



## Energy Harvesting Committee (EHC) Minutes 17<sup>th</sup> July 2020

Attendees	Apologies/Non attendees	
<p>Jim Stevens, FRABA            Andreas Beckes, FRABA            Thomas Becker, Thobecore            Dusan Vuckovic, Ikea            Mike Donnelly, Mentor/Siemens            Denis Pasero, Ilika            Roberto la Rosa, ST            Robert Andosca, Inviza            Michalis Kiziroglou, Imperial College London  <b>Brian Zahnstecher, PowerRox</b>  <b>Mike Hayes, Tyndall</b></p>	<p>Scott Thielman, Product Creation Studio            Maeve Duffy, NUIG            George Slama, Wurth (GUEST)            Mohamed Jatlaoui, Murata            Steve Savulak, UTRC            Johan Pederson, Sigma Design            Katherine Kim, UNIST            Anthony Laviano, NRAIT            Henrik Zessin, Fraunhofer IIS            Justin Knott, FCI            Jae-Do Park, Univ of Colorado Denver            Nathan Jackson, Univ of New Mexico            Warren Wambsganss, Astronics            Jeffrey Jouper, Astronics            Seshank Malap, Tektronix            Mike Wingard, Amphenol            John Horzepa, PSMA            Christian Pennisi, Jennova (GUEST)            Sri Kasichainula, Nimbus (GUEST)</p>	<p>Doug Osterhout, Google            Wensi Wang, BJUT            Peter Zou, Huawei            Ajinder Singh, TI            Aaron Stein, Dartmouth            Kevin Parmenter, TSC            Guoqing Liu, Huawei (HiSilicon)            Jochen Koszescha, Infineon            Laili Wang, Xi'an Jiatong University            David Newell, NUIG            Dan Stieler, PowerFilm            Sam Jones, PowerFilm            Jamil Khan, Univ of Newcastle (AUS)            Baoxing Chen, Analog Devices            Gary Johnson, Ilika (for Denis)            Joe Horzepa, PSMA            Marcus Taylor, IsoLode            Steve Reuter, Jennova (GUEST)            Sebastian Bader, MIUN            Lorandt Foelkel, Wurth            Peter Haigh, Tyndall            Francesco Carobolante, IoTissimo</p>

(Co-chairs in bold font)

**Next meeting:- Thurs 20th Aug, 10am CST, Mike to chair, Brian to type.**

### Agenda

0. EH COMM PURPOSE STATEMENT REVIEW (Aug)
1. Welcome any new members/guests.
2. EnerHarv 2021 planning.
3. APEC 2021 panning
4. Brief update by Robert Andosca on new EH offering
5. Industry Event Watch & List of active EH companies
6. Webinars
7. White paper
8. 'Treasure Chest' at end of the minutes.
  - 8A. Student Competition
  - 8B. Updated Goals
  - 8C. Forward-looking Thoughts

### 0. Committee Purpose Statement

**(REVISIT AROUND AUG TIMEFRAME)**

*"The purpose of the energy harvesting forum is to collect and disseminate information related to energy harvesting. The committee's mission is: To support the mission, vision, goals and objectives of PSMA by developing an ecosystem that provides subject matter expertise & direction on the adoption & integration of energy harvesting and related energy storage, conversion and low power technologies; demonstrating that collaboratively we can truly accelerate the adoption of IoT in commercially feasible consumer, industrial applications and beyond."*

### 1. Welcome New Members

Jim Stevens (USA) & Andreas Beckes (Aachen), FRABA

### 2. EnerHarv 2021

- o NCSU – North Carolina State **DEFERRED, NOTICE SENT 3/13/20, NEW DATE TBA**
- o **Brian to talk with Steve Savulak (DONE) and close out financials (DONE)**

### 3. APEC 2021

Discuss in Aug, will share outline plans and deadline, Brian & Mike made a verbal commitment to prepare this, uncertain if it will be in person or virtual. **PRELIM APEC '21 IS PLANS BEING REQUESTED IMMEDIATELY ... MH/BZ WILL REVERT TO TIM MCDONALD.**

