



Industry Session #12: Energy Harvesting

Energy Harvesting for a Green Internet of Things: A White Paper

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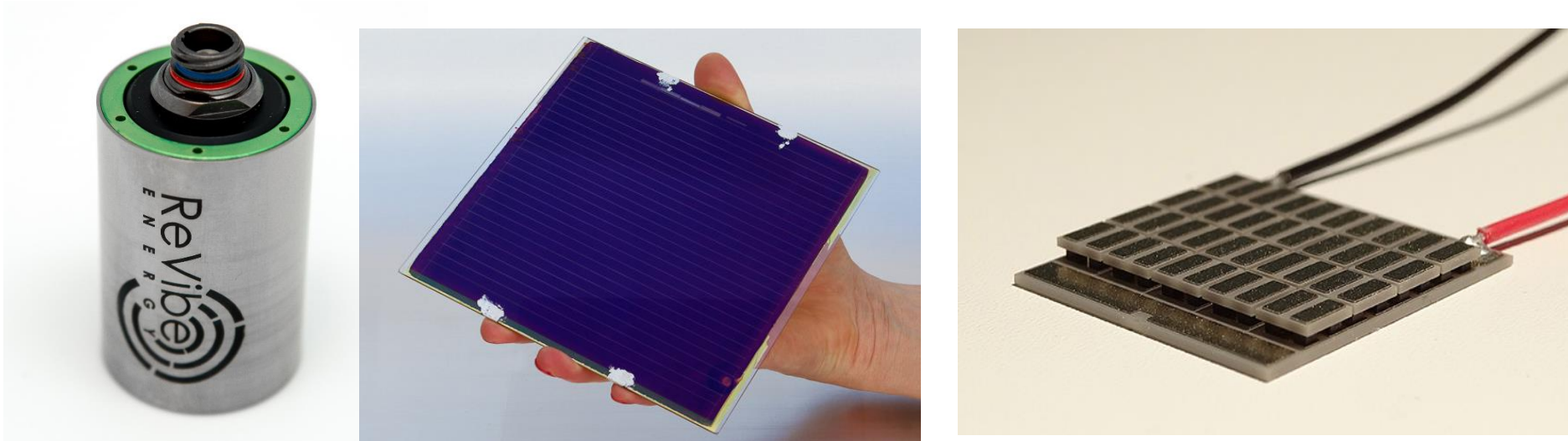
Key Findings

- 1) Energy Harvesting is a key enabling technology for the Green Internet of Things
- 2) And demonstrated its potential in several Use Cases.
- 3) But Industrial Adoption is still reluctant,
- 4) Despite positive Cost Benefits and Life-Cycle Impacts.
- 5) Therefore, massive future deployment requires a concerted strategy in Research and Innovation!

White Paper Structure

1. State-of-the-Art from the Perspective of the User
 - Technologies & methodologies, power & energy densities, limitations
2. Developing for a Use Case
 - Application examples & demonstrators
3. Key Missing Elements for Industrial Adoption
 - Industrial requirements, operational management, supply chains
4. Key Advantages
 - Cost benefits, life cycle assessment, sustainability & reliability
5. Opportunities and Future Research Strategy
 - Stakeholders, research agenda, green deal

