Long Life Power Platforms for Internet of Things

LoLiPoP-IoT

Chips JU — EUROPEAN PARTNERSHIP

Condition Monitoring UCs

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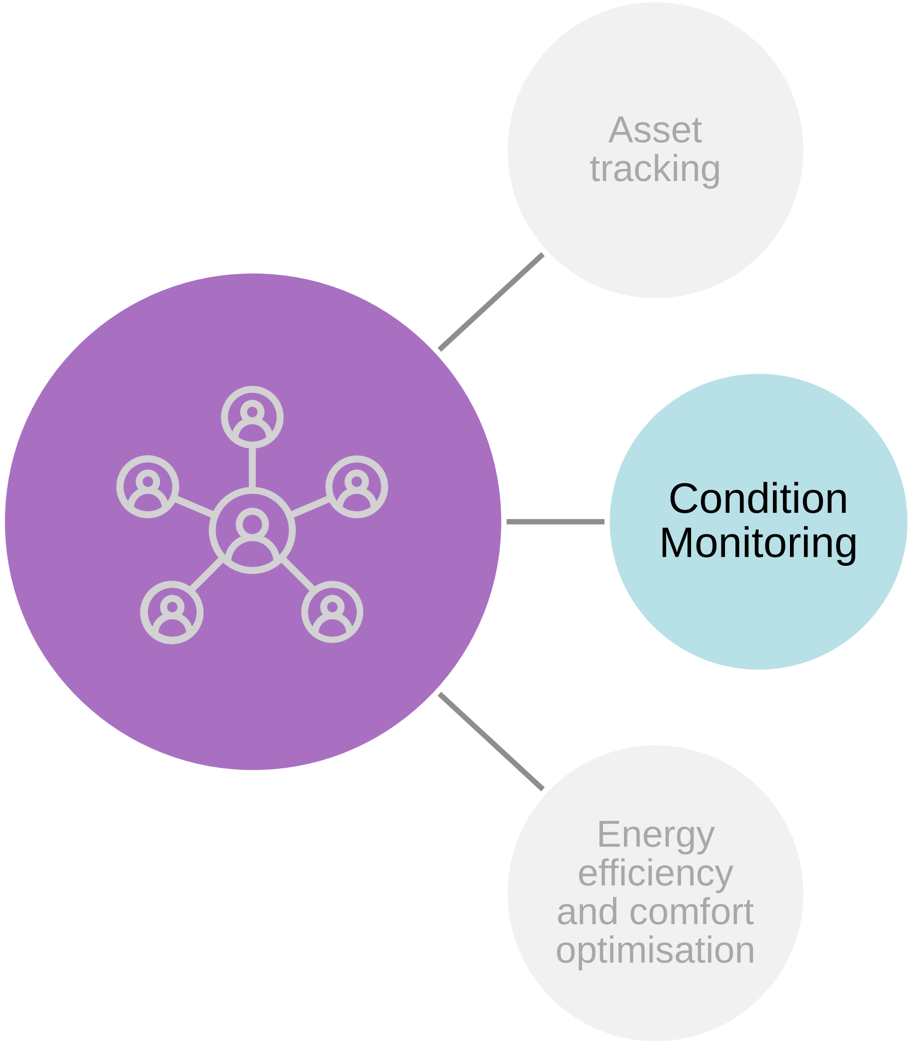
Supported by edacentrum

Fields of Action and Economic Impact



Motivation

- Maintenance costs range between 15% and 40% of total production costs*
- Unplanned downtime costs industrial manufacturers ~ $50 billion annually**

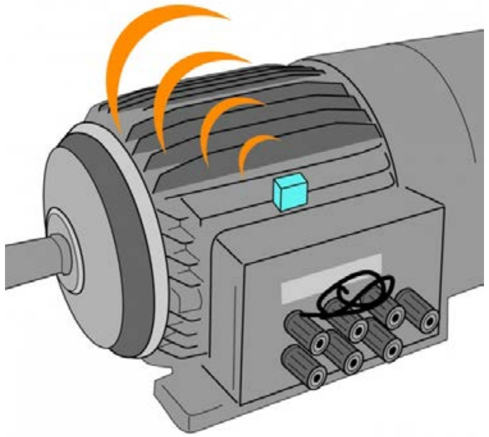
Goal

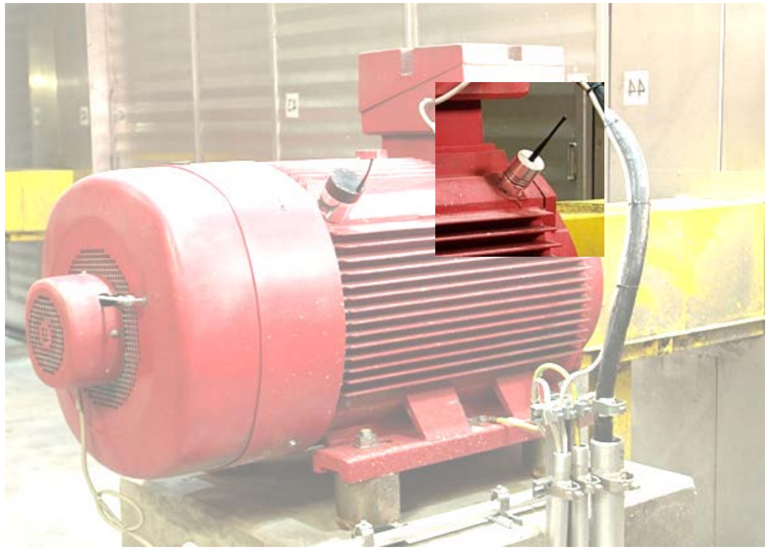
- Reduce maintenance overhead and operational downtime
- Increase Resource Efficiency
- Detection of anomalous equipment behavior and improve safety

* https://www.onupkeep.com/learning/maintenance-metrics/maintenance-statistics
** https://www.parsable.com/parsable-blog/12-manufacturing-maintenance-management-statistics

