EnerHarv 2024

PSMA International Workshop | 26-28 June, 2024 | Perugia, Italy

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EnerHarv 2024 Workshop:

Energy Harvesting Testbed for Optimising Energy-constrained WSN Nodes and Networks

Presented By –

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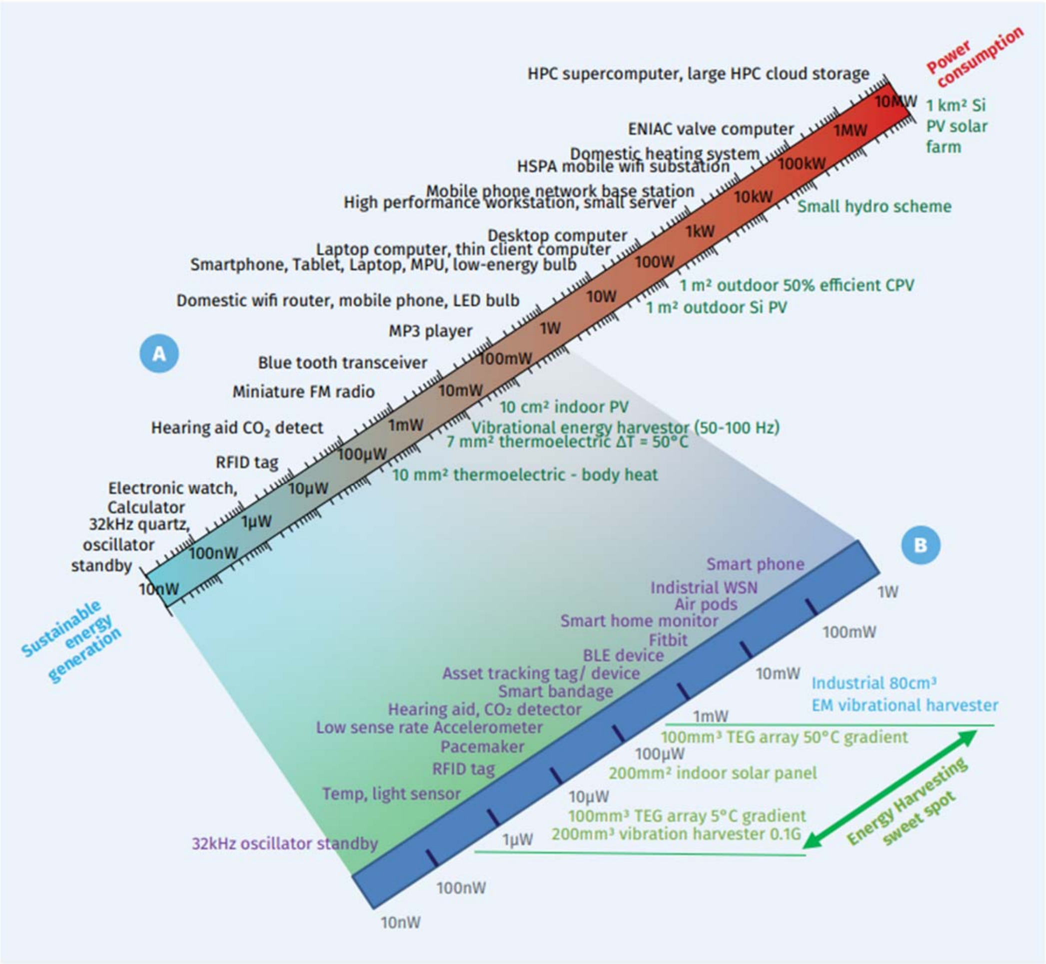
Research Area

- General area
  - Ultra Low Power Electronics with a view towards autonomous power
  - EH Technology at Ambient Energy Levels into Applications

- Current Focus
  - Leading the CONNECT Energy Harvesting Testbed
  - Developing the Testbed with other CONNECT and industry partners in mind



Energy Harvesting Testbed (EnTICe*) Primer

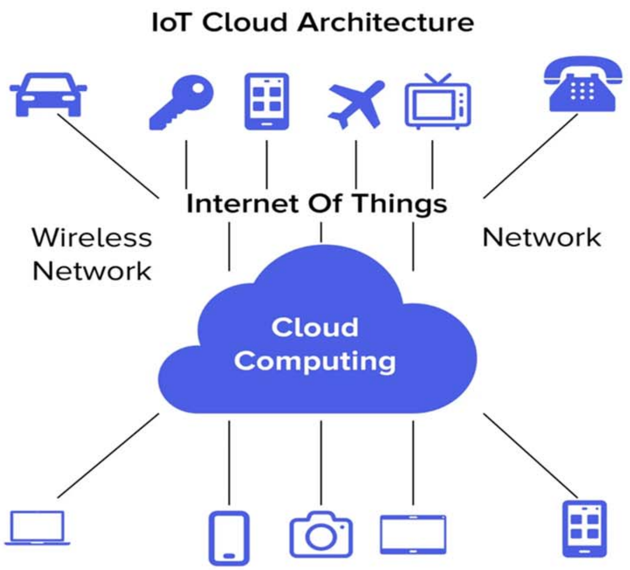
- **Creating an Energy Harvesting Testbed for Node and Network Level Energy Optimisation**

- **Off the Shelf Parts Combined to create WSN Network**

    - ☐ Harvesting Node - Solar, Vibrational, Thermal
    - ☐ Power Management IC
    - ☐ Microprocessor and Sensors
    - ☐ RF Technology (BLE)