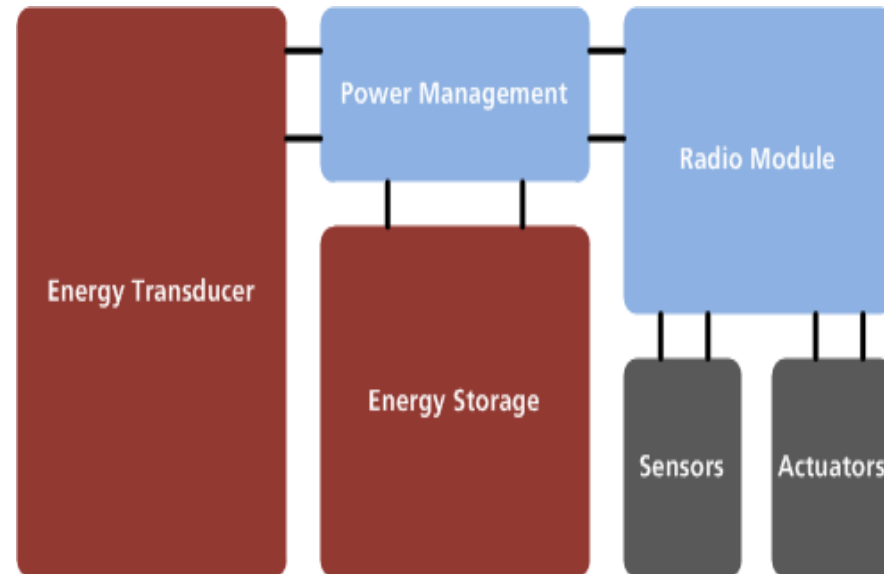
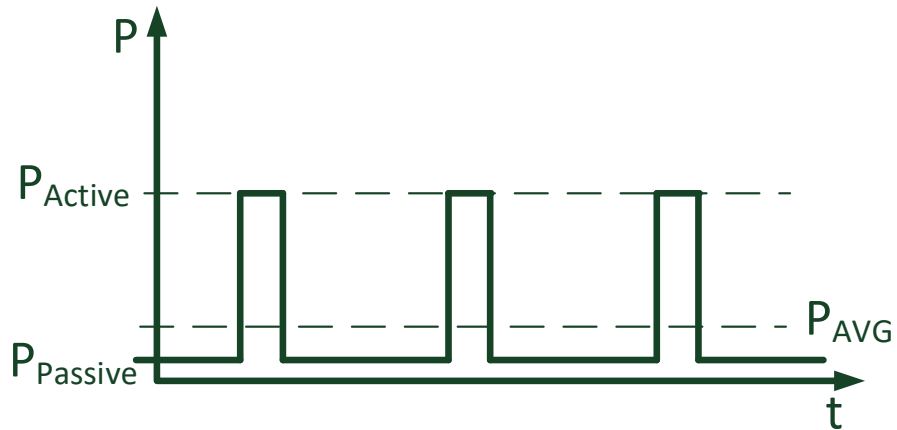
State-of-The-Art from the Perspective of the User



- Energy may be harvested from a range of environmental sources:
 - Vibration, light, heat, sound, electromagnetic fields
- Voltage and power levels depend on varying environmental conditions
 - Load devices need stable voltage and pulsed current on demand

[¹revibeenergy.com ²www.solliance.eu ³<https://chargedevs.com/newswire/thermoelectric-generators-convert-waste-heat-from-an-ice-to-electricity/>]

State-of-The-Art from the Perspective of the User



- Solutions for managing the mismatch in source and load power profiles
 - Energy storage: batteries (long term), supercapacitors (short pulsed power)
 - Source management: DC/DC or AC/DC conversion, MPPT, cold start
 - Load management: ultra-low power modes, intermittent operation

