AMANDA:

Autono**M**ous self-powered mini**A**turized i**N**telligent sensor for environmental sensing an**D** asset tracking in sm**A**rt IoT environments

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Agenda

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- Consortium and aims
- The Amanda card and possible use cases
- Some challenges
- Overcoming challenges

Acknowledgements

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Consortium and Aims

- **Aims**
  - Stretching the limits of Electronic Smart Systems' (ESS) autonomy
    - In terms of energy, decision making and maintenance-free lifetime extension
  - Develop and validate a cost-attractive next generation Autonomous Smart Sensing Card (ASSC) that will serve multi-sensorial IoT applications for smart living and working environments
    - Credit card dimensions, 3mm thick. Miniaturization in important
  - Strengthen the partners' technological excellence by delivering the needed ASSC parts, architecture, HW/SW

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Consortium and Aims

- **Consortium of 8 partners in 6 countries**
  - EU contribution € 3’999’625
  - 3 Research partners, 5 Industrial partners
    - CERTH, Greece (Consortium leader)
    - E-Peas, Belgium
    - Ilika Technologies Ltd, United Kingdom
    - Lightricity Ltd, United Kingdom
    - Microdul AG, Switzerland
    - Penta, Croatia
    - Stichting IMEC, Netherland
    - Zürich University of Applied Sciences, Switzerland

Consortium and Aims

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- **Sponsor: European Commission (Horizon2020 program)**
  - RIA project (Research and Innovation Action)
    - Low TRL (Technology Readiness Level)
    - The technologies would lead to market products in further steps
- **Time frame: 3 years, 2019 – 2021**
  - Possible time modulations (covid-19 ....)
- **It is about the development of low power technologies required for small energy autonomous embedded systems**
  - Energy harvesting elements (harvester, storage, power management)
  - Low-power sensing, intelligence, tracking and communication, security

Consortium and Aims

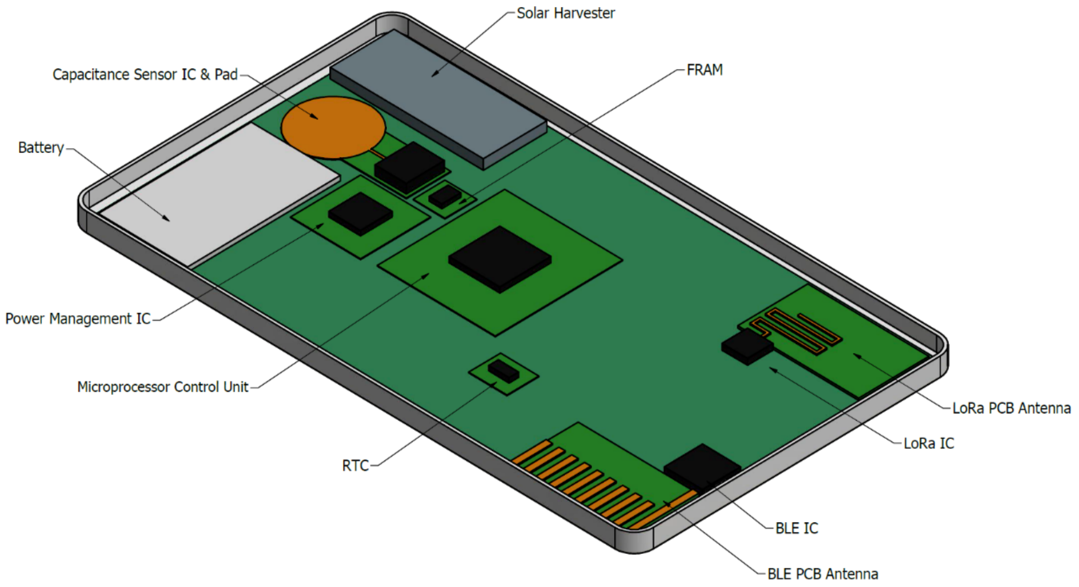
- **It is about the application of low-power technologies**
  - The card validates the technologies and shows how they can be used
  - Component level
    - Integrated circuits (Power Management device, Touch, Temperature, CO_2 sensors)
    - Solar cells, storage elements
  - System level
    - Wireless communication and tracking features (Wireless) (e.g. AoA, TDoA)
    - Low-power embedded system technologies (HW, FW, Architectures, Simulation, ...)
      - ► Low power processing, use of new NV technologies
      - ► Low-power Edge Intelligence

