Innovative sensing and control devices

Brendan O´Flynn, Tyndall, Ireland

WILS, Austria - Feb 28th 2019

MOEEBIUS

Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability

Project duration: November 2015 – April 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680517

Overview

- Tyndall - Who we are and What we do
- Moeebius Project Research Objective
- Moeebius NOD Technology Building Blocks & Implementation
- Deployment of Moeebius Nod systems
- Energy Harvesting systems for Next generation “autonomous” sensing and control devices
- Conclusions & Future Works
- References

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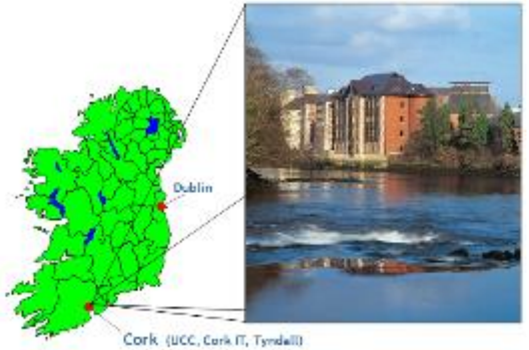
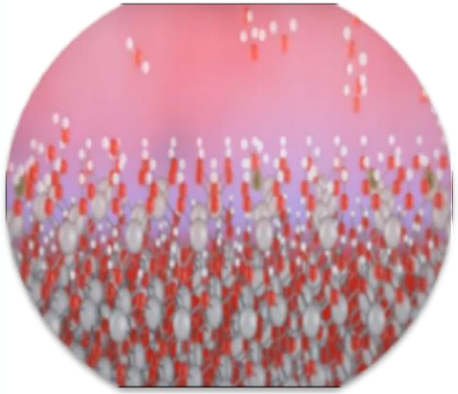
Tyndall Research



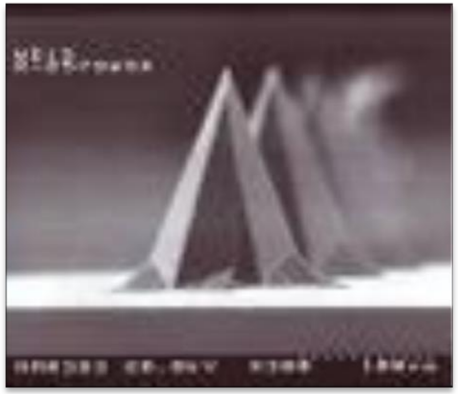
From atoms to systems

Atoms



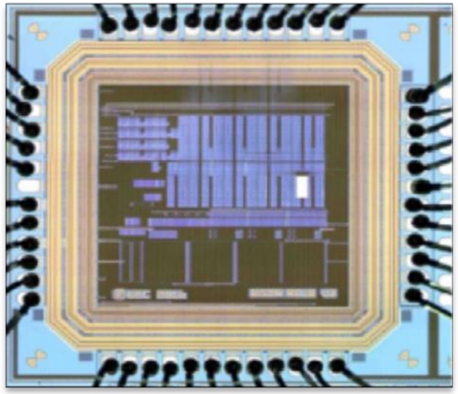
- Materials Research & ALD
- Atomistic Modelling & Simulation
- Synthesis & Processing

Devices



- Semiconductor wafer fabrication
- Nano materials and device processing

Circuits



- High performance RF & mixed-signal circuits
  - Data converters
  - Ultra wideband radar
  - RF circuit design
- Photonic light sources & detectors
- Power supply on Chip

Systems

- Smart sensors and systems
- Optical communication systems
- Microelectronic and photonic integration
- Application-specific Packaging

Conceive – produce – characterise – deploy

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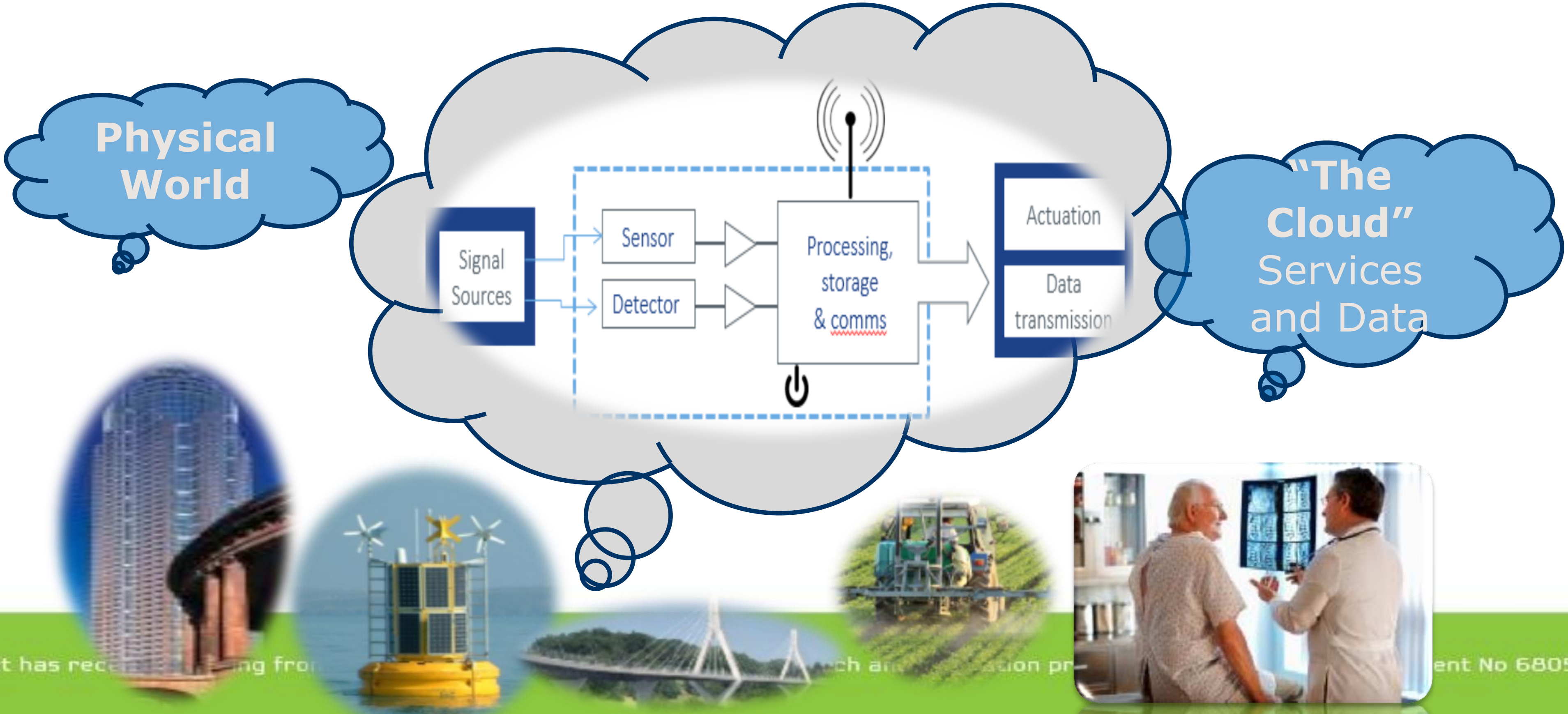
Cyber Physical Systems for the Internet of Things Creating Information from Data