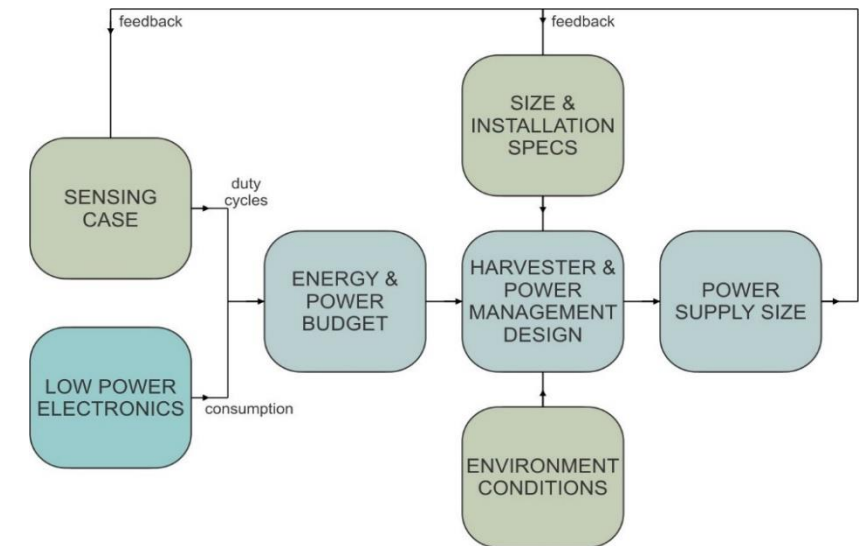
Developing for a Use Case

Status of Energy Harvesting Technology

- Energy harvesting can provide enough power
- Efficient management and storage available
- Low power electronics adequately low (1 mW active, 1 μ W sleep, duty-cycling)
- But bespoke solutions required

Developing application-specific power supplies – Required steps

- Identification of known environmental conditions by the technology user.
- Definition of the energy and power budget.
- Selection of one or more environmental energy sources and a suitable transduction mechanism.
- Development of a custom harvester prototype, suitable in terms of size, installation and power supply.
- Development of a power management / storage system that meets voltage, power, quality and reliability standards.
- Testing and adaptation towards a final product that can be deployed and offer the service desired.

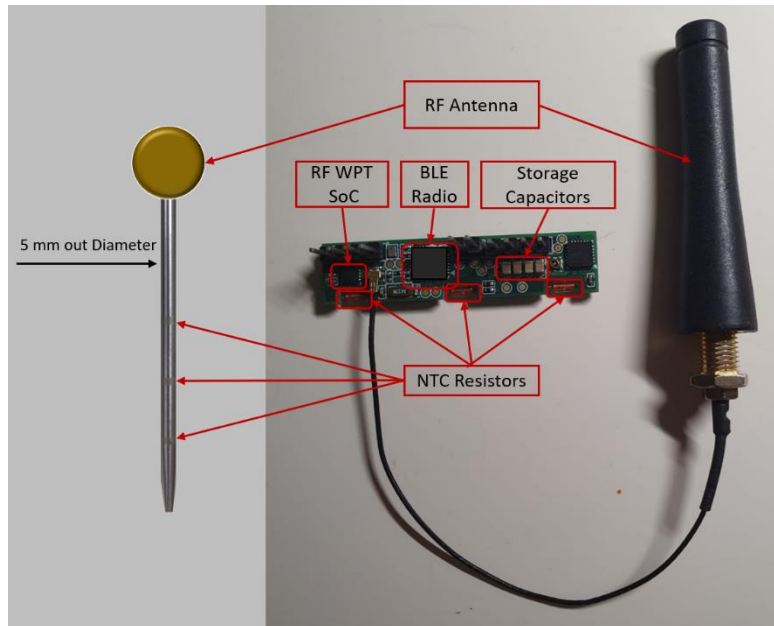


Schematic illustration of the design process for custom energy harvesting solutions

Developing for a Use Case

Example Use Cases

Roberto La Rosa, ST Microelectronics
Wireless temperature sensor for food cooking



Peter Spies, Fraunhofer IIS
Self-powered wireless smart screw.



Andrew Holmes, Imperial
Energy autonomous airflow sensor.