### 4. Industry Event Watch & List of EH companies

- **Event tracker**
- Revisit/update the list of good industry events for tracking.
- Francesco recommends [www.iwpc.org](http://www.iwpc.org) as resource.
- As a support document Mike has modified EnABLES event sheet and circulated 22<sup>nd</sup> April. He will update and circulate every quarter – next one due end July
- **Any volunteer to champion creating this? Scott considering – BZ will follow up**, keep it light, for now review and augment, circulate to the EHC, **people are free to forward on, all public domain info.**
- New inputs from Denis  
<https://www.facebook.com/events/conference-aston/eh2020-technology-showcase/615485432315554/>
- **ALL – any inputs (inc. COVID schedule changes) for the list??? Check monthly.**
  
- **Company ecosystem – Robert to drive**
- **Robert to help create unbiased & open list of companies involved in the EH ecosystem that we are aware of. Note this should not be interpreted as a PSMA endorsement.**
- **1<sup>st</sup> draft by 20 Aug. ....split into 4 parts, direct EH/PMIC, ES, MEMS/sensors/TRX, Users/integrators**

**ALL - EHC committee members please send links/suggestions directly to Robert!!!**

- **Dusan shares open call for supporting Ikea EH product integration. BZ/Robert A./Mike W. will reach out offline. Ikea planning to allocate more resources, Dusan compiling internal report, will revert after feedback on report, may come to Mike & Brian with Qs offline.**
  
- **Robert highlights involvement with Micro and Nanotechnology Commercialisation Education Foundation (MANCEF, <https://www.mancef.org/about/>), opportunity to leverage relationship with EHC for mutually beneficial growth. Looking for presenters for COMMS 2020.**
- **Robert will share exciting press release on Inviza over the coming weeks, giving him a brief slot also in the Aug. meeting.**

### 5. Webinars

- **BZ suggests potential webinar focused on EH ecosystem folks to have a pitch event.**
- There will be an EnABLES power mgt webinar 22<sup>nd</sup> (use cases) & 29<sup>th</sup> July (online ambient energies)....presented by .....- details can be found here <http://www.enables-project.eu/webinars/>
  
- Old webinar suggestions (in italics) – **we need everyone to review this and give us updates**
  - *Dan Stieler, PowerFilm was considering one (will be chased by way of Sam)*
  - *Sample abstract suggested per existing blog (<https://www.powerfilmsolar.com/about-us/the-horizon-blog/2018/08/10/outdoor-vs-indoor-solar-the-key-differences>),*
  - *Lorandt willing to do 1 back n 2019*
  - *Dusan was thinking about an applications orientated presentation*
  - *Brian and Raj (Georgia Tech) gave IEEE EPS webinar on IoT with Dushan, Marc & Denis - Can do a variant for PSMA?*
  - *Would be good to do 1-2 on 'practical real life performance' of parts and systems – comparison of technologies. Saw some good examples at EnerHarv e.g. Ilika & ARM presentations*
- Good source for future PTR material.
- Also looking at cross-promotions for IPC – industrial automation, Industry 4.0, smart mobility, etc.
- Any material you want to re-cycle.. once not too much of a sales pitch?
- New suggestions
  - *Robert Andosca + Singapore colleague, flexibles? Direct also to MANCEF, start with PSMA, record a version, PSMA version is available for free live attendance but recording normally kept for members*

- BZ to chase Patrick Mercier based on a presentation he saw recently.

## 6. White paper

- Michalis Kiziroglou & Thomas Becker leading this initiative, latest strawman was reviewed at the May meeting and on the next 4 pages.
  - Volunteer list so far:- Maeve Duffy, Mike, Brian, Peter Spies, Oskar Olszewski, James Rohan, Guangbo Hao, Baherah Zaghari, David Stenzel, Roberto A, Sri Kasichainula, Robert Andosca, Roberto LaRosa, Mike Donnelly
- MK/TB will propose schedule and key actions (5-6 lines).
- BZ requests capture ('weaving in') of Modeling/Sim (supported by Robert A., Mike D. can help with content)...Michalis/Thomas making point this should not be a major area/section within whitepaper, which all agree with.
- Michalis/Thomas to propose schedule/methodology, followed by initial list for task group...Thomas requests dedicated, subcomm task group focused on white paper. BZ/MH can facilitate logistics.
- Keep to reasonable page limit.
- Kick Off meeting Mon 27<sup>th</sup> July, 10 Central, then tentatively bi-weekly moving to monthly when settled, shortly before monthly EHC monthly.