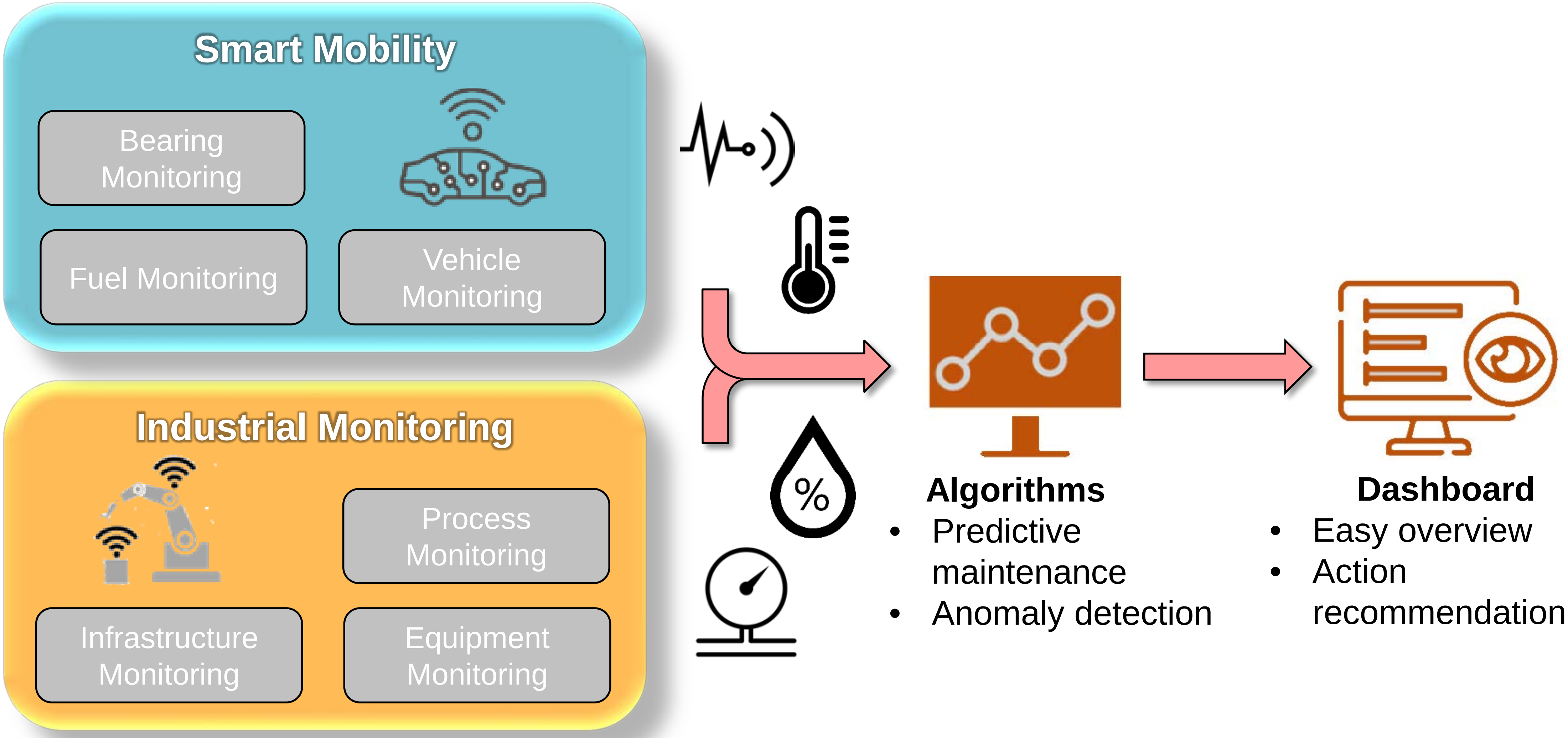
Requirements for Realization

- **Retrofitting solutions for existing infrastructure and equipment**
  - Compatibility with legacy systems
  - Modular platforms to adapt to various equipment types and brands
- **Easy installation and maintenance**
  - Plug-and-play
  - Longevity
- **Withstanding harsh industrial environments**
- **Non-intrusive operation**
  - EMC
  - Wired vs. Wireless





Applications of Condition Monitoring



Towards Edge Computing in Condition Monitoring

› **Centralized approach**

Raw data acquisition
Minimal processing
Communication of Data

Data handling

Database
Algorithms
Decision support

Towards Edge Computing in Condition Monitoring

LoLiPoP-IoT

› Centralized approach

Wireless Sensor Node → Gateway/ Base station → Server/ Cloud

Wireless Sensor Node	Gateway/ Base station	Server/ Cloud
Raw data acquisition Minimal processing Communication of Data	Data handling	Database Algorithms Decision support

› Decentralized approach

Smart Sensor Node → Gateway/ Base station → Server/ Cloud

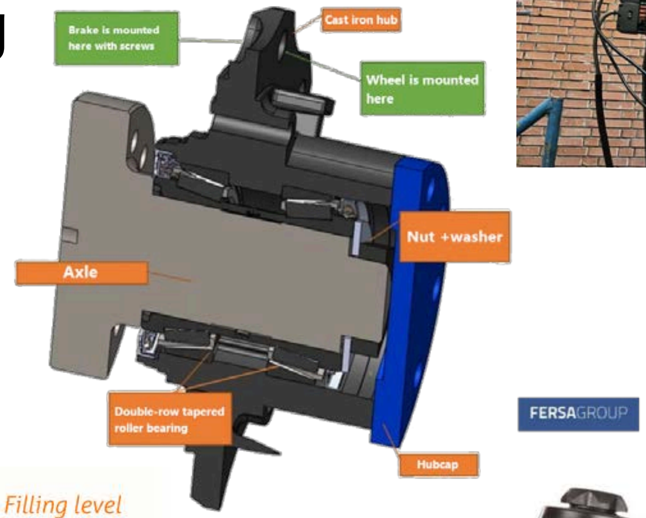
Smart Sensor Node	Gateway/ Base station	Server/ Cloud
Raw data acquisition Edge computing for extended processing and algorithms Communication of information	Data handling Data processing Algorithms	Dashboard