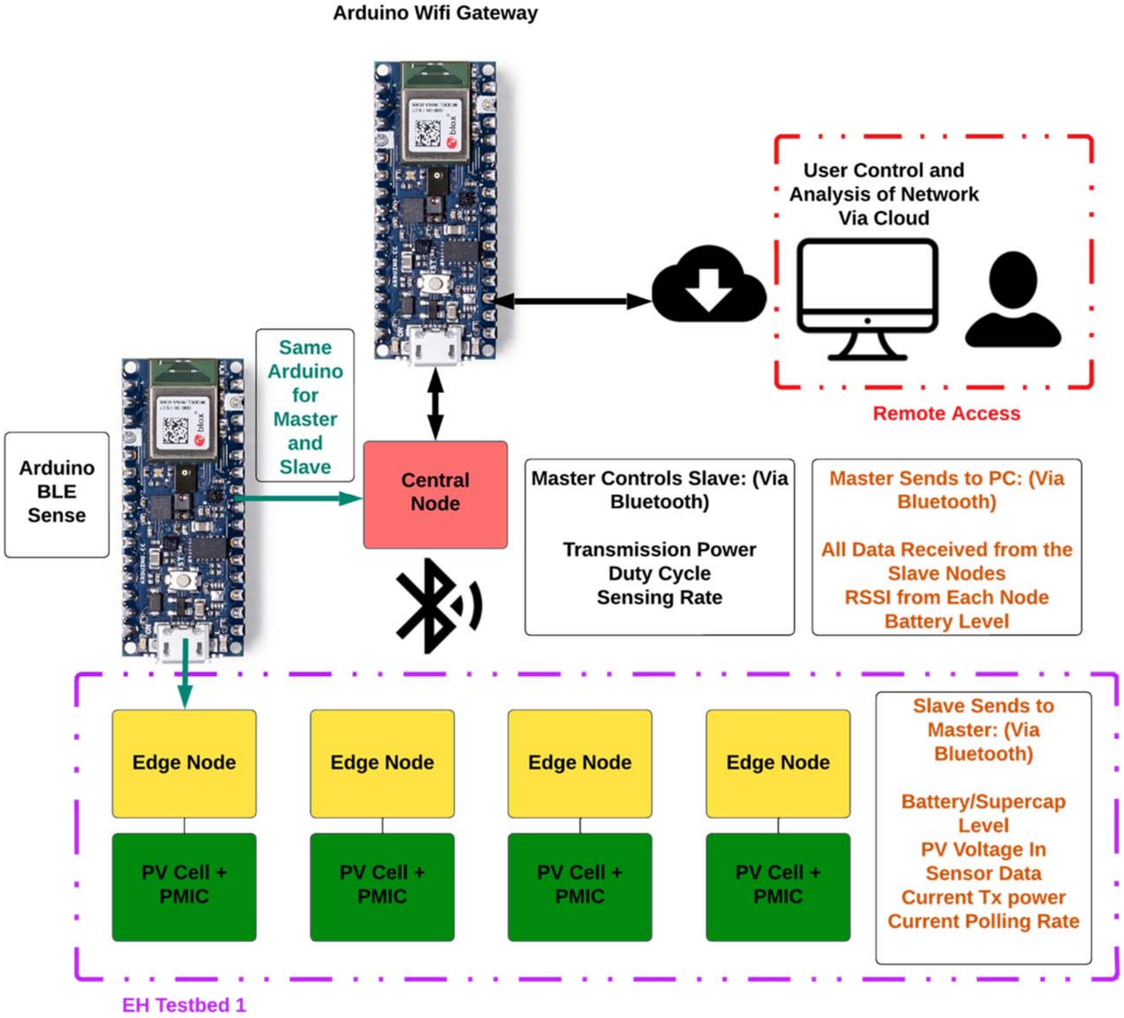
- **Multiple Peripheral Nodes (20+) Reporting to and controlled by Master**

- **Control Via Cloud API**



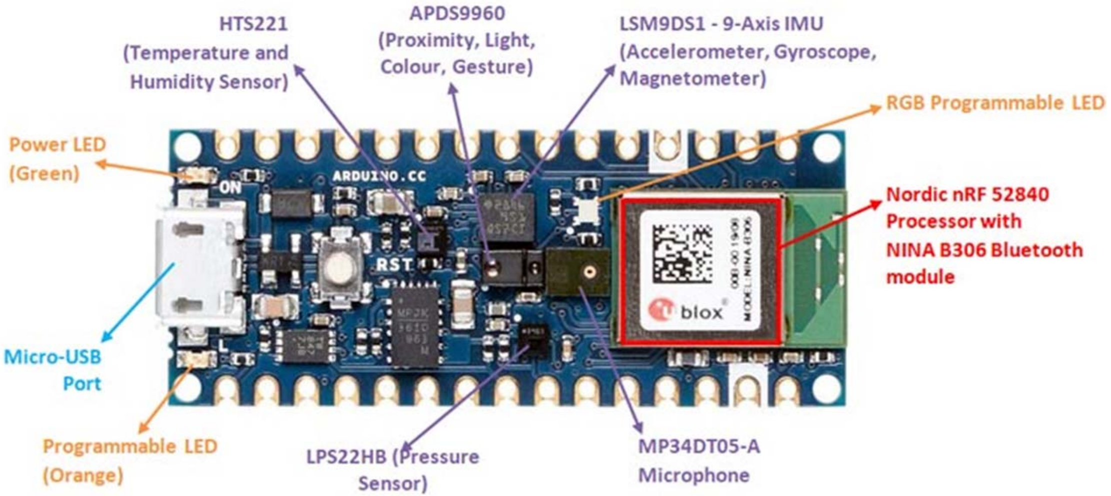
*Energy Harvesting Testbed for Integrated and Connected eSiP

Energy Harvesting Testbed Flowchart



Our Starting Point

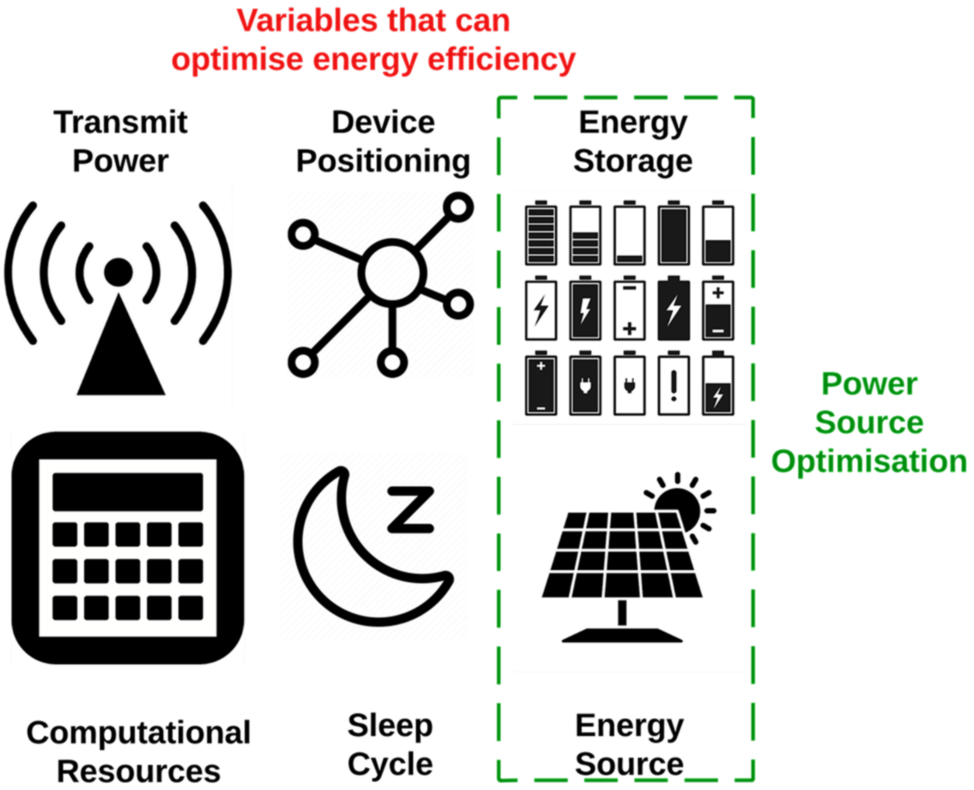
- **Harvesting Ambient Light Energy & COTS Power Management IC**
- **ULP Wakeup - RTC**
  - ☐ Capable of Measuring
    1. Ambient Light, colour, gesture
    2. Accelerometer, Gyroscope, Magnetometer Data
    3. Atmospheric Pressure, Temperature and Humidity
    4. Audio
    5. Battery Level