# White Paper

## Energy Harvesting for a Green Internet of Things

### Executive Summary

Responsible/Contributor: Brian, Mike...?

Introduction from PSMA EHC perspective

### Abstract

- Objectives of the white paper

+ To identify challenges and opportunities in adopting energy harvesting as a method to ensure an environment-friendly Internet of Things.

+ ...

- Guide through the white paper,

- Classification against renewable energy etc.

### Content

#### 1. State-of-The-Art from the Perspective of the User (Responsible: .. /Contributor: Michalis ...)

1.1 Motion, Thermal, Inductive, RF, Solar, Acoustic

1.2 Broadband functionality (environmental range, multiple functionality)

1.3 Power Management and Storage

• THIS SECTION SHOULD EXPLAIN WHAT 'WE' AS ACADEMIC PARTNER (UNI, RES) WANT TO DO IN TERMS OF R&T

• & WHY FUNDING IS NEEDED ON NATIONAL/LOCAL, EU, US... LEVEL

#### 2. Developing for a Use Case (Responsible: Michalis /Contributor: ...)

2.1 Specifications. A loop of size and power.

2.2 Energy and Power Budgeting

2.3 Ultra-Low Power Consumers

• THIS SECTION SHOULD EXPLAIN WHY 'WE' AS ACADEMIC AND INDUSTRIAL PARTNER WANT TO WORK TOGETHER IN TERMS OF R&D

• & WHY FUNDING IS NEEDED ON NATIONAL/LOCAL, EU, US... LEVEL

#### 3. Key Missing Elements for Industrial Adoption (Responsible: Thomas /Contributor: Eric ...)

3.1 Operational

3.2 Economical

3.3 Standards

• THIS SECTION SHOULD EXPLAIN WHY 'WE' AS ACADEMIC AND INDUSTRIAL PARTNER WANT TO WORK TOGETHER IN TERMS OF R&I

• & WHY FUNDING IS NEEDED ON NATIONAL/LOCAL, EU, US... LEVEL

#### 4. Key Advantages (Responsible: .... /Contributor: ...)

4.1 Cost benefit

4.2 Reliability

4.3 Environment and sustainability

• THIS SECTION SHOULD EXPLAIN WHY 'WE' AS ACADEMIC AND INDUSTRIAL PARTNER WANT TO WORK TOGETHER IN TERMS OF R&T&I

• & WHY FUNDING IS NEEDED ON NATIONAL/LOCAL, EU, US... LEVEL

#### 5. Opportunities (Responsible: Eric /Contributor: Thomas ...)

5.1 New Ideas

5.2 Green Impact

5.3 Funding Modes

• THIS SECTION SHOULD EXPLAIN HOW COMMON R&T&D&I EFFORTS SUPPORT NATIONAL/LOCAL, EU, US OBJECTIVES ON CLIMATE, INNOVATION, LEADERSHIP...

• AND WHY THEY SHOULD GIVE US MONEY ☺

## **1. State-of-The-Art from the Perspective of the User**

This section reviews the methods and summarises the related technologies for energy harvesting systems. The focus of the review is to demonstrate the technical excellence of energy harvester devices, to illustrate the technical implementation into IoT devices and to analyse the technical limitations in autonomous wireless sensor and actuator networks. The state-of-the-art analyses provides the background for the economic and ecological assessment of energy harvesting systems. Opportunities derived from cost benefit analyses and life cycle assessments are depicted in the next section.

- Energy harvesting (EH) is an umbrella term to describe methods for converting ambient energy sources into electrical energy in the context of wireless sensor networks (WSN) or the internet of things (IoT)!
- Power management and energy storage are integral parts of an energy harvesting device!

### 1.1 Motion, Thermal, Inductive, RF, Solar, Acoustic

*Michalis...*

### 1.2 Broadband functionality (environmental range, multiple functionality)

### 1.3 Power Management and Storage

Impedance Matching, rectification and sub-threshold switches, buck/boost, inductor integration, key storage issues - resistance limitations, circuit/storage co-design, cold-starting.