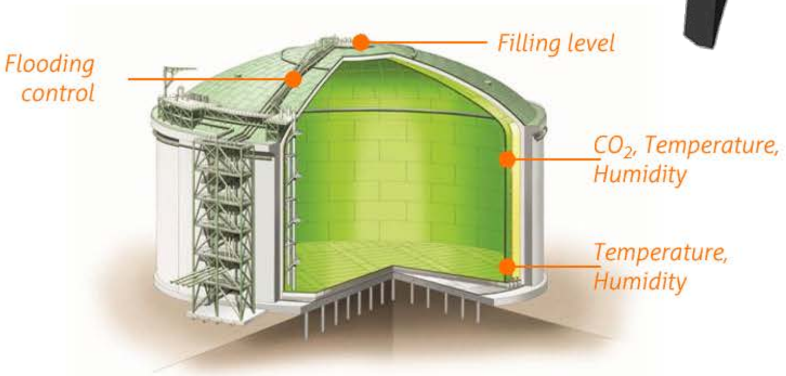
- More computing capabilities needed on edge devices
- Less communication overhead
- Trade-off for optimal energy efficiency

Condition Monitoring Use Cases in LoLiPoP-IoT

- › Use Case 5: Spray Painting
- › Use Case 6: Electric Vehicle Smart Bearing
- › Use Case 7: Factory Process Monitoring
- › Use Case 9: Motorcycle Fill Level

  - – Introduction
  - – Objective and scope
  - – Architecture
  - – Results





Use Case 5: Introduction

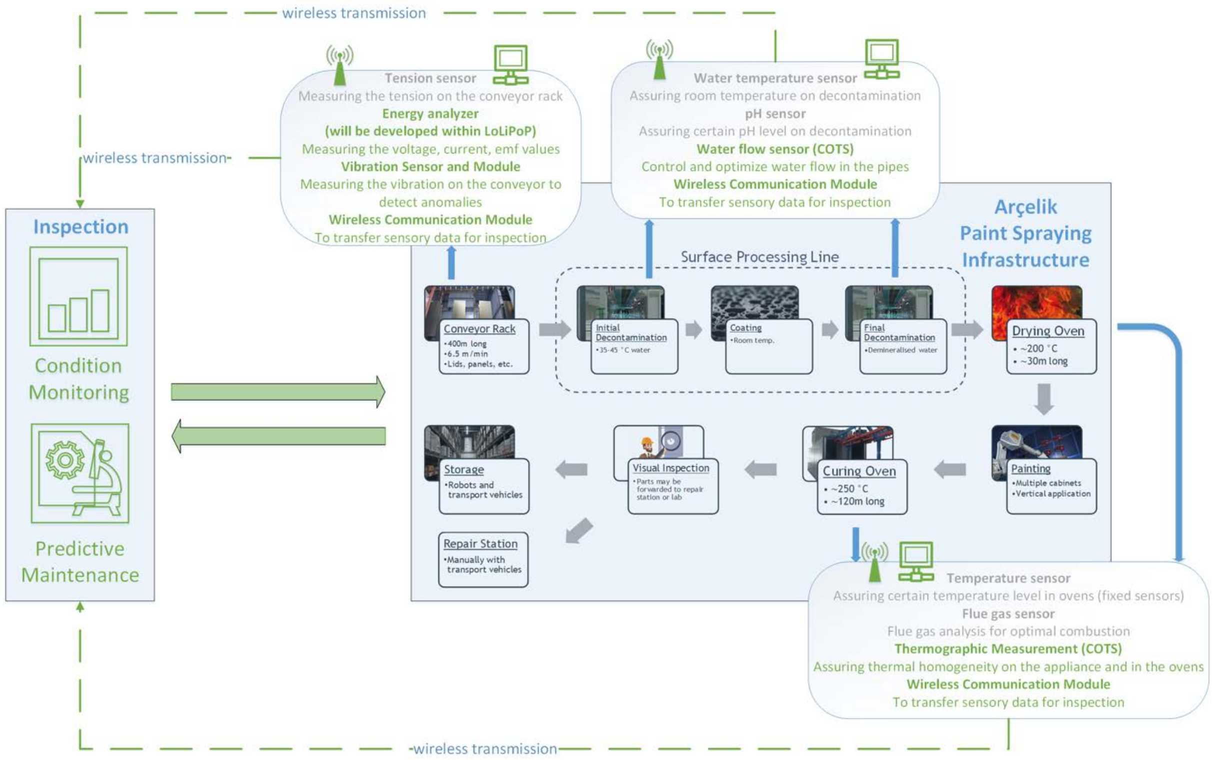
UC5 – Spray Painting: Condition monitoring of a spray painting production line for white goods

- **Processing line** for industrial coating and painting of household items
- Present sensors are **not sufficient** to assure quality of produced parts and avoid breakdowns
- Large energy consumption shows **great potential for savings**
- Energy monitoring helps also to **detect and prevent failures** and to **optimize efficiency**