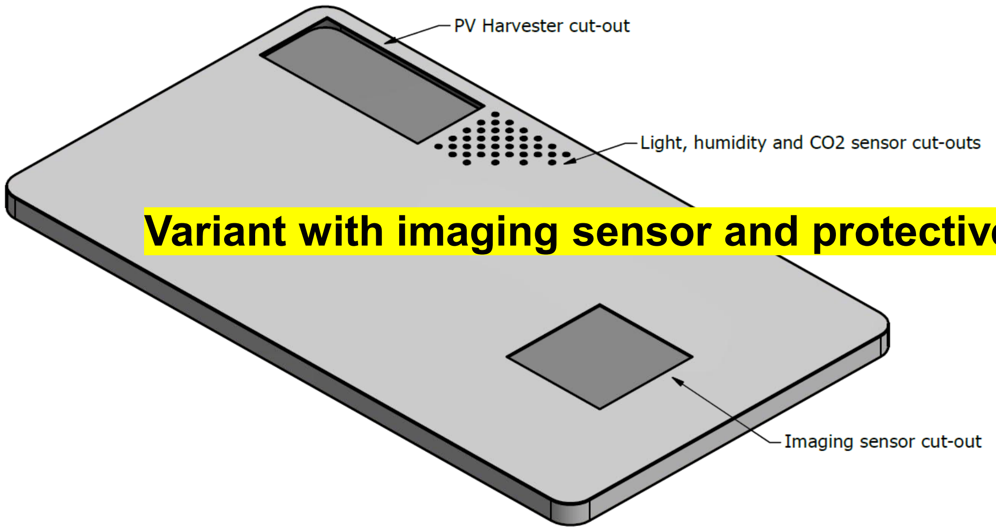
Card and use cases: Block Diagram

Energy	Processing and control	Sensing	Communication and tracking
Solar Cell	NV-Memories	RH&T sensors	Imaging and Other sensors
Storage Elements	Microcontroller	CO2 Sensor	Wireless Communication LPWAN
Booster and Power Management	RTC	Capacitive Sensing	Wireless Communications WPAN

The card is equipped with several sensors and communication interfaces. The storage can be recharged in presence of light to allow use in different situations (indoor, outdoor, wearable)

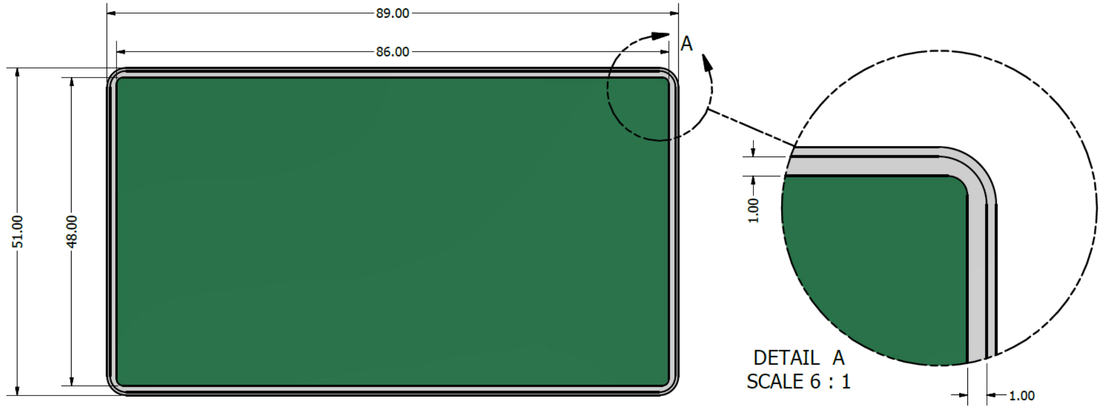
Card and use cases: (conceptual core system)





Variant with imaging sensor and protective enclosure

Possible view of the card with different components



The target dimensions of the ASSC are 89mm × 51mm. The maximum thickness of the system will be constrained to 3mm.