## **2. Developing for a Use Case**

### 2.1 Specifications. A loop of size and power.

- A detailed analysis of the application is necessary for selecting the suitable energy harvesting technology!
- Adequate measures to balance energy and power demands from the application with the energy and power provision capabilities of the harvesters are essential!

### 2.2 Energy and Power Budgeting

- Energy balance harvester vs consumer (budgeting of power and energy, graph of duty cycle vs size?)

### 2.3 Ultra-Low Power Consumers

Passive sensors

Multilayer sleep modes

Multilayer duty cycling: sensing, processing, storing, transmitting.

## **3. Key Missing Elements for Industrial Adoption**

- Technological end-users perspectives may differ dramatically from technology provider point of view, since the total system performance requirements are essential!
- Commercial end-user expectations are clearly focussed on the overall efficiency enhancement instead of isolated technological improvements!

Energy harvesting offers many advantages compared to batteries or wires as described in the previous chapters. However, for a successful implementation in future applications several acceptance limitations have to be solved. Key challenges are listed below:

- System integrators are used to specify the technical behaviour of devices as a black box with defined interfaces for input and output parameters. In case of energy harvesting devices detailed information about the installation environment is required from the supplier. Even though system integrators and Tier-X suppliers are working today in closed-loop development frames the exchange of data is critical. For example the data of vibration frequencies and amplitudes of a car or an aircraft may exhibit design compromises in terms of noise or comfort.
- Durable assets, such as cars, machinery or aircraft, require a certain MTBF (meantime between failures) guaranteed. Moreover, the consequences for the subsystem, where the energy harvesting device might be integrated, have to be considered in case the expected lifetime cannot be achieved. As a consequence, the user's confidence in the product is fading away.
- In most cases, energy storage is required additionally to the energy harvester device itself. In general, batteries or supercaps are often seen as potential hazard source because of the high energy density. In any case, due to the electro-chemical nature of storage devices limitations in lifetime and therefore maintenance costs are expected.
- Adequate energy supply in the situation of non-standard operation (repair...) of the system is a key challenge for energy harvesting. The energy harvesting devices are designed to cope with a broad spectrum of in-service operations. However, during MRO (maintenance, repair and overhaul), longer downtime or other unexpected events the energy harvester might not supply energy and the energy storage might be drained. Changing procedures for MRO or restarting the system 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. Due lack of standards and many start-ups a possible long term supply chain remains unclear.

### 3.1 Operational

### 3.2 Economical

### 3.3 Standards

All the above mentioned aspects need be carefully analysed in a detailed CBA (cost-benefit-analysis). Moreover, the CBA needs to be substantially supported by cradle to grave life cycle assessment (LCA). In addition, standardisation efforts should be made to pave the way for using energy harvesting devices.

## **4. Key Advantages**

This section describes opportunities with regard to economic and ecological excellence of autonomous wireless sensor and actuator networks. The expected benefits clearly underpin the demand of further R&D&I efforts towards a sustainable green transition of the internet-of-things supporting world-wide Green-Deal measures.

### 4.1 Cost benefit

- Positive cost-benefit-analyses (CBA) may result in implementing energy harvesters into systems in order to reduce personnel, maintenance or in-service costs!
- Rethinking the touchstone application with 'infinite power' might be inevitable to achieve positive CBA results!

- Could costs be saved by EH?
- Cost Benefit Analysis, Comparison to wires, batteries,
- Reconsideration of the Application Scenario/Virtual Sensing

#### 4.2 Reliability

#### 4.3 Environment and sustainability

- Environmental benefits may not turn to account today but in future due to changing regulations!
  - Products with positive life cycle assessment (LCA) may reach higher consumer acceptance at higher prices!
- Are there other good reasons to use EH?
  - Life Cycle Assessment, GWP, CO<sub>2</sub>eq, SO<sub>2</sub>eq

### **5. Opportunities**

#### 5.1 New Ideas

- Massive IoT may lead to less complex but denser measurement strategies enabling autonomous virtual sensing!
  - Standardisation efforts are desperately required to enable wider commercial deployment of energy harvesters!
- Future Harvesting Research Needs
  - Standardisation (current situation, suitable organisation)

#### 5.2 Green Impact

- Autonomous virtual sensing requires will a complex ecosystem with many stakeholders and needs support and guidance in research agendas worldwide!
- Standardisation efforts on component level have to be support in concerted actions to reach standards on subsystem level!

