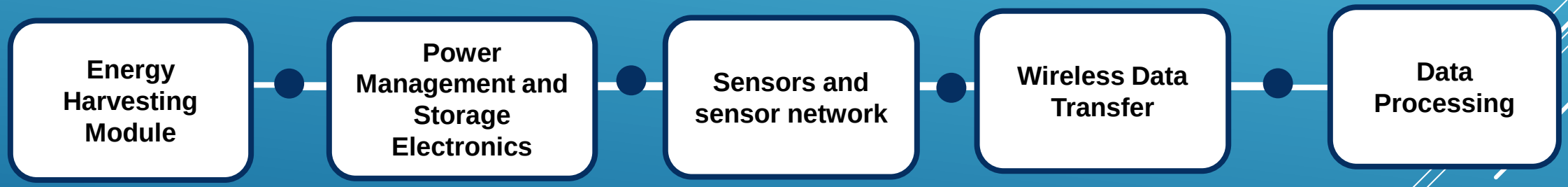


*Fig.17. Energy autonomous IoT platform from energy source to data processing.*

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