Card and possible use cases

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- **There are many possible use cases. Here are some examples**
  - Environmental sensing for personal comfort
    - Sense parameters in your environment and trigger decisions
      - Work place, home (e.g. CO_2 detection indoors)
  - Asset tracking
    - Track objects indoor, outdoor
  - Parking
    - Determine presence/absence of vehicles in parking lots
  - Teaching
    - Teach and experiment with energy harvesting technologies
  - New sensors can be added for different applications

Challenges

- **There are many challenges. Here are some examples**
  - Energy
    - Can one harvest enough energy?
      - Especially indoors or when the card is used as wearable
      - How will the harvesting work in low-light situations?
    - Can one store enough energy?
      - Storing enough energy is challenging (thin device)
  - Component level
    - Reduce load (implement needed functions that require less energy)
- **System level, miniaturisation**
  - Fit all on small size (components should be thin, manufacturable)

Overcoming the challenges

- **Reduce energy requirements**
  - At component level
    - Sense with less energy, boost manage power with more efficiency
      - ► Better CO_2 sensing (away from NDIR methods)
      - ► Improve energy requirements of all sensors
    - Appropriate system architecture
      - ► Implement support in components to allow reduction of energy
      - ► Power modes that improve transition to sleep mode
      - ► Use of new NV-technologies (FRAM, MRAM, ReRAM, …)
    - Low-leakage, thin storage combined with appropriate PM
    - Efficient energy harvesting, especially indoor (small size)

More information from: https://ieeexplore.ieee.org/document/8966223

Overcoming the challenges: some technologies

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- **Solar cell (from Lightricity)**
  - Build on existing technology to deliver necessary energy, form, packaging
  - Example product (https://lightricity.co.uk/)
    - EXL2-1V50 → 47µW @200 lux
    - Energy output in relation to Amanda

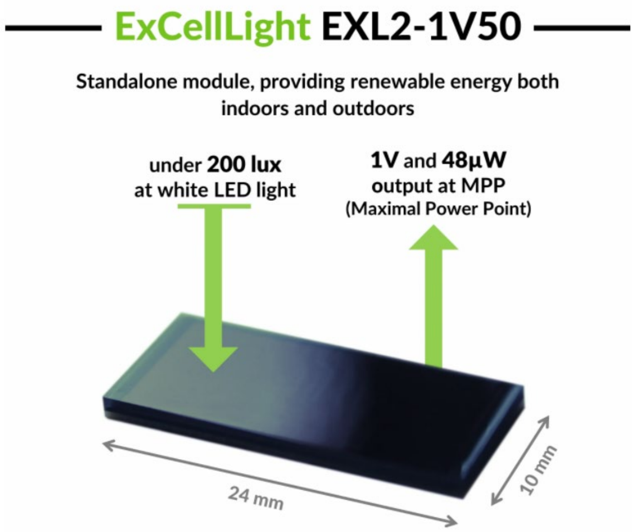
    More than150mJ in 1 hour

    → Several LPWAN frames

    → Over 3000 ADV frames (Bluetooth Smart)

    Considering 50µJ per ADV event

    → Also works in low-light conditions



Performance (indication only)	Module 200 lux white LED spectrum
Size	23.8 x 10.2 x 1.5 mm^3
Active area	2.15 cm^2
Number of cell(s)	1
Open circuit voltage	1.15 V
Short circuit current	49.8 µA
Operating voltage	1.0 V
Operating current	47.6 µA
Operating power	47.6 µW
Power density (active area)	22.1 $\mu W.cm^{-2}$

Overcoming the challenges: some technologies

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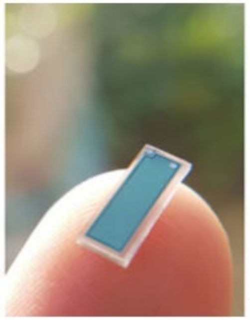
- **Solid State Battery (from Ilika). Rechargeable storage**
  - Build on existing technology to deliver low-leakage and thin storage device. Example product is the Stereax M300
  - (https://www.ilika.com/battery-innovation/stereax-m50)
    - Moisture resistant, low self discharge. Miniature footprint (3.6mm x 5.6 mm)
    - All solid-state construction. No liquid or polymer components, no free lithium
    - M300: 300μAh @ 3V → 3.24J. Energy for > 60K ADV events (@ 50μJ/ Event)
    - Shape can be customized. Cells can be stacked for more power (e.g. M300 is the 6-stack version of M50)
  - Some of these features will be improved in Amanda