#### 5.3 Funding Modes

- Why we should go ahead with EH?
- Expectations to funding bodies, EU, US, China...!

Key Requirements for Profitable Public Investment

Key Requirements for Profitable Private Investment

Profitable investment: Energy harvesting as a combination of

Environment-friendly approach

Recyclable materials

Operational sustainability for industry, transportation and infrastructure

Minimized operational cost in economical, environmental and complexity terms.

### **1. References**

**maybe in the footer of each section?**

**About PSMA and EHC**

*Responsible/Contributor: Brian, Mike...?*

**END OF WHITE PAPER**

# TREASURE CHEST

Approach these items one at a time in future meetings as people raise them.

## 7A. Sponsorship of a program where students build demonstrators.

- Lorandt has a budget to supply kits
- Help with education links – Qualcomm 'High Tech High'. Francesco will follow up.
- Green story. International dimension. Technology and applications dimensions.
- Wurth running design challenge.
- Keep simple, easy to use
- Competition or roadshow?
- PSMA has money to support.
- Action:- Catherine and Mike met at EnerHarv & discussed, She will write ½ page strawman for student engagement mechanism. Mike will ping again. **NEED A CHAMPION TO LEAD EFFORT FOR COMM** **Maeve willing to help but does not have bandwidth to lead.**

“Here are Katherine’s thoughts on the competition:

There are two main styles of the competition that could be developed:

### 1. Engineering-Style Competition

- planning committee chooses specific EH devices that can be used and the target load
- planning committee also specifies energy input conditions (lighting setup, vibrational input, etc) for testing
- specifications are announced and teams would develop the power converter solution based on the specification
- teams can submit videos and/or reports on their team and proposed idea
- final teams are selected and they test their prototypes on site at an event competition (could be a conference)
- judging is based on technical criteria measured during the test (size, weight, efficiency, etc.)
- implementation is the most important aspect for this style of competition
- over different years, the specification and scenarios would focus on different technologies with the same basic format
- more similar to the International Future Energy Challenge run by PELS

### 2. Design-Style Competition

- planning committee could choose a theme based on a technology or application (e.g. smart homes, wearables, building monitoring, etc.)
- planning committee may want to specify some constraints or scenarios for the competition
- teams come up with complete EH design ideas (transducers, circuitry, load) and develop a prototype
- teams can submit videos and/or reports on their team and proposed idea
- final teams are selected and they present and demonstrate their prototypes on site at an event competition (could be a conference)
- judging is based on mostly qualitative and some quantitative judging criteria (so balanced judge selection will be important)
- this style of competition is more focused on the idea and design, but implementation is also important

There should probably be some discussion on which style the committee would like to see. The engineering-style requires a lot of prep work before even announcing the competition, while the design-style is more work for the judging and evaluation. I could see either being good for students. I hope someone can take these basics ideas and further development them into a competition.”



## 7B. Updated Goals

- Open to suggestions.
- We should try to forge links with other groups/sessions, e.g. capacitor, magnetics, packaging. – addressing this via “Tiger Team” effort within PSMA (multiple focused initiatives with small teams from various committees)
- **BZ INITIATIVE:** working on feasibility for an official, IEEE Future Directions initiative on Energy Harvesting (a 1-6yr process)
  - JOE notes PSMA would be happy to support such an initiative, **BZ to figure out if/how**
  - BZ has obtained process detail (<https://cmt.ee.org/futuredirections/fd-opportunities/>), **BZ to pitch initial proposal to PELS TC6 at ECCE on 10/1/19... WILL SHARE FINAL PPT WITH TEAM**

## 7C. Forward-looking Thoughts

- Software? Packaging/industrial design? Modelling?

**Mike Hayes & Brian Zahnstecher,**  
16th July 2020.