Research Challenges

There are multiple aspects of a network that can be optimized through Machine Learning. A few to mention

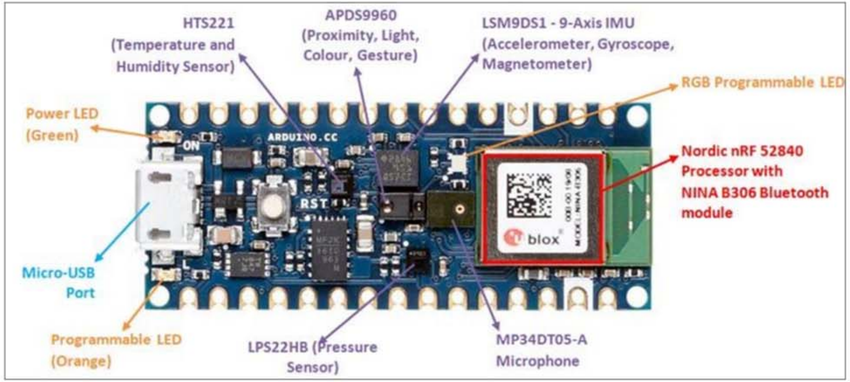
- **Localization of the IoT devices**
- **Transmit Power of each**
- **Power source optimization**
- **Resource optimization**
- **Sleep Cycle**

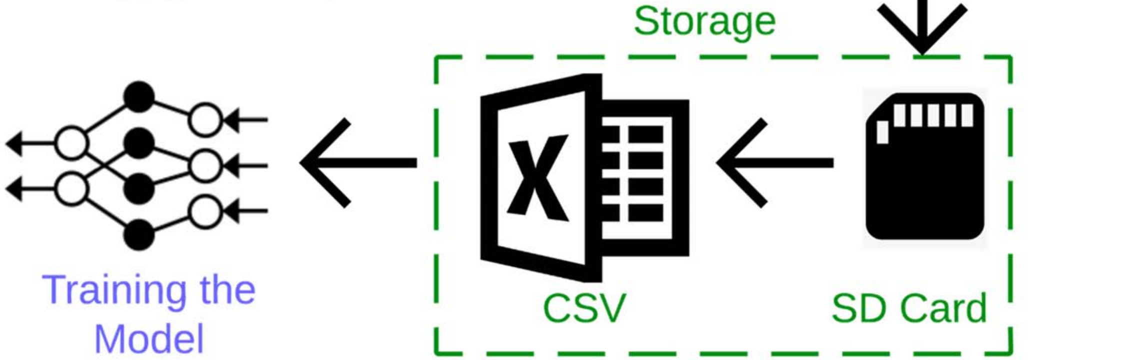


Data Collection Unit

- **Storing as much relevant data as possible from these sensors**
- **Create Machine learning models from data**
- **Providing open-source access to all data collected**
- **[Intel-Berkeley 2004 Dataset]**