Interfaces to users, to the physical world and the cloud



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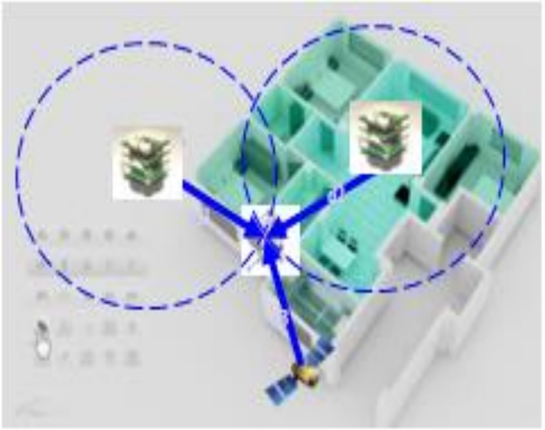
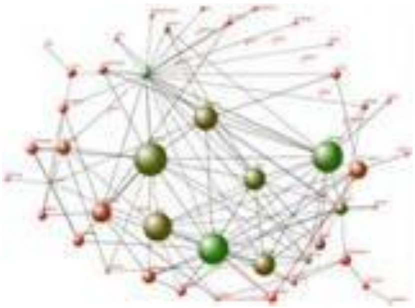
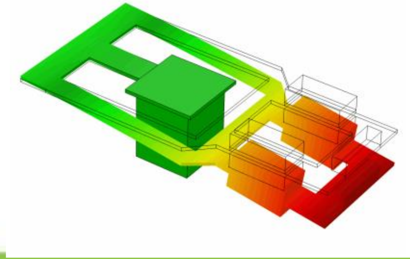
Smart Systems Research
To enable "smart everything everywhere"

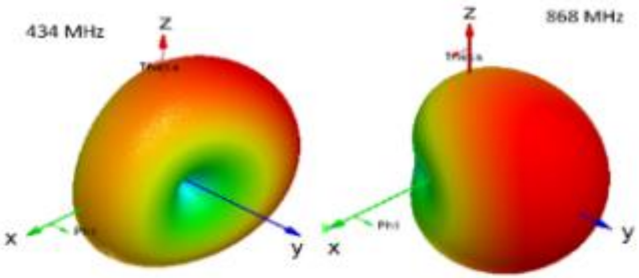
- Focused on delivering an industry-relevant "applied" research agenda
- Balanced with a more fundamental scientific research supply chain
- Multidisciplinary teams needed
- **Development of actuator and control systems need**:
  - Energy Aware Software and Systems
  - Smart RF Circuits and Systems

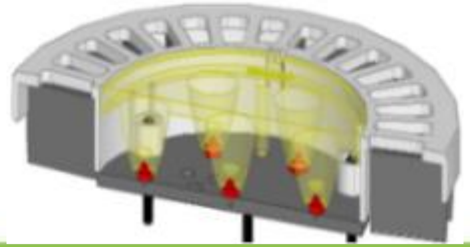
  - Hardware/Software Co-design of smart sensing systems
  - Deployment of industry Focussed Demonstrators











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Motivation for Building and structural monitoring

These WSNs require efficient low cost, low power consumption Sensor Nodes, with monitoring and actuation and control capability

Interoperability between sensor networks is required

- Occupation
- Light (Lux)
- Temp/Humidity
- Security

- Structural Integrity
- Energy Management
- Assisted Living & Entertainment

- Energy Consumption Low Power Systems
- Interoperability

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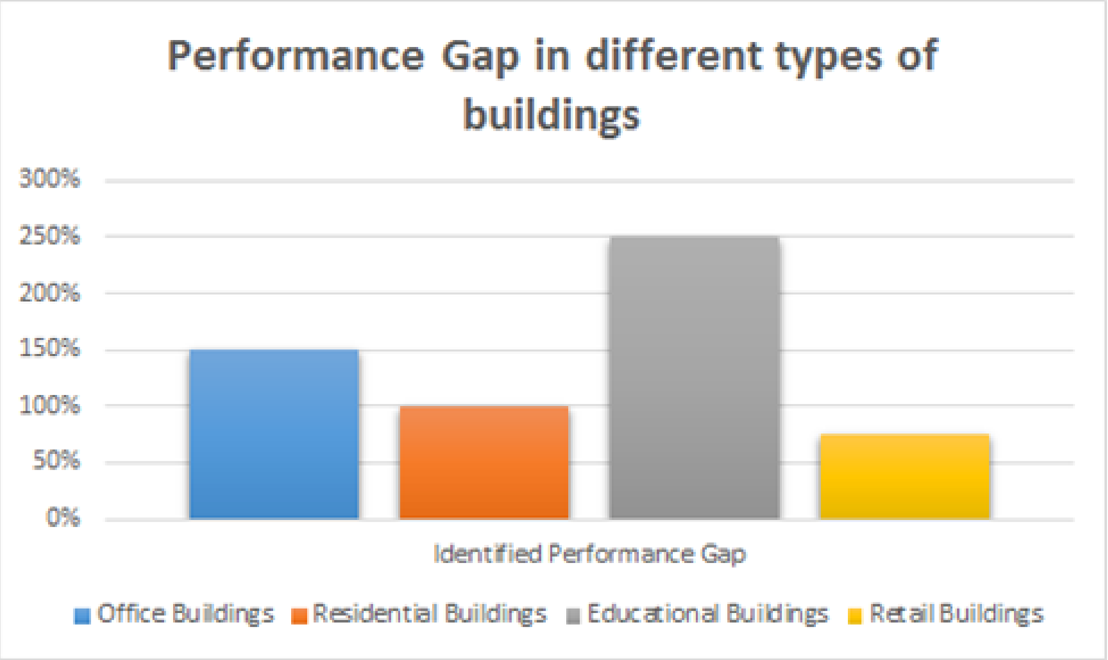
MOEEBIUS Research Objectives: The Problem

- Huge **gaps** between **predicted and actual** energy consumption
- Inability of current modelling techniques to represent **realistic use and operation** of buildings
- Impact of **occupants' behavior** on the energy performance of buildings needs to be quantified
- Holistic energy **performance optimization** framework is required



- WSNs enable **continuous optimization** of building energy performance as a means to mitigate the **identified "performance gap"** in real-time through retrofitting.