Key Missing Elements for Industrial Adoption

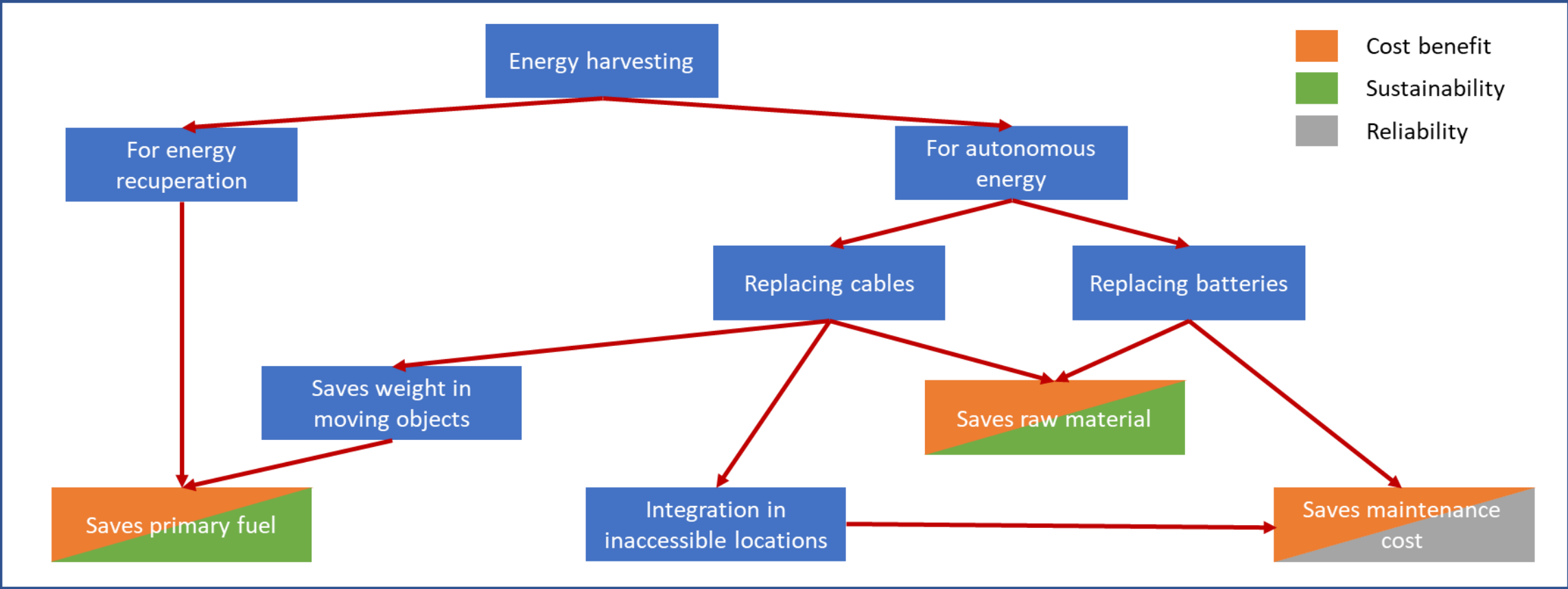
- System integrators specify the devices as a black box with defined interfaces for input and output parameters. In the case of energy harvesting detailed information about the installation environment is required by the supplier.
- Durable assets and components require a certain MTBF guaranteed. Otherwise, the user's confidence in the product is fading away.
- Energy storage is often required additionally to the energy harvester. But batteries or supercaps are a potential hazard source because of high energy densities and limitations in lifetime are expected due to their electro-chemical nature.

Key Missing Elements for Industrial Adoption

- Adequate energy supply in the situation of non-standard operation (MRO) of the system is a key challenge for energy harvesting. Changing procedures for such situations is costly and unlikely.
- Materials aspects and recycling are likely to generate additional costs. Energy harvesting devices may contain substances hardly to recycle although complying with RoHS, REACH obligations.
- Obsolescence management is another key challenge. In the split and dynamic emerging market of energy harvesting devices the provision of spare parts is a critical issue.