UC5

Use Case 5: Objective and scope

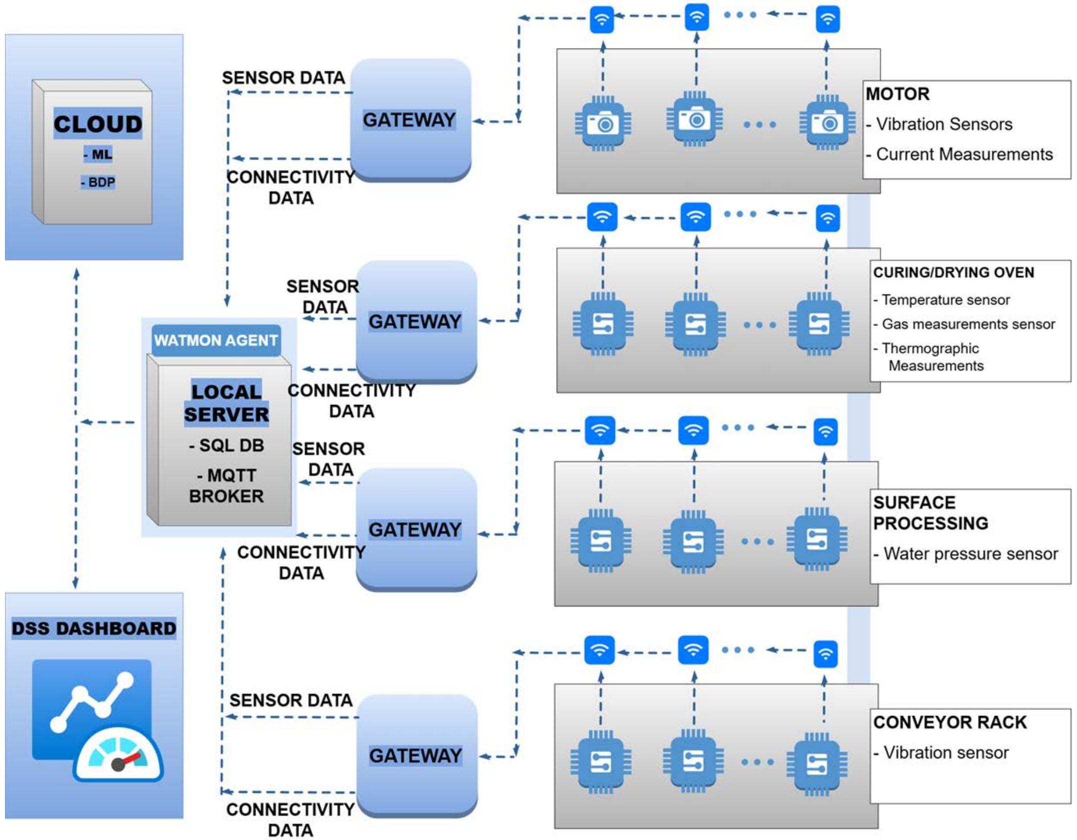
- Improved monitoring to be **compatible with Industry 4.0**
- Reliable and centralized **sensor data collection & processing** infrastructure
- **Algorithms**
  - to **reduce energy costs** in different processes and stages in the facility
  - **for predictive maintenance** on conveyor to reduce total down-time and maintenance costs
- **Monitor and control**
  - **vibration** to monitoring condition of the conveyor
  - **input/output temperatures** for predictive maintenance on heat exchangers
  - **the curing quality** to reduce oven temperatures
- Continuous **heat analysis** for optimal combustion



UC5

Use Case 5: Architecture

- **Sensors:** Water pressure, temperature, vibration
- **Energy Harvesting:** Thermal harvesting, potential vibration harvesting
- **Energy management and battery:** Secondary battery, charged by energy harvesting, energy management in sensor node
- **Processing units:** Edge devices, local server
- **Algorithms:** Condition monitoring and predictive maintenance algorithms for conveyor rack and conveyor motor, Monitoring of drying and curing oven; Algorithms for energy optimization, algorithms for data collection, management, storing and monitoring the whole system.
- **Communications:** BLE with the gateway devices; Wi-Fi with the local server



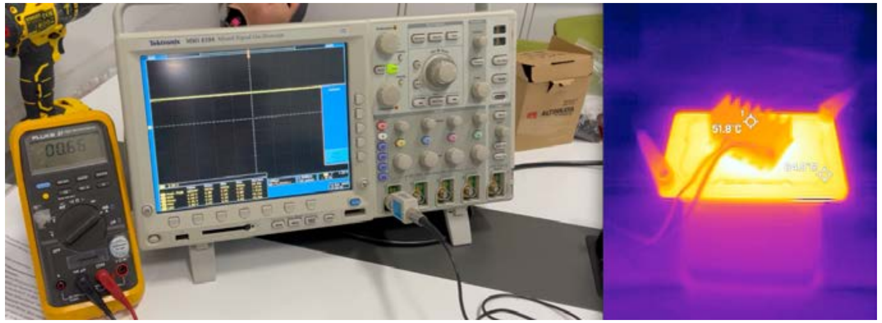
Deployed WSN Architecture

UC5

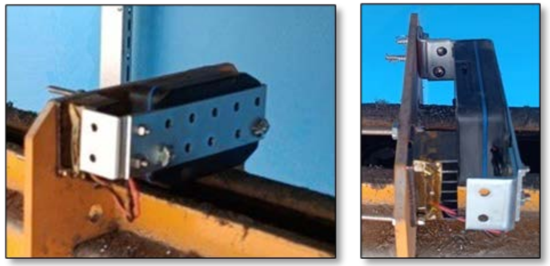
Use Case 5: Results

- **Deployment** progressed from lab validation towards operation in **real industrial environment**
- **Improved** general **resource and energy efficiency**:
  - Reduction of consumed gas by 5%
  - **€59K direct energy savings** per year
- Built big data platform to collect, store, and structure process data
- Successful **predictive maintenance**:
  - Improved system failure rates by 10%
  - 90% accuracy fault/anomaly detection
  - Resulting in **€20K maintenance savings** per year
- **Scalable, modular** architecture and **interoperable** components: Facility wide deployment will be planned