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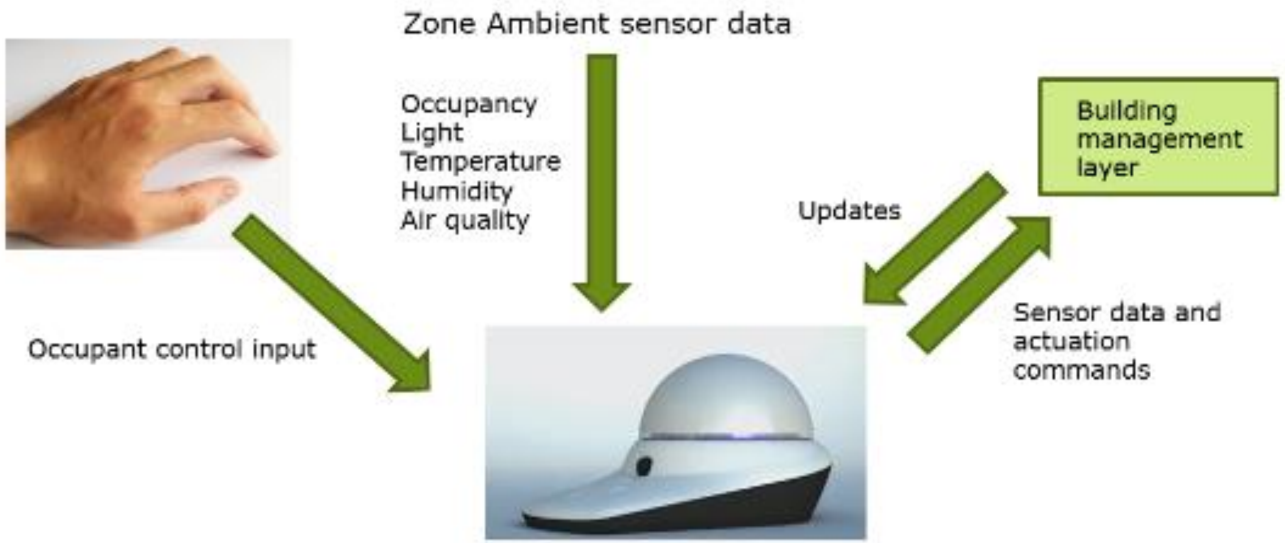
NOD Description and scenaerio requirements

And communicate these parameters wirelessly to a gateway

NOD Use case scaenerio

1. Desktop device which will sense:

   - human presence
   - ambient temperature
   - humidity
   - air quality
   - light conditions in the user's vicinity



2. User interface to send commands to the Building management layer through a gateway to control the ambient environment in order to maximize user comfort.
3. The latency (delay) should feel real time to the user.
4. Battery operated. A rechargeable battery will be used with a battery life of a minimum 1 week. Energy harvesting will be incorporated into the device if appropriate.

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NOD System Deployment/User Requirements

User Requirement	Nod Requirements & Specification
Communication protocol	Wi-Fi, sub-1GHz, UWB, (BLE)
Light Sensor	0-10000 lux; +/- 20 lux
Air Temperature Sensor	-10°C - +85°C; +/- 0,5°C
Air Humidity Sensor	+/- 5%
Proximity Sensor	0-20 cm; +/- 5cm
CO2 Sensor + VOC sensor	450 – 2000ppm; +/-50ppm
CO sensor	Avoid; Use VOC sensor
Occupancy Sensors	PIR Sensor
Microcontroller	Mid / High range
Display	TFT EPD display
Buttons	Touch buttons
LEDs	✓
USB port	Micro USB
Battery charger chip	✓
JTAG interface	✓
Battery	Li-Ion or LiPo + connector
Antenna	PCB

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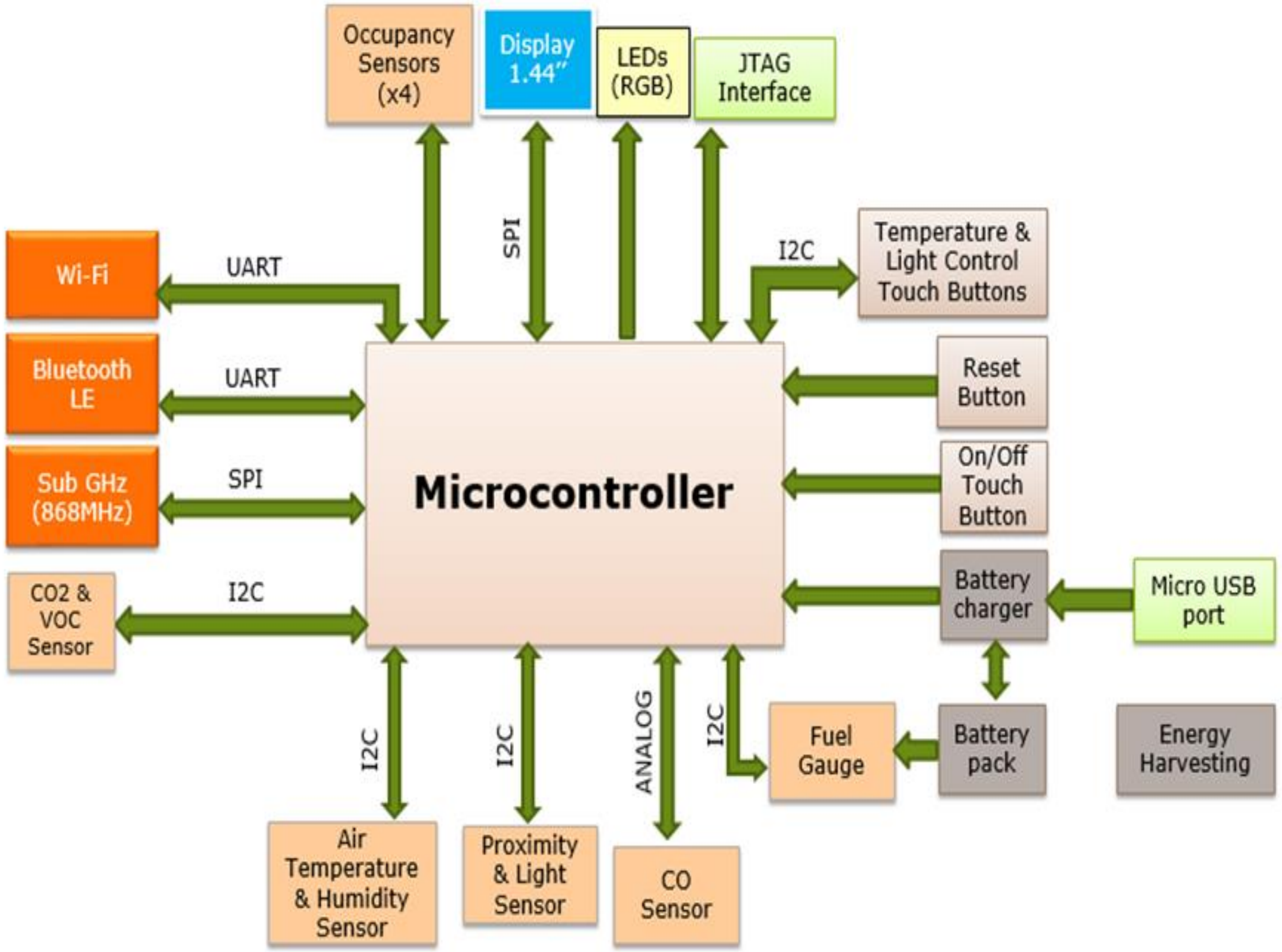
NOD System Block Diagram