Arduino Nano BLE Sense

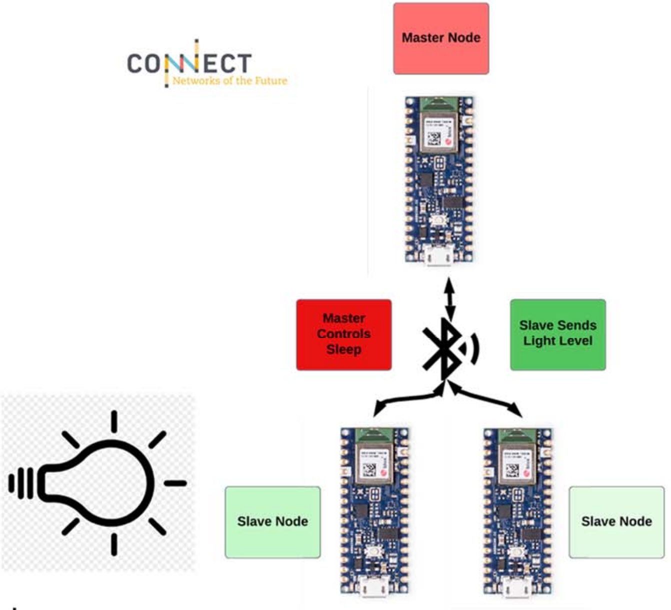


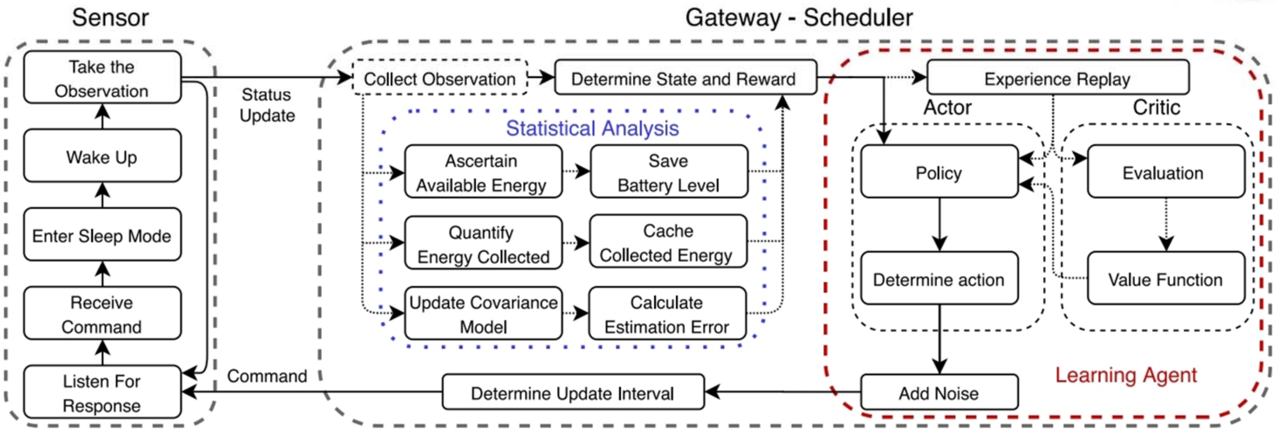


Arduino Implementation of Sink and Source model

CONNECT Networks of the Future

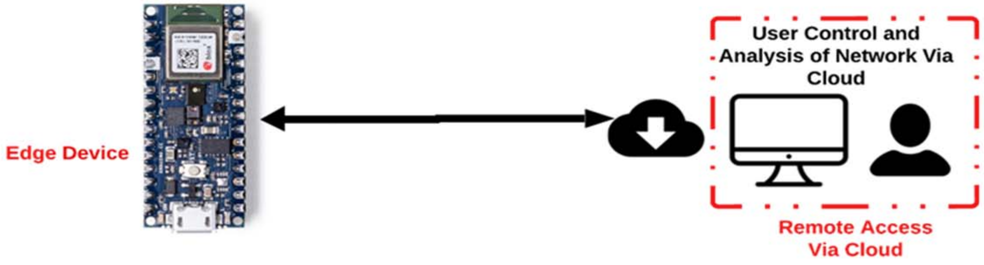
- **Infrastructure for something like the gateway scheduler below available**
- **Master controls update interval/sleep interval**
- **light level, voltage stored and PV cell voltage**

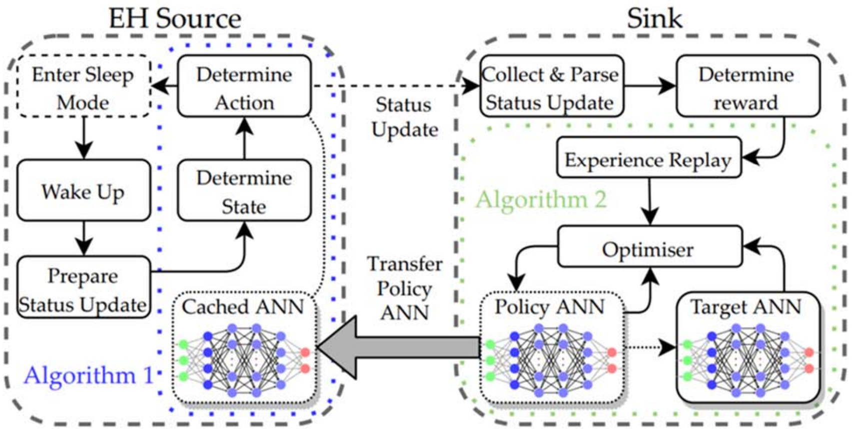




Arduino Implementation of Sink and Source model

- Arduino edge devices act as sink
- Access via cloud allows user to remotely train and deploy ANN
- Opportunity to move from simulation to

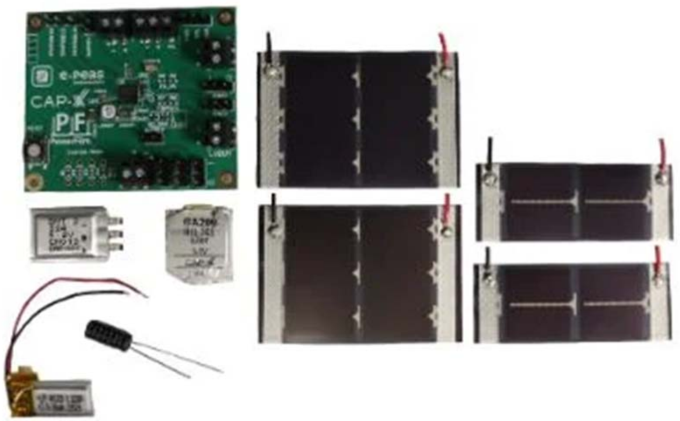





```
void setup()
{
  Serial.begin(9600);
  NeuralNetwork NN(layers, weights, biases, NumberOf(layers)); // Creating a NeuralNetwork with pretrained Weights and Biases
```

Power Characterisation: Implementation

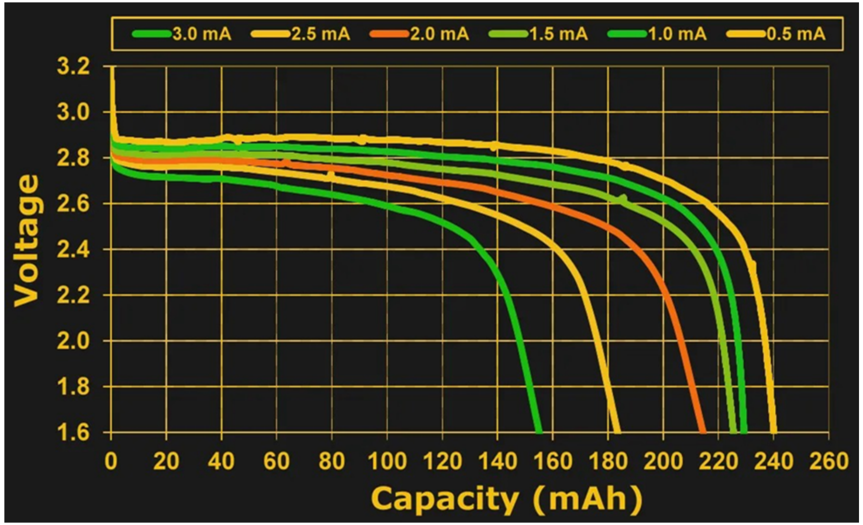
- 89uW= Rate Being Stored in Capacitor Bank
- 1.2uW = Load in Sleep Mode
- Allows for Charging of the Device While In Sleep