EoE device



Optimised TEG for temperature gradient at the plant



EoE device installed with TEG

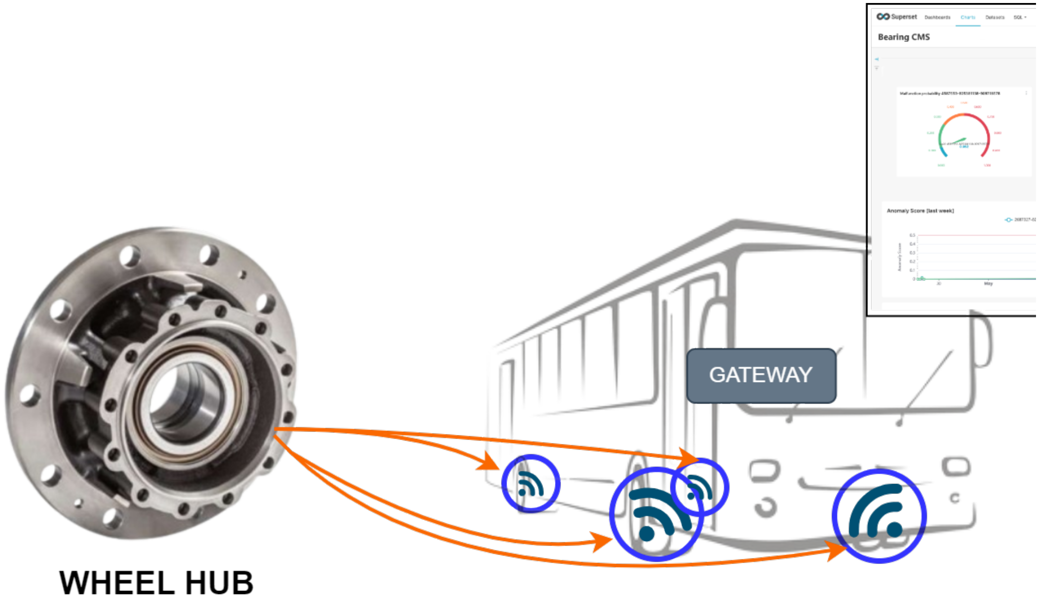
Dashboard of decision support system

UC5

Use Case 6: Introduction

UC6 - Condition monitoring of electric vehicles using smart bearings:
Develop smart sensor devices monitoring bearing health for preventive maintenance

- Continuous health monitoring to **reduce maintenance cost** and **improve fleet availability**
- **Space constrained** installation
- Rotational motion **restricts wired solutions**
- **Battery lifetime** is key, replacement of sensors is unfeasible



Associated partner:

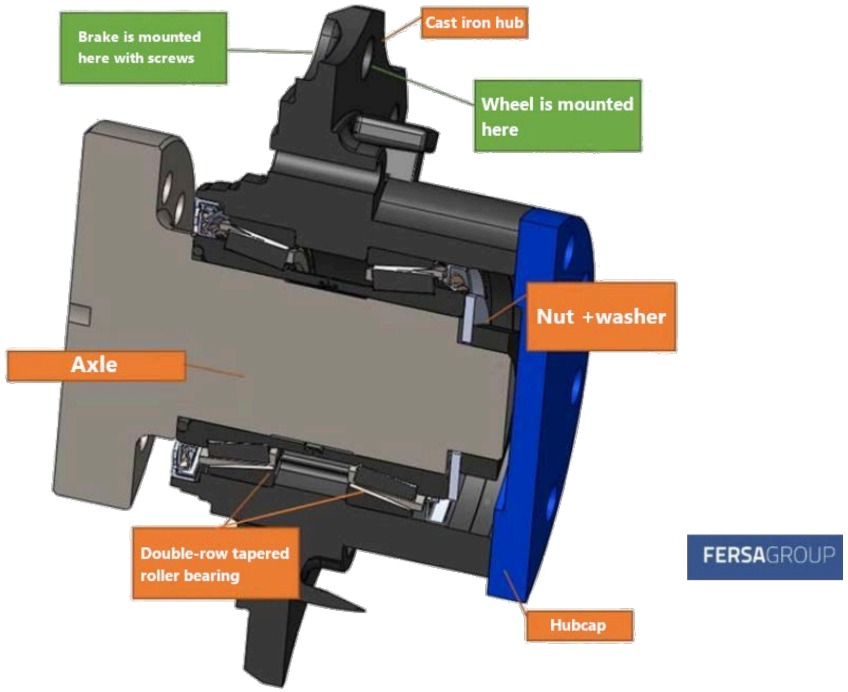
UC6

Use Case 6: Objectives and scope

› **Technical objectives for developing the WSN module**
- Develop an Energy Harvesting solution based on VREH.
- Develop an efficient energy management system integrating multiple energy sources and storage.
- Develop an ASIC with ML capabilities.
- Develop optimized ML algorithms for condition monitoring of bearings.
- Integrate EH, sensors, processing, and communication electronics in the available space of the bearing’s hub.

› **Validation**

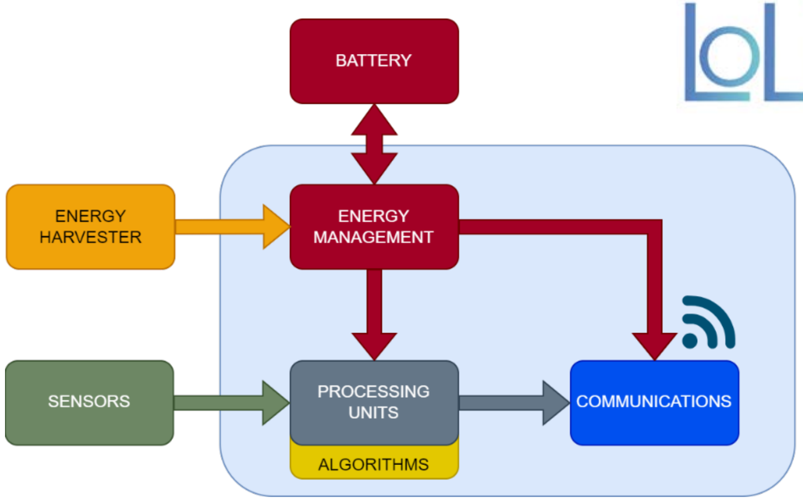
The final validation will be done in **laboratory environment:**
- Physical suitability of WSN module
- Functionalities:
    - Energy Harvesting and management
    - Communication
    - AI models