MCU – STM32F302ZET6 from ST
Wi-Fi – ATWINC1510-MR210PB from Atmel
Sub Ghz(868MHz) – SPIRIT1 from Atmel
Bluetooth - CYW20737S from Cypress
Temperature and Humidity sensor – Si7020-A20 from Silicon Labs
Proximity and Light sensor – VCNL4020 from Vishay
CO2 and VOC sensor – CCS811 from Ams
Occupancy sensors - EKMC1601111 / EKMB1301111K from Panasonic
Display – E144CS021 from Pervasive Displays

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NOD Board Implementation – 10cm x 10 cm

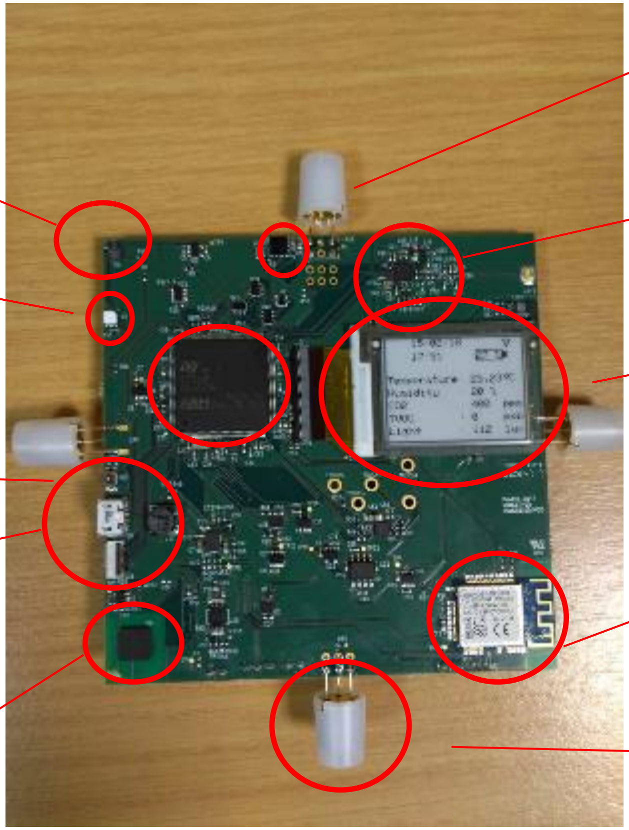
CO2 and VOC sensor – CCS811 from Ams

Temperature and Humidity sensor – Si7020-A20 from Silicon Labs

MCU – STM32F302ZET6 from ST

USB connector

Bluetooth - CYW20737S from Cypress



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MOEEBIUS NOD deployment

The NODs are currently deployed in several sites across Europe:

- United Kingdom → School Pilot (4 units), City Hall (7 units), Kindergarten (2 units)
- Portugal → Moor House (5 units), Ernest Dance (10 units)
- Serbia

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MOEEBIUS NOD deployment

Location	*No of Buildings*	*Types of Buildings*	*Total Surface of Buildings*	*Total Annual Consumption*	*No of Occupants*	*Shared Infrastructure*
UK - London	4	Residential, Hotels, Retail	22.500 m^2	3.100 MWh (EL) 80 MWh (NG)	1.200	RES (PV), Back-up Generators
Portugal – Mafra	5	Educational, Sports, Office	8.100 m^2	535 MWh (EL) 760 MWh (NG)	800	HVAC (Natural Gas Boilers)
Serbia - Belgrade	48	Educational, Office, Residential, Retail	434.000m^2	12.400 MWh (EL)	11.700	District Heating



Real-life conditions, in different buildings (office buildings, residential buildings, hotels, schools, sports complexes), districts characterized by increased **heterogeneity** (incorporating a variety of energy management systems) and interaction features between buildings (district heating systems, storage facilities and renewable energy sources) and under **different environmental, social and cultural contexts** in three dispersed geographical areas (UK, Serbia, Portugal).

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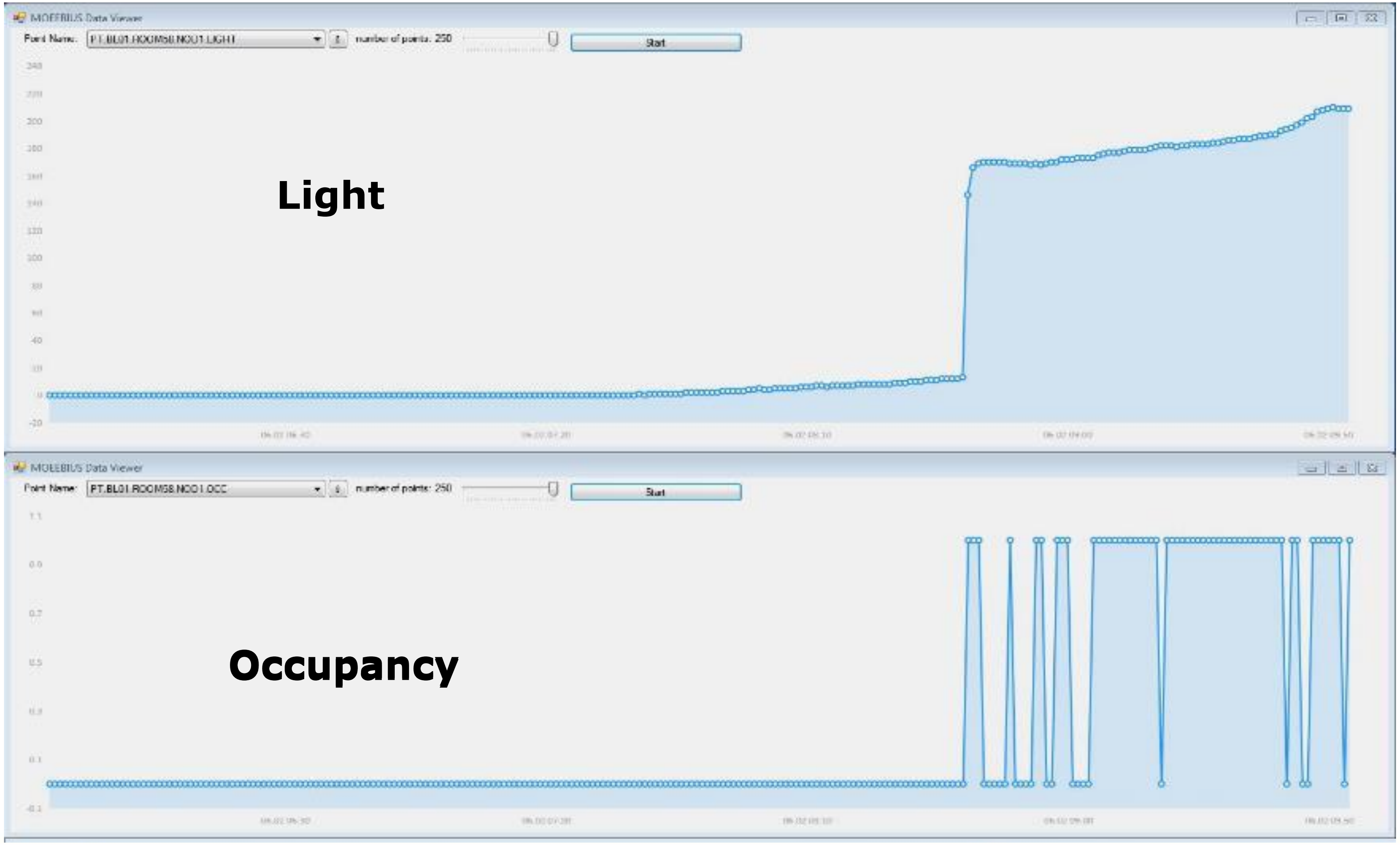
Moeebius Deployment Results
Occupancy Impact