Overcoming the challenges: some technologies

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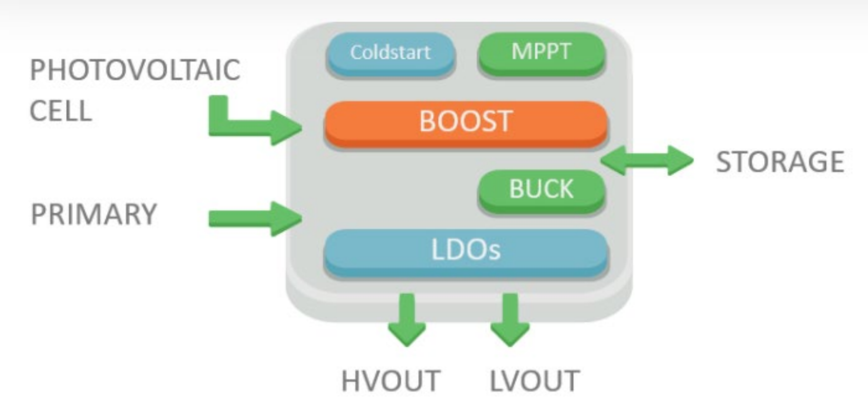
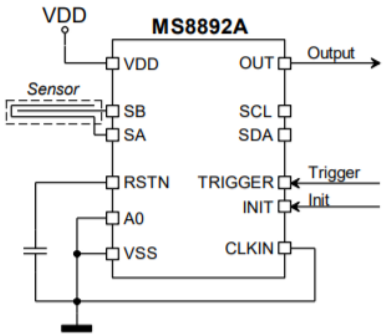
- **Power Management and booster (from e-peas)**
  - Example product with current technology is the AEM10941
  - (https://e-peas.com/product/aem10941/)
    - Booster with MPPT
    (70%, 75%, 85% or 90%)
    - Input voltage from 50mV - 5V
    - Cold Start: 3µW @380mV
    - Power in: 3µW – 550mW
    - Power out: 20mA @ 1.2/1.8 V and 80mA @ 1.8-4.1 V



  - E-peas also develops imaging sensor and LP microcontrollers
  - Energy transfer, PM architecture will be improved in Amanda

Overcoming the challenges: some technologies

- **Low-power capacitive, temperature sensors (from Microdul)**
  - Capacitive sensing is used for MCU-less user entry (Touch)
    - Configurable without CPU intervention (OTP). Reduces system energy
    - Architecture facilitates low-power modes for the system
  - Example products (https://www.microdul.com/):



MS8892 Touch/proximity sensor. Compare/measure modes (range 200 - 1000fF)

- ► Average current (2Hz) with/without external clock: 65nA/725nA
- ► Can be combined with other devices to allow power control of MCU

Temperature sensing (MA188C). Delivers digital values over serial link

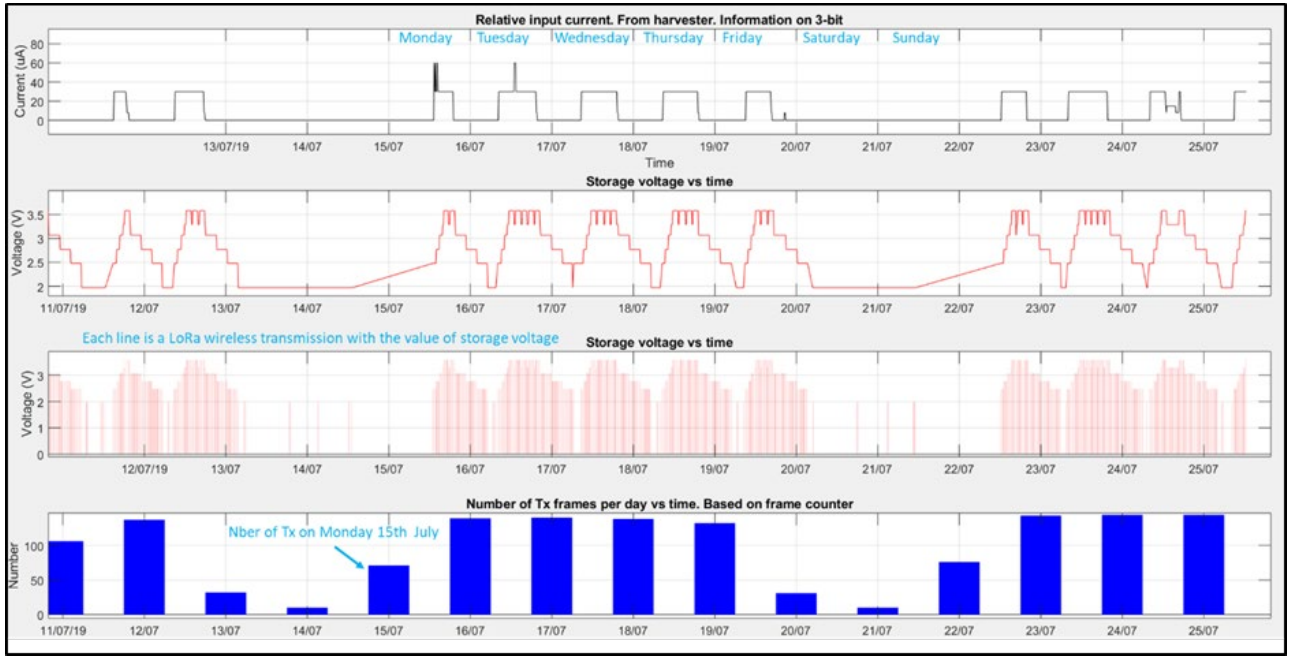
- ► Range: -40°C to +120°C. Typ. accuracy ±0.3°C (+20°C to +40°C);Res: 0.05°C
- ► 1 meas. per min → 60nA; stand-by 20nA; active measuring 75μA
- ► Some features will be improved within the Amanda project