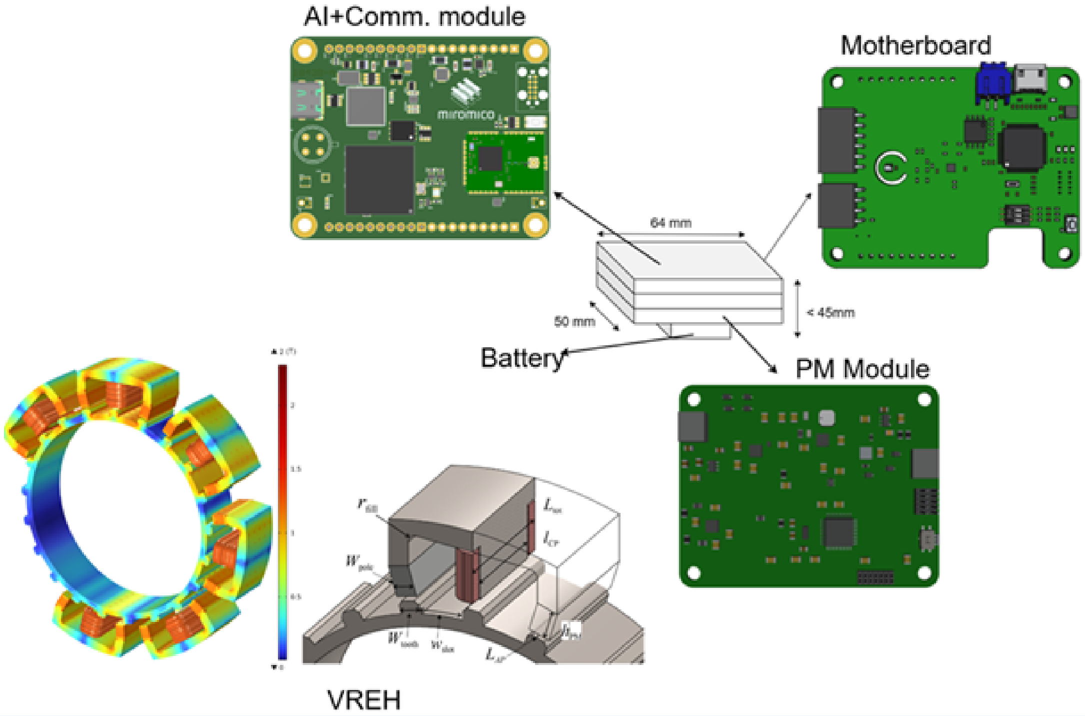


UC6

Use Case 6: Architecture

- **Energy Harvesting:** Variable Reluctance Energy Harvester
- **Sensors:** MEMS tri-axis accelerometer (± 16-32-64 g) and digital temperature sensor (–55 to 175 °C)
- **Energy management and battery:** Variable impedance matching controlled by MCU, secondary battery
- **Processing units:**
  - Low power MCU to manage device operation
  - Low power ML ASIC for data processing at the edge
- **Algorithms:** Unsupervised learning models for anomaly detection
- **Communications:** Low power wireless communication with nearby gateway





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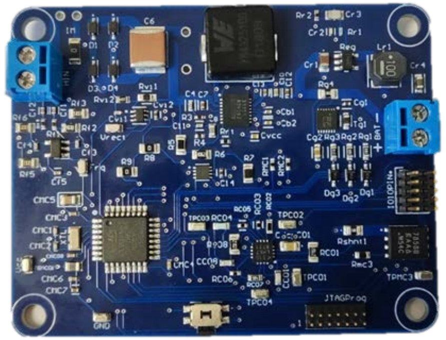
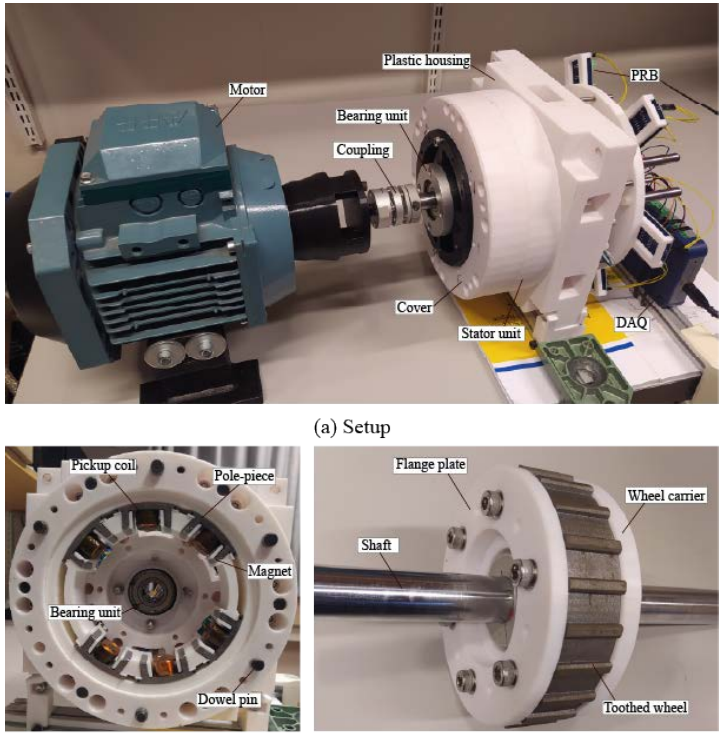
Use Case 6: Results