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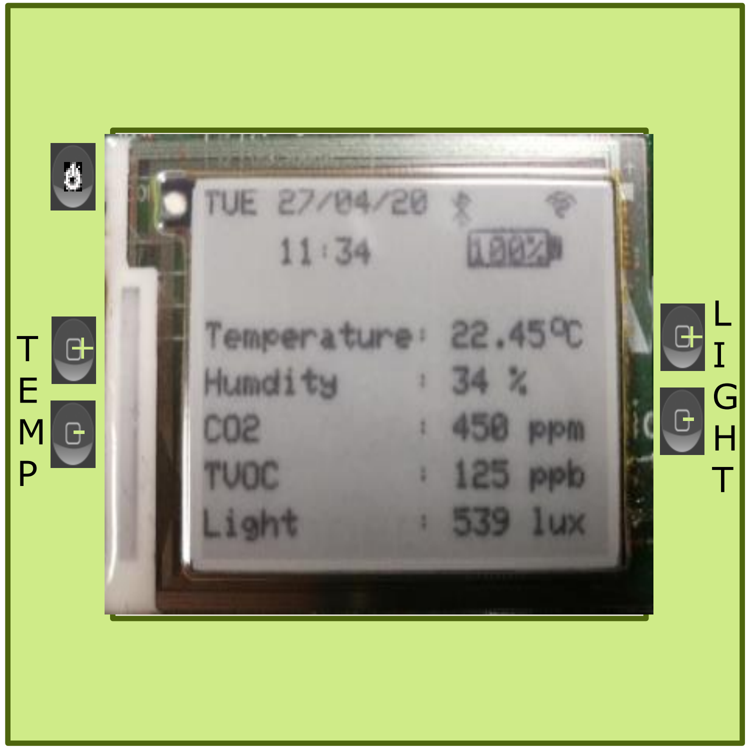
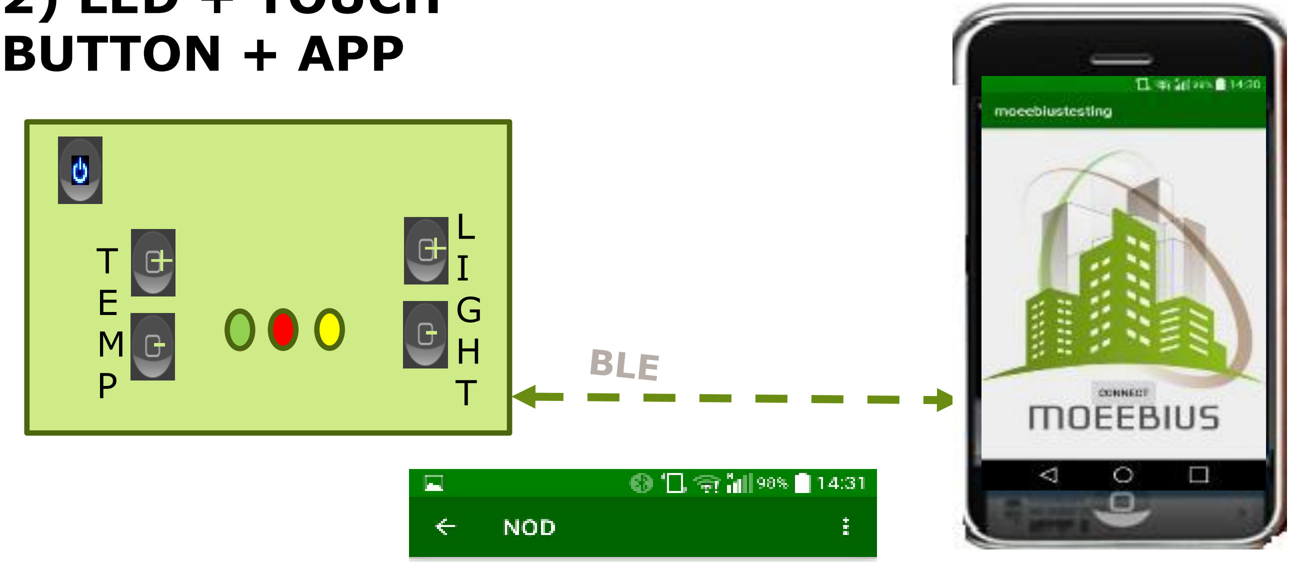
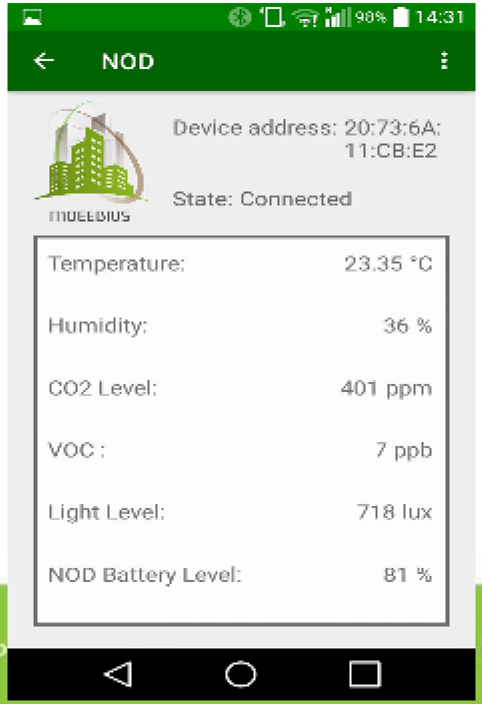
MOEEBIUS Interface for sensing actuation and control