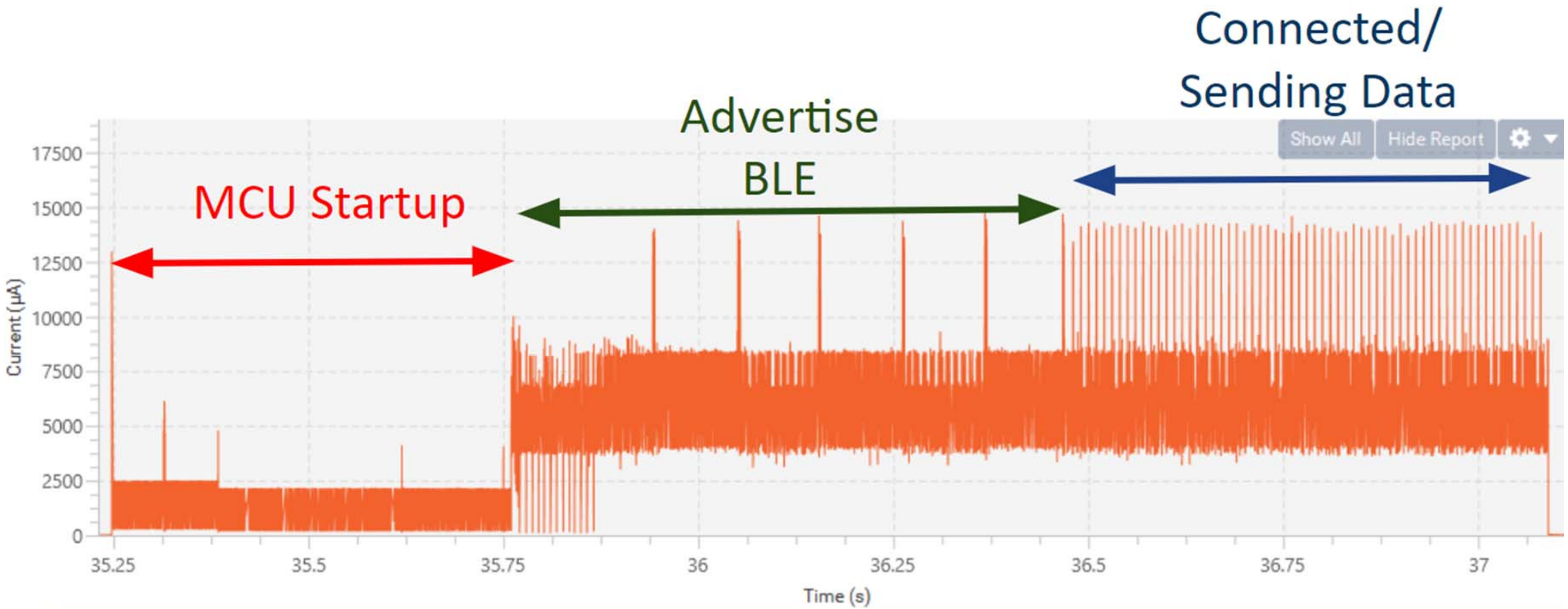
- 220mF
- Charged/Discharged to 2.7V/1.85V
- Enough energy stored to connect, communicate and sleep 22 times on average (assuming average 20mJ +ideal output regulator)

Putting Energy Used in Context

- **10.8 Joules per mAh in 3V Coin-Cell Battery @ 240mAh stores 2592 Joules**
- **2592 Joules =129,600 connections w/o Energy Harvesting (20 mJ per connection)**
- **Sleep interval of 10 minutes = coin cell battery lasts ~2.38 years**
- **Energy harvesting can extend this to 10 years at least**



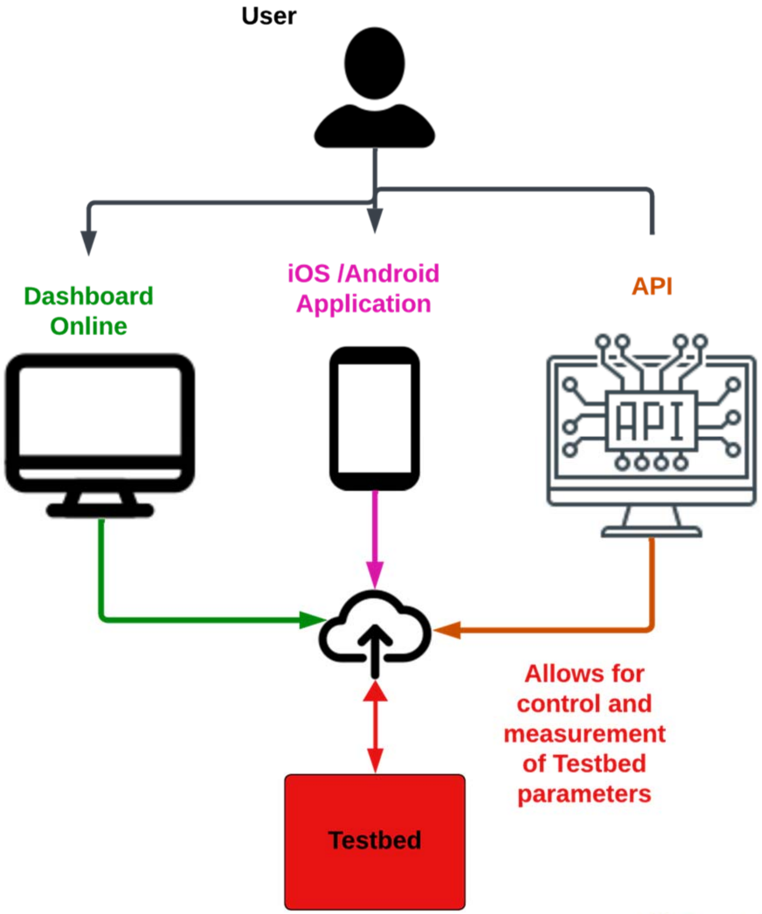
Example Power Analysis



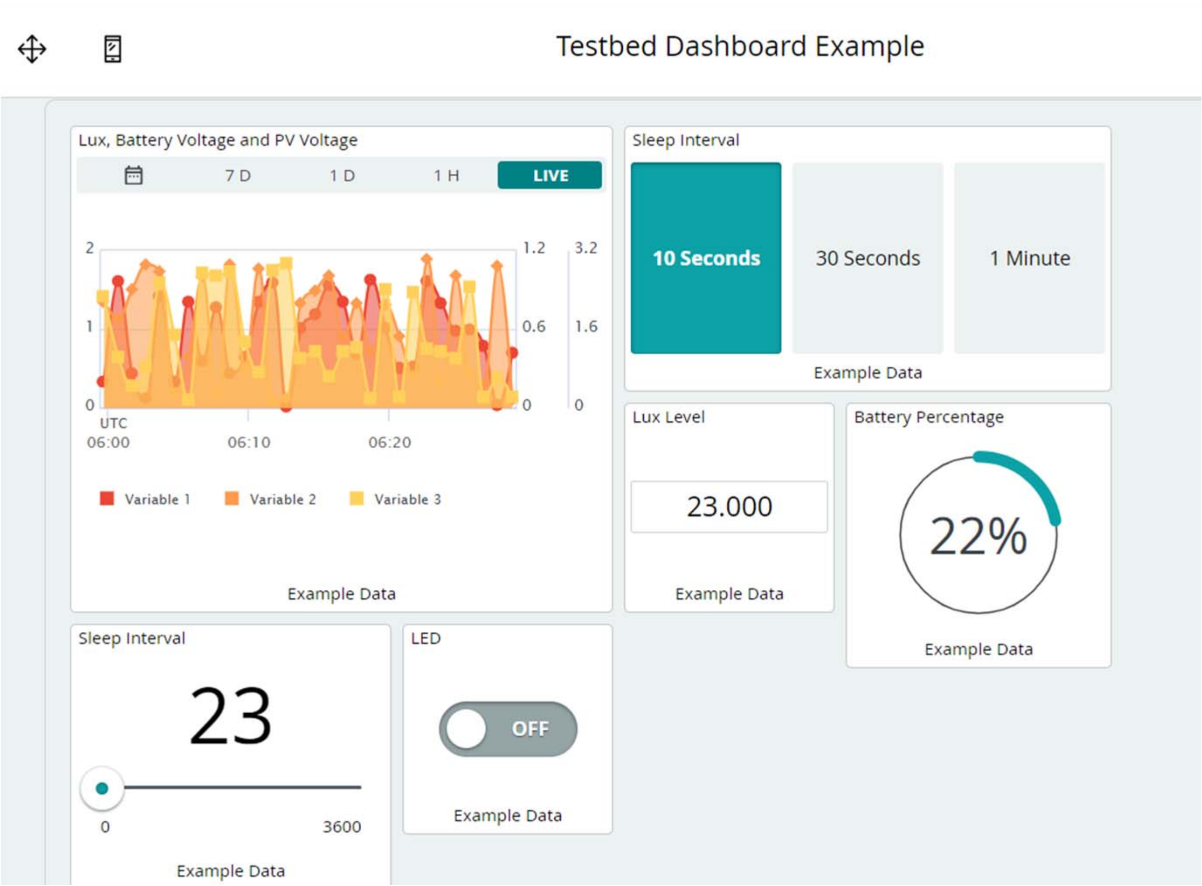
	FULL						SELECTED TIME FRAME 1.894 s					
	Min:	Max:	Average:		Energy:		Min:	Max:	Average:		Energy:	
Current:	0.000	18630.981	438.506	µA	66699.115	µJ	0.122	14785.767	4132.058	µA	14087.906	µJ