- Successful **end-to-end laboratory demonstrators**
- Precise **anomaly detection** to distinguish unhealthy form healthy bearings **on the edge** (F1-score of 0.96)
- **Local AI processing** reduces necessary data payload by 99.6%
- Energy harvesting and power management confirmed, reaching **800 mW output power** at maximum speed
- **Sensor node total power** need of **0.32 mW**

Processing & Communication



Power Management

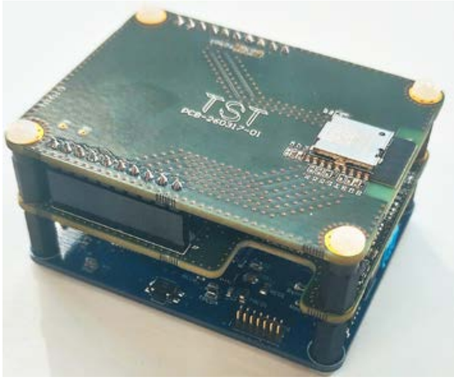


(a) Setup

(b) Stator unit

(c) Rotor unit

Demonstrator Setup



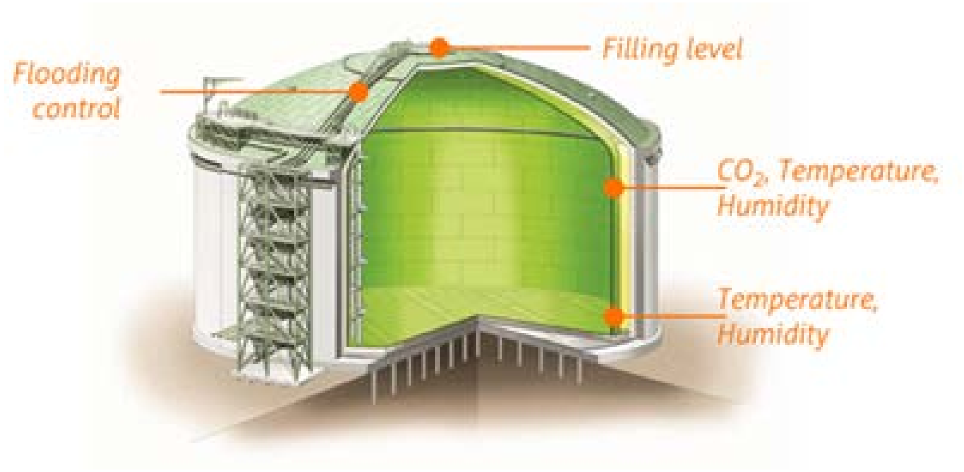
WSN Modules

UC6

Use Case 7: Introduction

UC7 – Factory Process Monitoring:
Condition Monitoring of bulk material containers

- **Silos** to store **organic bulk** material (pellets, grain, seeds, etc.)
- Monitoring **fermentation** and prevent **spontaneous combustion** processes
- **Large distances** between containers possible (> 5 km)
- **Ambient energy levels vary** significantly depending on environmental conditions



UC7

Use Case 9: Introduction

UC9 – Mobile Device Fuel Monitoring:
Monitoring of fuel levels and quality in motorcycle fuel tanks

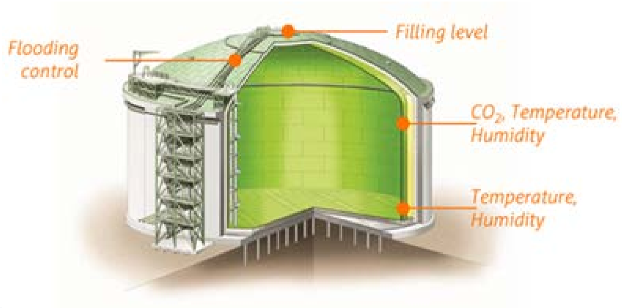
- Reliable **fuel level** monitoring under **dynamic motion**
- Fuel quality: **water content, sedimentation, contamination**
- **Irregular tank geometries**
- **Auxiliary tanks** lack integrated fuel sensing
- Importance for **retrofitting** with minimal wiring

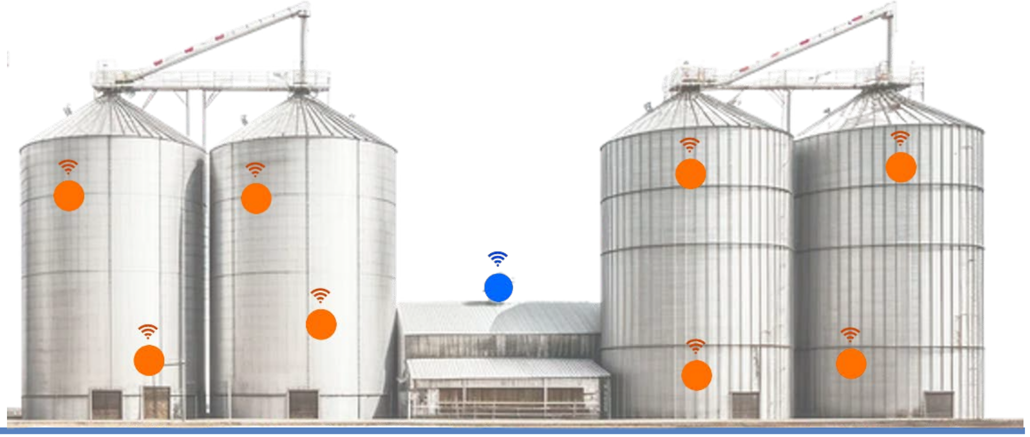
UC9

Use Case 7 & 9: Objectives and scope

› **Technical objectives for developing the WSN**
  – Develop a **modular** technology platform for smart, cable-less, self-sufficient IoT sensor systems for mobility and condition monitoring, ensuring robustness and reliability
  – Deploy **IoT sensor systems** for configurable/reusable use cases
  – **Maintenance-free** operation by using different sources of energy harvesting (vibrations, thermal gradients)
  – Safe data transfer, robustness, and different sensor data analysis methods