1) EPD DISPLAY(B/W) + TOUCH BUTTON



2) LED + TOUCH BUTTON + APP





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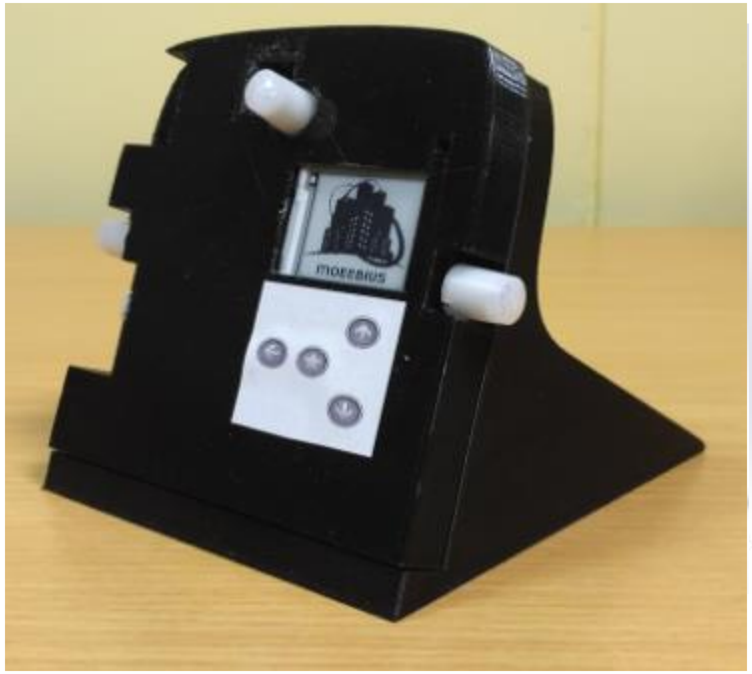
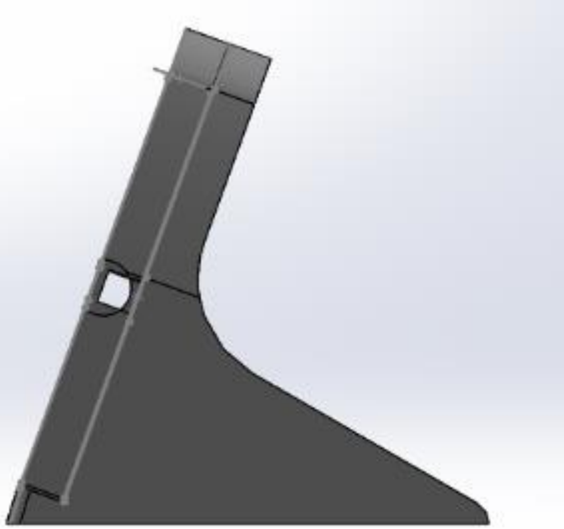
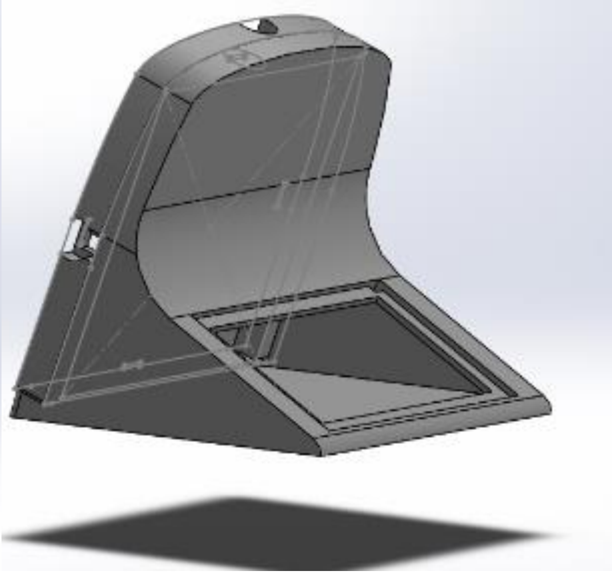
NOD Rev.2 – MOEEBIUS Exploitation

3D printed Enclosure
– User experience , Robustness and Commercialisation:

User friendly, good looking and improved version of the enclosure taking into account the inputs from the partners
(Enterprise Ireland Funded commercialisation feasibility study)