Overcoming the challenges: some technologies

- **Low-power CO_2 sensor (from IMEC)**
  - Measurement of CO_2
    - NDIR methods require much volume and energy
  - Impedance measurement method developed by IMEC
    - Small dimensions. Fits in a corner of the Amanda card
    - Low-power, very suitable for low-power IoT applications
    - The sensor consists of an interdigitated electrode on top of which a layer of gas-sensitive material is drop casted. Gas diffuses into the CO_2 sensitive layer and changes its electrical property. The change can be read out as a change of electric impedance between interdigitated electrodes.

Overcoming the challenges: indoor context

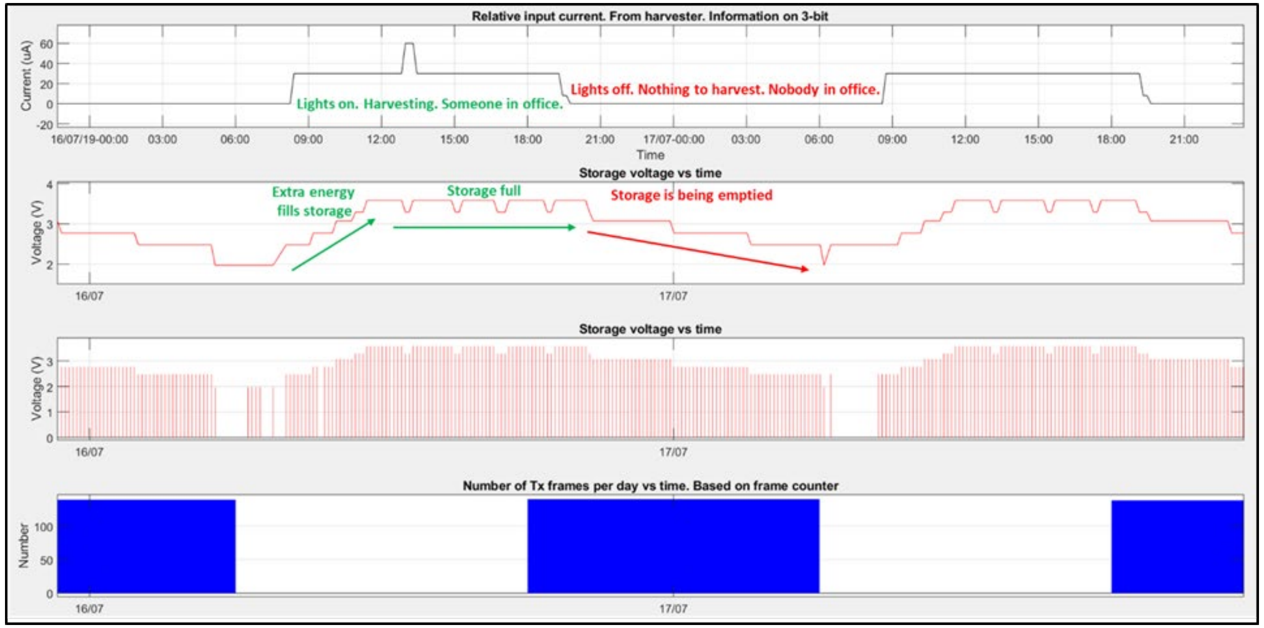
- **Solar harvesting in a typical office**
  - (Lightricity solar cell technology)
  - Normal working days, light conditions allow harvesting
  - >200 lux
  - Measurements and wireless communication possible
  - No light at night or week ends → no harvesting. Storage should bridge this situation