› **Validation scope**
  – Proof-of-concept deployment and performance test within **laboratories at partner facilities**
  – Generate operating conditions as in field-based deployments to get meaningful test results

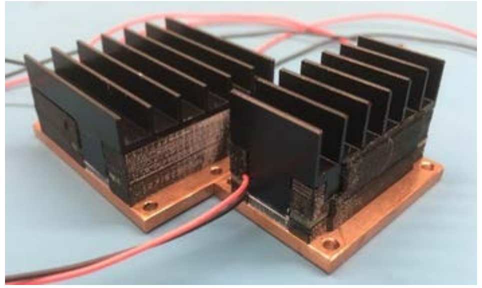




UC7&9

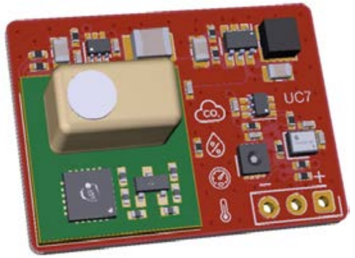
Use Case 7 & 9: Architecture

- **Energy Harvesting:** Thermal (UC7) and vibration (UC9)
- **Sensors:**
  - UC7: Temperature**,** CO_2, radar, pressure, humidity
  - UC9: capacitive fuel sensing, inclination
- **Processing units:** Low power MCU on radio module
- **Communications:** Mioty (UC7), BLE (UC9)
- **Energy management:** Dynamic QoS levels depending on energy balance
- **Security:** Hardware security module to harden application layer encryption

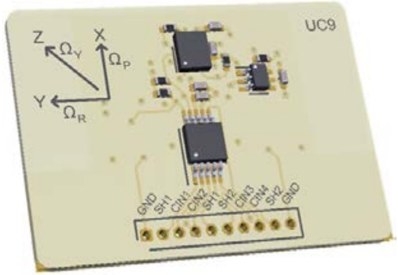


Thermal harvester

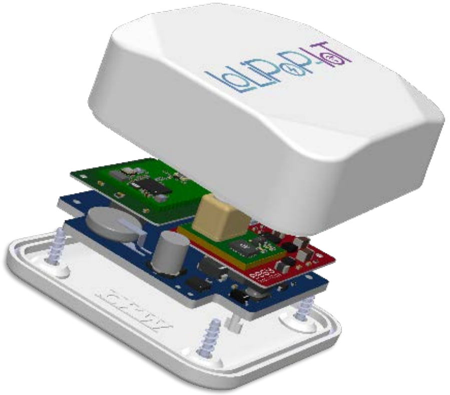
Vibration harvester



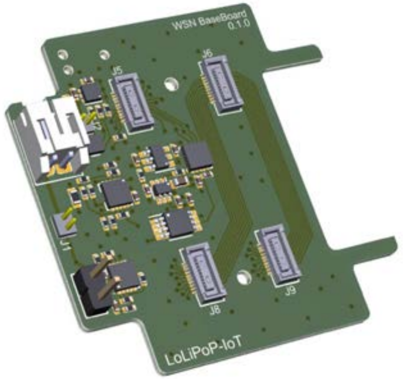
UC7 Sensors board



UC9 Sensors board



Sensor node in housing



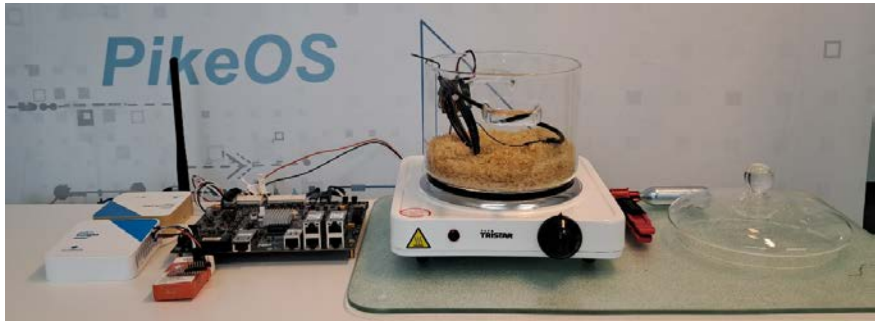
WSN Baseboard with battery holder

UC7&9

UC7&9: Results

Energy Harvesting

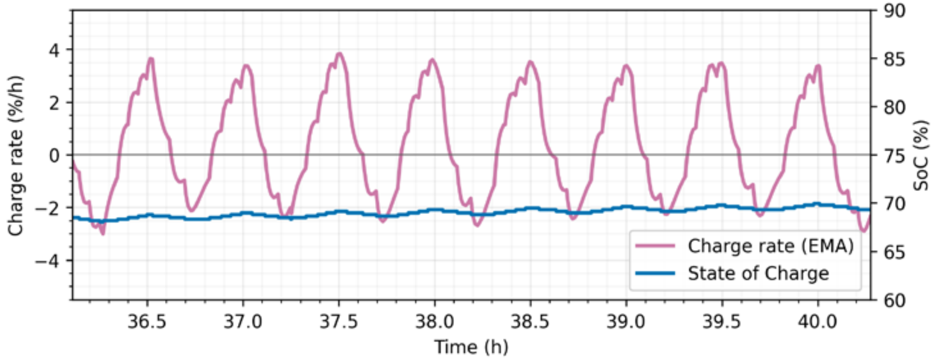
- Analysed vibration data to determine the amount of energy available through VEH
- Simulations and tests **optimized VEH** performance for the application
- Adapted TEG harvesters including power management to provide power at low **thermal gradients**



Laboratory test setup

Power management

- **Adaptation** of sampling and reporting intervals **learned on the sensor node**
- Implicit **prediction** of **available energy and harvesting**



Dashboard hosted on the gateway

UC7&9

Thanks for your attention!

Questions?

- Long Life
  Power Platforms
  for Internet of Things

- www.lolipop-iot.eu