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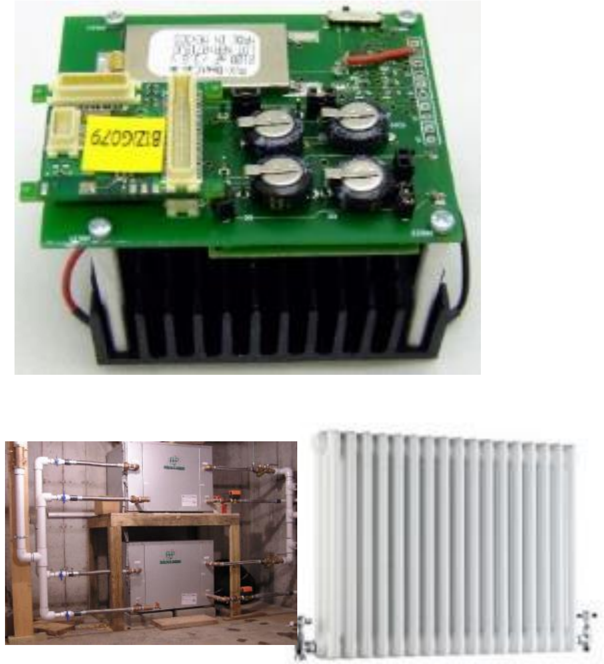
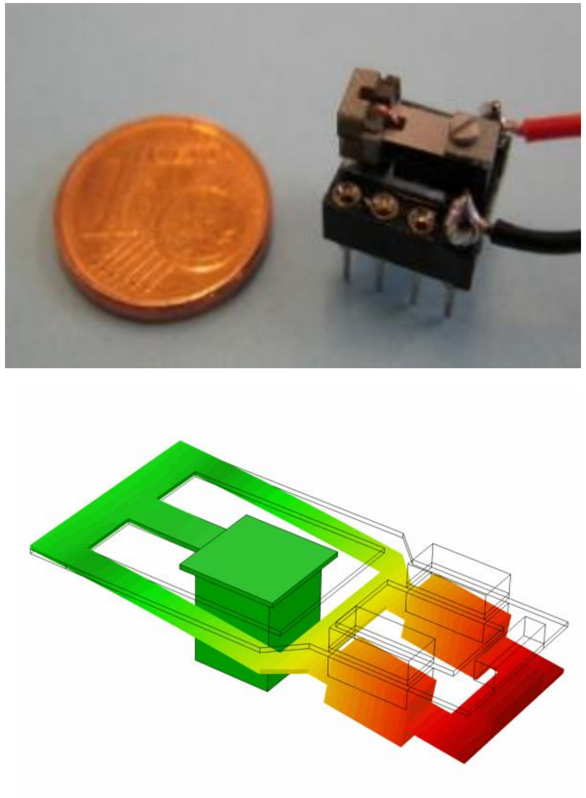
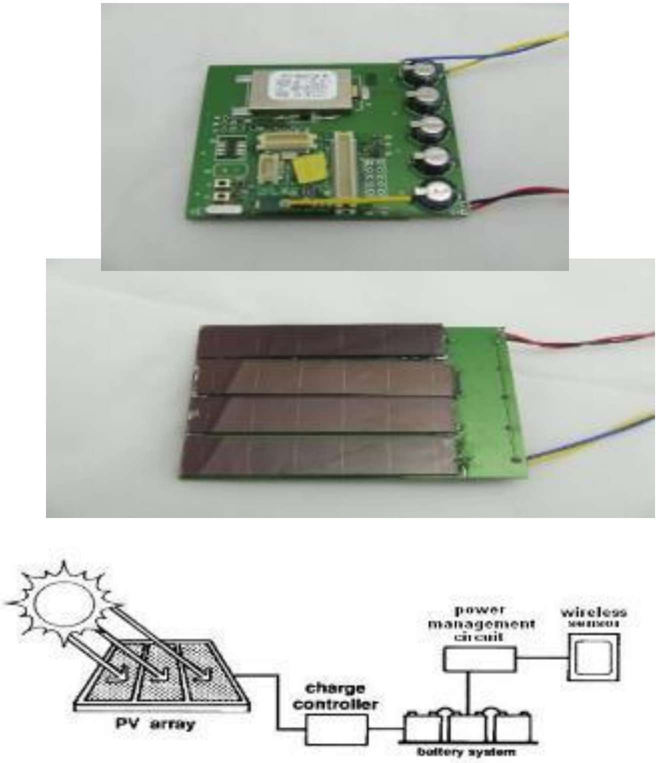
Energy Harvesting Solutions for in Building Autonomous Sensing, Actuation & Control Systems



Thermoelectricity Generator (TEG)



Vibrational Generator



Indoor High-Efficiency Solar Panel

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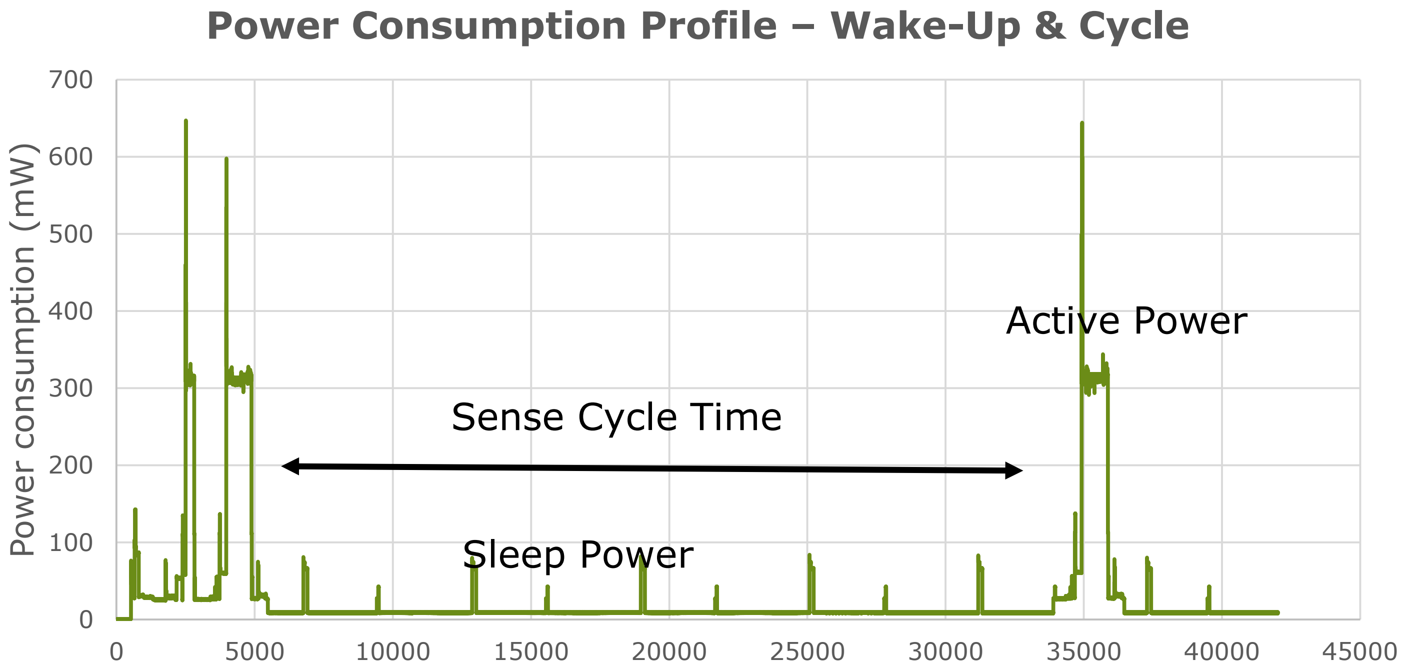
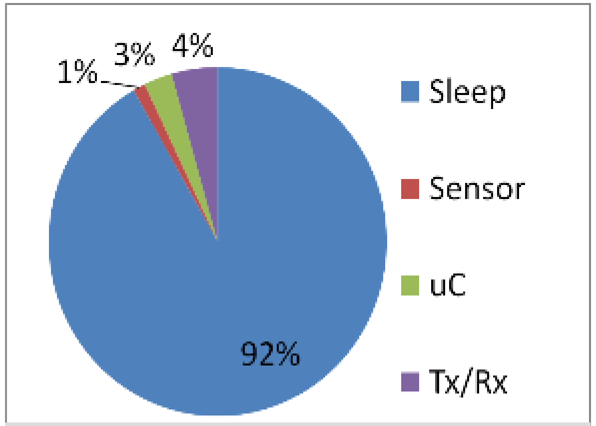
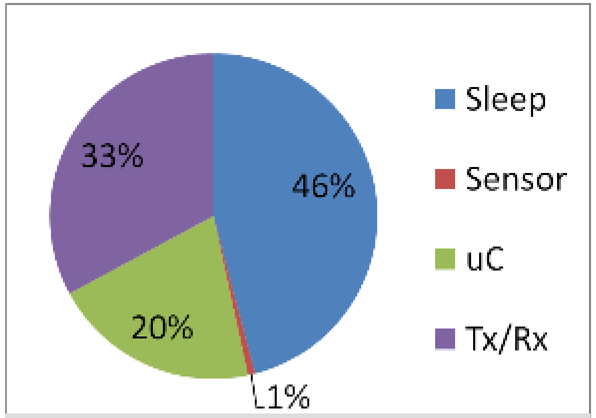
Optimising Power Consumption of Autonomous Sensor