How we communicate with the Cloud: Implementation

- **3 methods tested for communication from end-user to edge node**
- **Simple Dashboard: Sliders, text boxes and graphs;**
- **Arduino Cloud Phone application**
- **Arduino Cloud API via Python;**

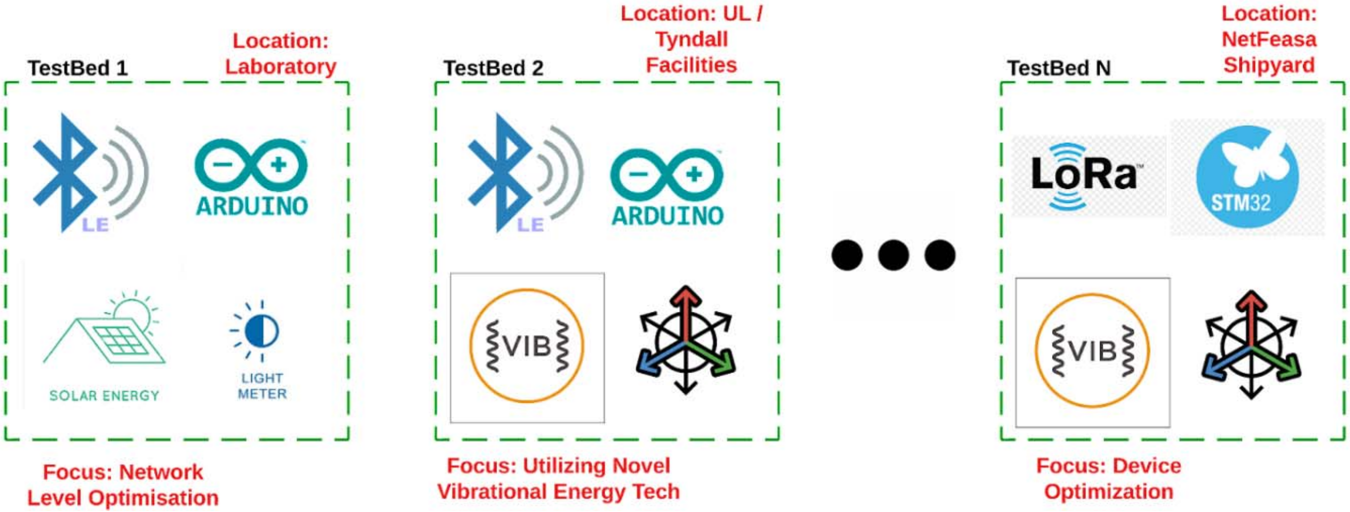


How we currently communicate with the Cloud: Dashboard



Testbed Iterations

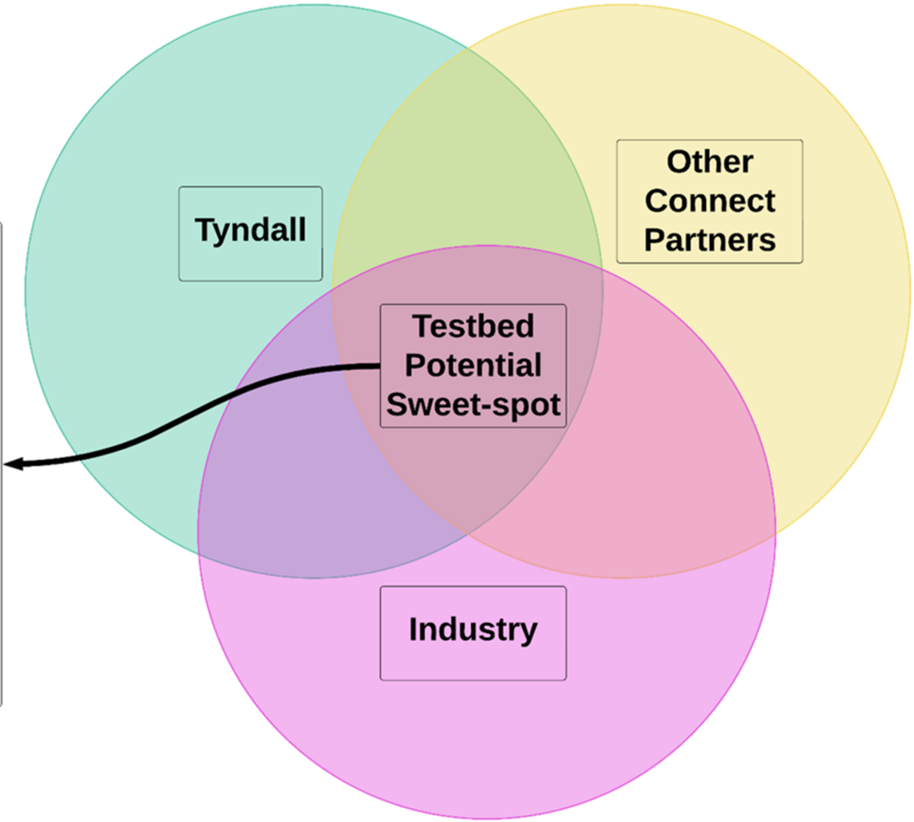
- **Multiple different locations**
- **Different Energy Harvesting Tech**
- **Different Radio Technology**
- **Network and Node Level Analysis/Focus**