Solar Harvesting Embedded System used to evaluate harvesting in office environment.
Measurements in an office at ZHAW-InES show:
- **Relative measurement of the illuminance**
- **Storage voltage (supercapacitor used)**
- **Transmission frames represented by vertical line**
- **Number of frames transmitted per day**

Overcoming the challenges: indoor context

- **Solar harvesting in a typical office (zoom)**
  - The charge level is then stabilised by the power management and the energy is being used and the harvester still delivers enough energy.
- **Tests have been made down to 30 lux (reported in another paper)**



Solar Harvesting Embedded System used to evaluate harvesting in office environment.
Measurements in an office at ZHAW-InES show:

- **Relative measurement of the illuminance**
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- **Transmission frames represented by vertical lines**
- **Number of frames transmitted per day**

Overcoming the challenges: outdoor context

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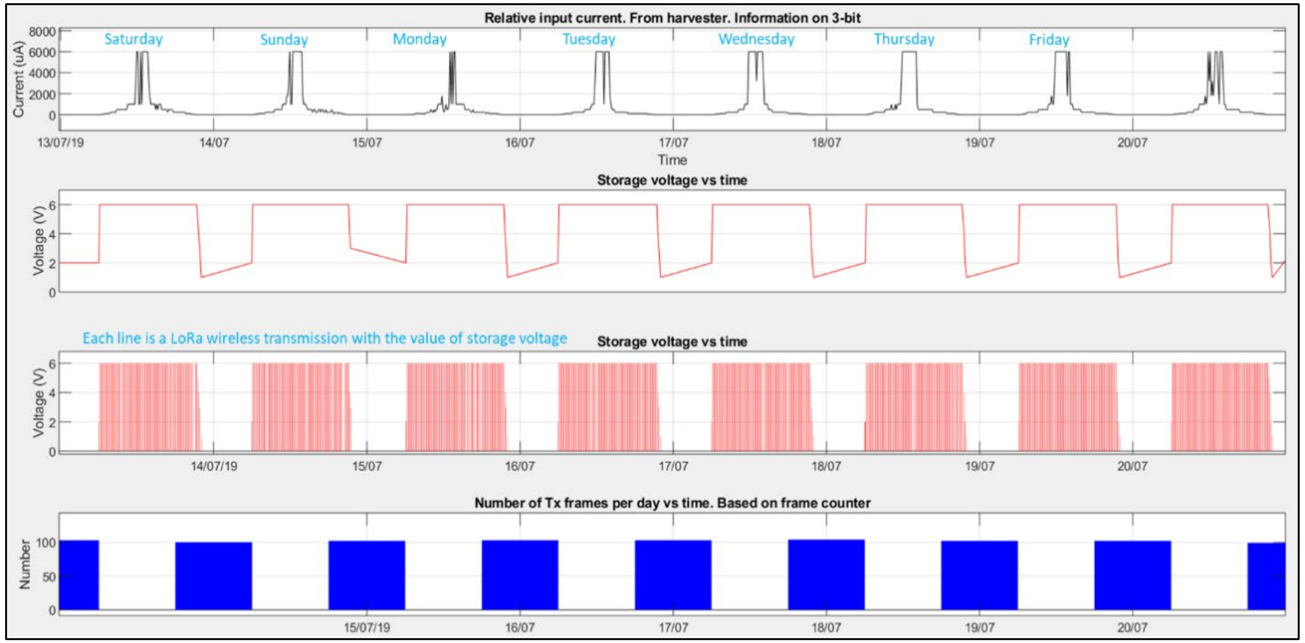
- **Solar harvesting in a typical office, at window**
  - Sunlight is predominant
  - More energy is harvested
  - The week-end effect is not present. More could be done with the device, since there is much more energy.



Solar Harvesting Embedded System used to evaluate harvesting in office environment.
Measurements at window in an office at ZHAW-InES show:

- **Relative measurement of the illuminance**
- **Storage voltage (supercapacitor used)**
- **Transmission frames represented by vertical line**
- **Number of frames transmitted per day**

How does this relate to you?

- **Technologies developed can be used in different applications**
  - Basically low-power embedded systems
  - Feel free to contact me / the consortium if you want to be kept informed
- **Thanks you for your attention**
- **Links**
  - https://cordis.europa.eu/project/id/825464
  - https://amanda-project.eu/
  - https://ieeexplore.ieee.org/document/8966223