Sense every 15 mins
0.01% Duty Cycle



Sense every minute
0.15% Duty Cycle

- To improve performance we can increase the cycle time to reduce impact of the Active sensor and Communications power
- Using Bluetooth/868MHz opposed to Wi-Fi communications can reduce average communication power significantly
- Implementing smart sleep modes for sensors reduces quiescent current supply reducing sleep power

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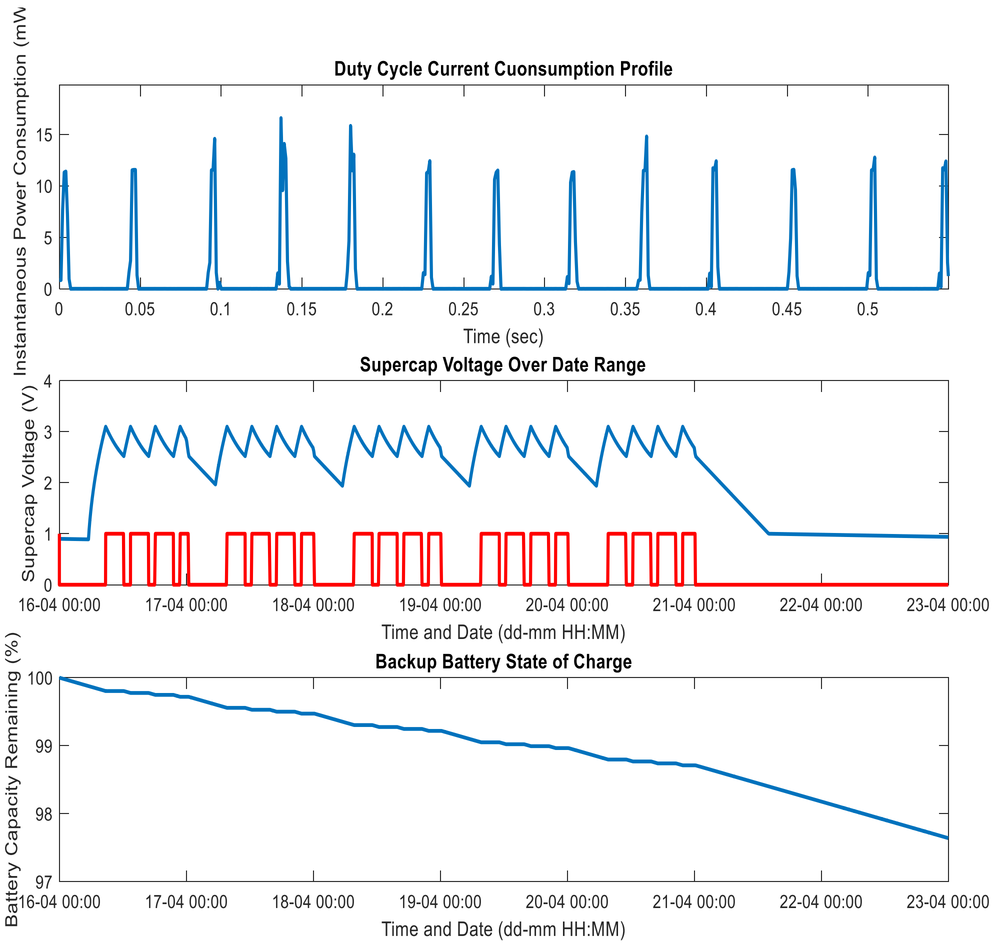
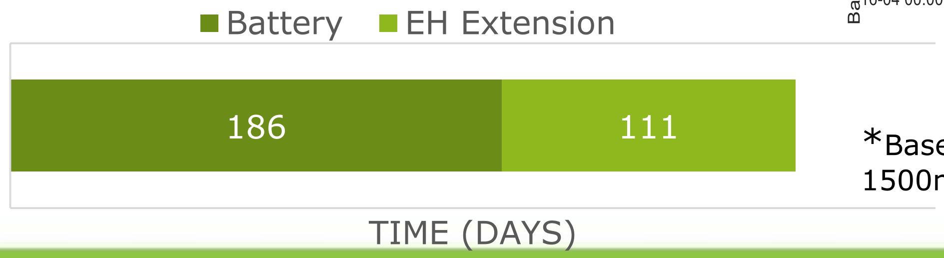
Power Modeling to Optimise & Predict Performance

- By capturing the duty cycle current for the end device, characteristics of the harvester and intended environment we can predict the effectiveness of the intended Energy Harvesting device
- For an example a 1 mW average load being supplied by a battery and PV has been simulated over a week
- 750 µW to over 1 mW may be generated by the harvester during lighting hours but a backup battery is still needed
- If the average device power consumption were reduced to 420uW the device would be self-sufficient (battery-less) in these conditions





*Based on 12 hour lighting availability in office conditions, 1500mAh battery, 600 Lux using energy availability model

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Conclusions

- MOEEBIUS is looking to **reduce the gap** between building performance and models
- The Tyndall team have developed a multi modal sensing system to provide the necessary data sets to optimise building performance models
- **The MOEEBIUS NOD is currently deployed and gathering data across Europe as part of the EU funded project**
- Research activities include optimisation of energy consumption of the NOD to increase battery lifetime through incorporating **energy harvesting technology** and **predictive operational models** and autonomous behaviour

Main MOEEBIUS Impact	Targeted Value
Performance Gap Reduction	<10%
Additional MOEEBIUS Quantified Impacts	***Annual Values***
Peak demand reduction	50%
Energy demand reduction	35%
GHG emissions reduction	180.000 Tn CO_2
Long-term MOEEBIUS Impacts	
Potential investment through EPC Europe-wide	€2.32 billion/ annum
Potential savings through EPC	€0,232 billion/ annum
New jobs created through EPC deployment	44.080 new jobs/ annum
Energy savings	2,6 TWh/ annum
New companies operating in Europe (total)	2.100 until 2020

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MOEEBIUS Partners

Project coordinator

Ander Romero Amorrortu
TECNALIA
Parque Tecnológico de Bizkaia
ander.romero@tecnalia.com

www.moeebius.eu

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