Where I see the Testbed Benefitting Most

- **Foster collaboration between industry, other CONNECT partners and Tyndall**

- Research Excellence for Tyndall and other Connect Partners
  - Papers, simulation models, historical sensor data for training machine learning models
- Useful experiment-based data for industry partners
- Detailed Edge node analysis and data as an addition to Network Level



Battery Life Simulation Model

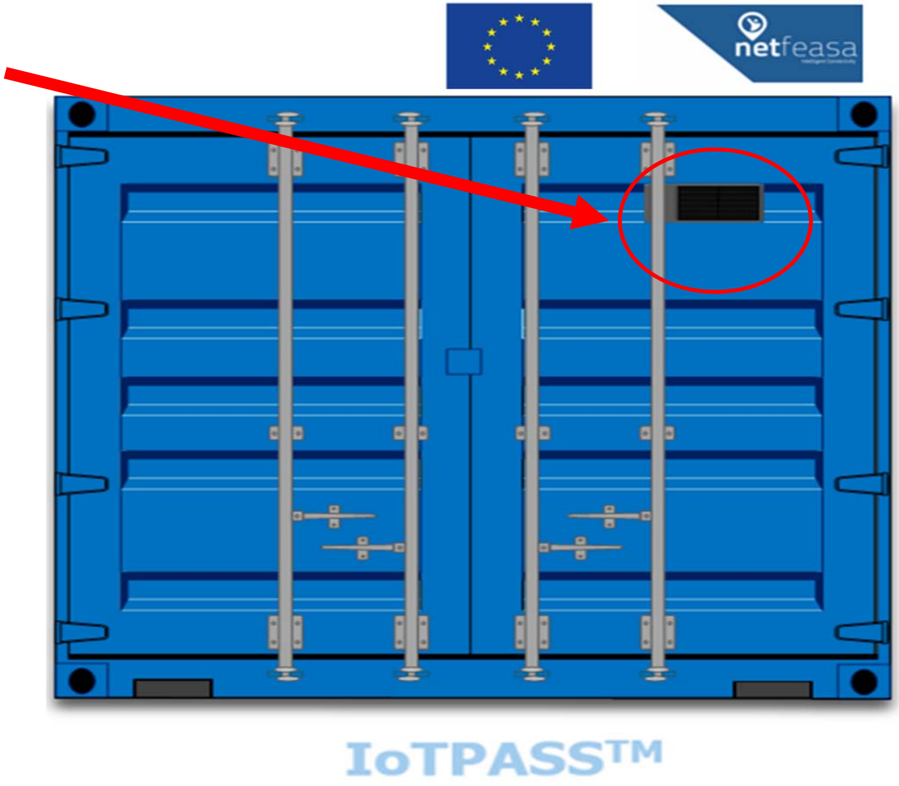
- **Helps all stakeholders in sizing of**
  - **Primary battery**
  - **Secondary battery**
  - **PV Panel**

- **Demonstrates the potential to reduce primary battery size + extend battery life**

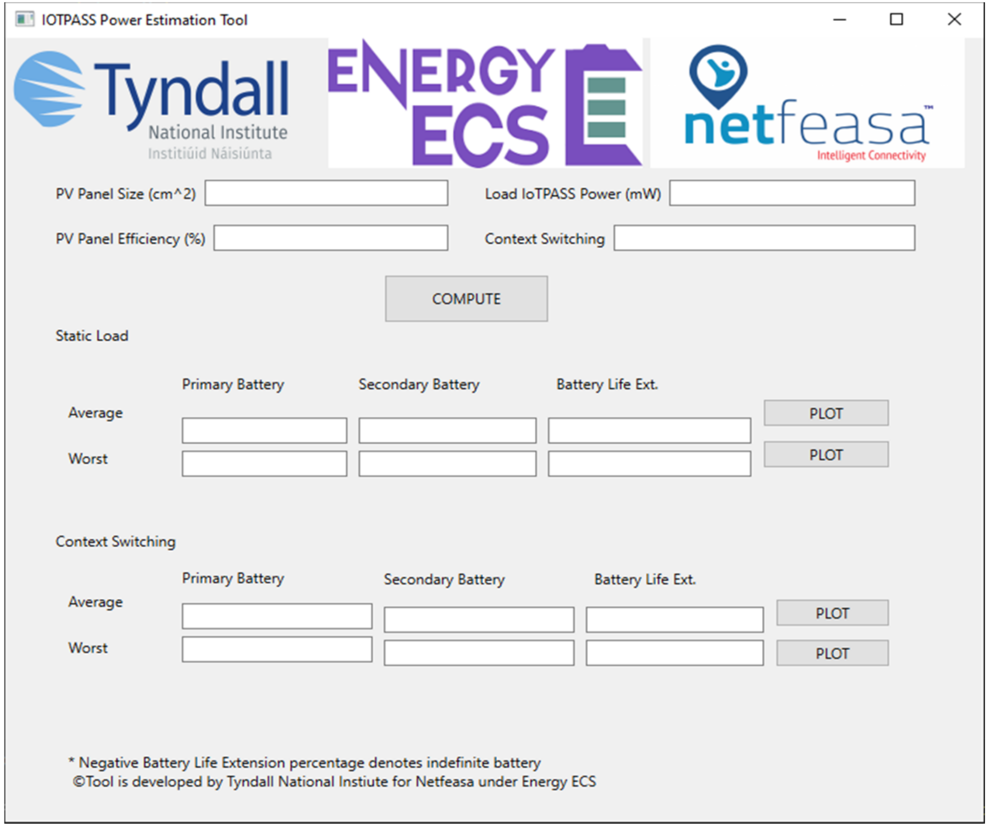
- **stakeholder engagement to make tool user friendly and how to get the most out of it.**

IoTPASS (NetFeasa)

- **CSEM Solar powered tags attached to dry containers**
- **Temperature, motion detector and location Sensors**
- **PV system extends battery from < 2 years to a target of > 10 years (ideally autonomous).**