Key Advantages

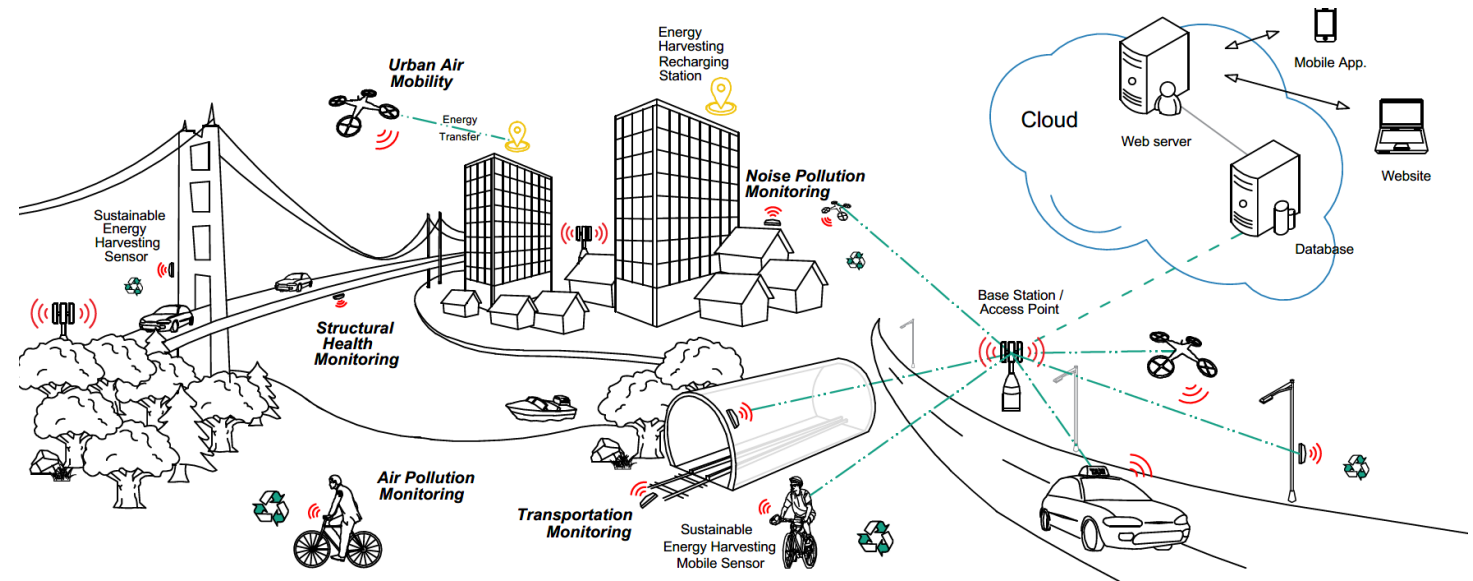
Assigning the advantages of energy harvesting to three key areas: cost benefit, sustainability, and reliability



Mostly all energy harvesting applications can be categorized based on this basic decision tree. Thus, in the end the application of energy harvesting has either benefits in cost, sustainability or reliability, whereas the last two can also be converted in cost.

Remote smart sensing

- Autonomous monitoring in smart cities can enable more sustainable solutions in the city and increase the reliability of sensing.
- Air and noise pollution monitoring, assets health monitoring, and transportation health monitoring in inaccessible locations are enabled by energy harvesting solutions.
- Energy harvesting devices can spread without battery replacement or cabling.



Opportunities

- The Energy Autonomous Microsystems Technology comprises a complex ecosystem with many start-ups
- Standardisation efforts are important to enable wider commercial deployment of energy harvester
- Combination with wireless power transfer and battery advancements
- Integration into smart packaging, towards a holistic device-to-environment interface
- Support and guidance in research agendas and funding bodies worldwide is required!

White Paper Updates

- The energy harvesting white paper committee is currently preparing a full text version as well as various specific papers and talks.
- Please check the psma.com website for updates and contacts.
- The support of the Power Source Manufacturer Association (PSMA) and the Energy Harvesting Committee is acknowledged.