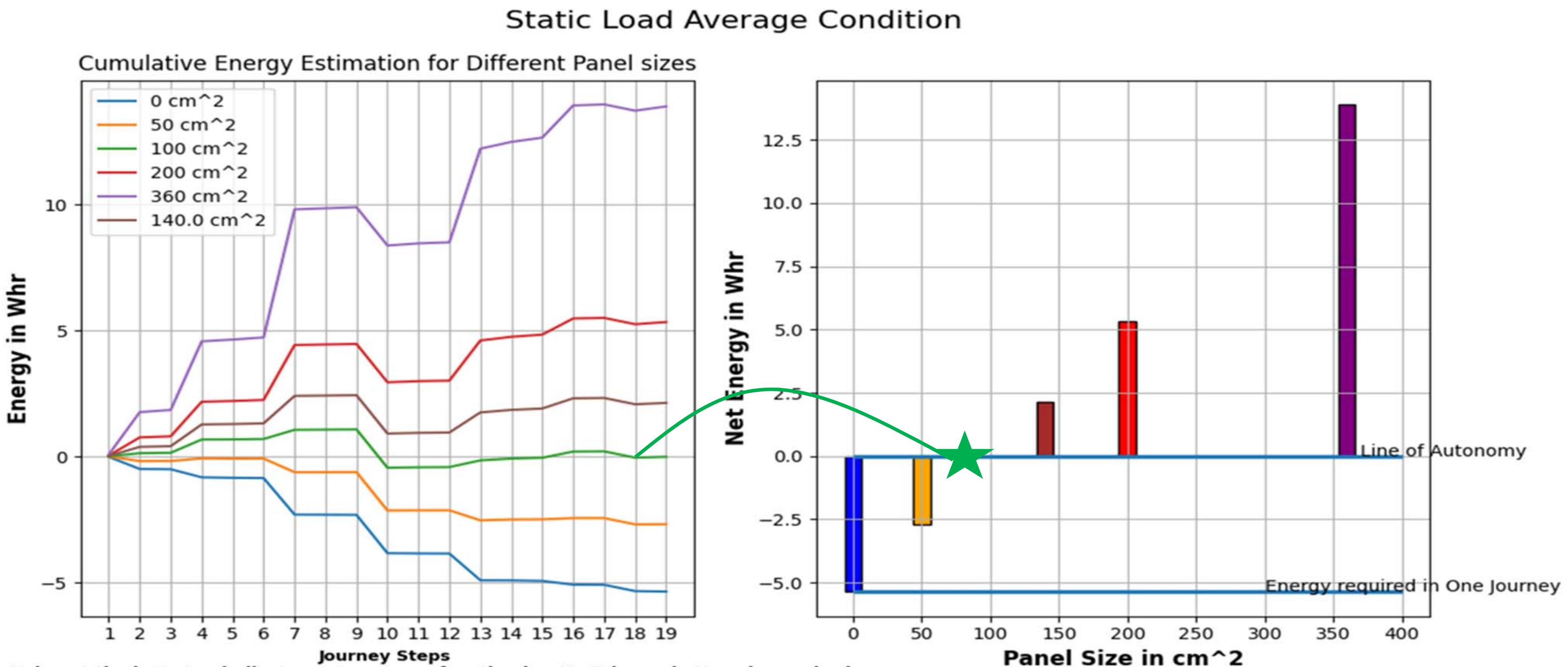


Battery Life Simulation GUI Display (Non-expert)



- **Platform independent APP developed on Python**
- **Gives step by step and overall journey energy consumption analysis**
- **Provides size of primary battery required for a single journey**
- **Provides size of secondary rechargeable battery size and battery life extension**
- **A graphical analysis that helps in appropriate panel sizing,**

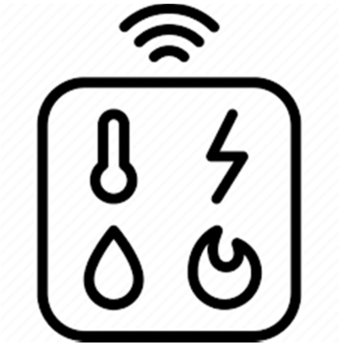
Line of Autonomy



: Value at the last step indicates autonomous function i.e. No Primary battery is required

Next Stages

- Developing Beds with Different Energy Sources
- Drawing on SMART patch demonstrator
- Adding Tyndall PMIC
- Adding Different RF Tech LoRa Sub-1GHz outside of BLE
- Allowing Access for other Researchers Through Cloud Services



CONNECT Networks of the Future

NB-IoT

Sub-1GHz

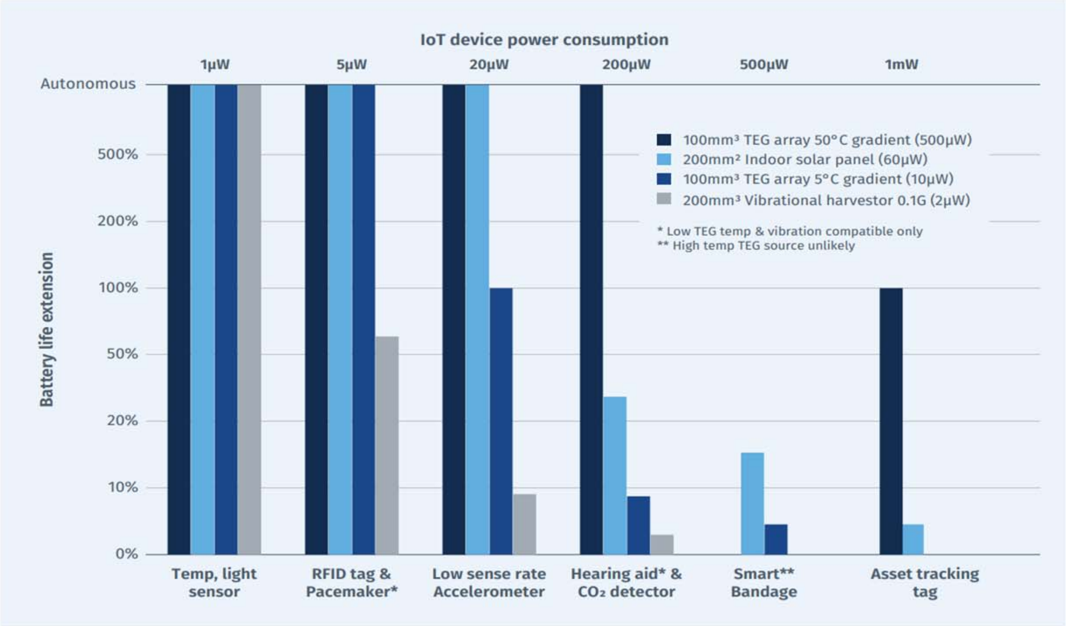
Conclusion: Expected Outcomes and Impacts

Scientific Outputs and Outcomes:

- Devices that can power themselves and can operate without a battery
- Devices with extended battery life and less need for replacement
- Novel use cases such as HOLISTICs TEG Demonstrator, NetFeasa Asset Tracker, More detailed Simulation Models

Wider Societal Impact:

- Stakeholder impact from device users, patients, consumers to manufacturers, integrators and developers
- Battery replacement needs will exponentially increase without this work
- Making Wireless Sensor Networks more robust and trustable



Q & A

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Thanks very much for your time and attention!

Questions/comments???

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