



Energy Harvesting Committee (EHC) Minutes 21st November 2019

Attendees	Apologies/Non attendees	
John Horzepa, PSMA Michalis Kiziroglou, Imperial College London Thomas Becker, NTA- ISNY Scott Thielman, Product Creation Studio Peter Haigh, Tyndall Mohamed Jatlaoui, Murata George Slama, Würth (GUEST) Brian Zahnstecher, PowerRox Mike Hayes, Tyndall	Robert Andosca, AEI Francesco Carobolante, IoTissimo Steve Savulak, UTRC Johan Pederson, Sigma Design Mike Wingard, Amphenol 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 Ben LeNail, Alta Devices Denis Pasero, Ilika Lorandt Foelkel, Würth Marcus Taylor, Fleximatix Roberto la Rosa, ST Maeve Duffy, NUIG Aarohi Vijh, Alta Devices	<i>Doug Osterhout, Google</i> 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) Liubov Ebralidze, Silent Sensors Raj Budhabhatti, Alta Devices Alex Liu, Alta Devices Dusan Vuckovic, Ikea Gary Johnson, Ilika (for Denis) Baoxing Chen, Analog Devices

(Co-chairs in bold font)

Next meeting:- Wed Dec 11th at 10:00 Central, Brian to chair, Mike to type.

Agenda

1. **Welcome any new members.**
2. **EnerHarv 2020 planning.**
3. **APEC 2020.**
4. **White paper.**
5. **AOB, anything from 'treasure chest' at end of the minutes.**

1. Welcome New Members

Potential new member from a Swedish Univ, Mike is inviting as a guest to next meeting.

2. EnerHarv 2020

- **NCSU – North Carolina State TUE-THU, JUNE 16-18, 2020**
- **Mehmet compiling hosing agreement with PSMA help. ASSIST needs to hire temp.**
- **COMMITTEE**
 - Latest tentative table of chairs (most people willing to move around)

(# slots targeted)	Chair	Co-chair
Keynotes	<i>Host:</i> <i>Gues:TBD</i> <i>Guest2: TBD</i>	
Energy Transducers (NAME OK?)	Baoxing Chen	Medhi? (ASSIST Rep) flexible
Power Mgmt	Peter Spies (EnABLES Rep)	Maeve Duffy or Roberto La Rosa
Energy Storage	Mohamed Jatlaoui	James Rohan (EnABLES Rep)
System Integration The Italian quarter!	Francesco Carobolante (PELS Rep)	Francesco Cottone or Roberto La Rosa (EnABLES)
Low Power Loads (FINALISE NAME)	Shad and Mike investigating	Yang Yuan
Demos	Lorandt Foelkel	EnABLES Person?
Panels Sessions	1. Compare with the '5G experience' (panel style prep...smoother experience than '18)	

	Prepare & assign carefully FRANCESCO CA. TO DRIVE 2. Bring together cluster leaders!! (ASSIST, EnABLES, EHN, Sheshank Pria, PowerMEMS)
Posters	Jane Cornett
Media	Julie Holder (supported by Carolin Lehmann of NCSU)
Admin	Julie Holder (supported by Carolin Lehmann of NCSU)
Treasurer	Steve Savulak
Technical Chair	Mike Hayes
Technical Chair	Shad Roundy
General Chair	Mehmet Ozturk
Co-General Chair	Brian Zahnstecher
Industry liaison	Adam Curry

Other committee members to date

- Denis Pasero
 - Marcus Taylor
 - Michalis Kiziroglou
 - EPeas – Geoffroy Gosset
 - Dusan considering....answer in Sept
 - Johan also considering – Brian will stay in touch
 - Brendan O' Flynn, Tyndall – subject to availability – willing to chair panel session.
 - Julie Holder, ASSIST temp.
 - Prof. Hengzhao Yang, New Mexico Institute of Mining and Technology- Brian in contact
- **Sponsors**
 - **TECH**
 - **EnABLES, PELS, ASSIST, CPSS**
 - Yang Yuan (CPSS) prepared write up on EH (& related) activities, lobbying for EnerHarv talk
 - **FINANCIAL**
 - PSMA
 - **COMMERCIAL** (more open this time, but MUST be related to program, content, etc.)
 - **How2Power will circulate flyers – get preliminary one ASAP**
 - PowerMEMS opportunity to promote EnerHarv, Mike, Shad, Michalis, Francesco Cottone planning to attend.
 - Write-up prepared for PSMA Quarterly Newsletter, will be highly leveraged into press release for distribution in early-Dec.
 - **Adam has circulated targeted sponsorship invites - preliminary interest from ADI, EPEAS, Wurth**

KEYNOTES

COMMERCIAL SLOT – For now trying to find an ADI candidate. 1st preference was Katsu Nakamura – ADI fellow healthcare, low power, consumer projects. Not available, Boaxing or Jane will revert with alternative.

ACADEMIC SLOT –

Shad Roundy compiled a ranking, will only approach 1 person at a time before moving to next ranking. Ana Arias from Berkeley not available. Was chasing Patrick Mercier (UCSD)...he's unavailable, but recommended a former student (Sally Safwat, now Intel) that is now on the chase list.

- **Bring up possibility of professional development credits at next EnerHarv meeting**

3. APEC 2020

- FOR APEC 2020, WILL BUMP RIGHT UP AGAINST ENERHARV 2020 SO SUGGEST TAKING A SLIGHTLY LESS INVASIVE ROLE IN APEC 2020 (I.E. – 4-SLOT INDUSTRY SESSION)
- **Session accepted, scheduled for Wed, 3/18/19, 8:30-10:15am CST!**
 - Proposed presentations so far **(LAST CHANCE FOR ABSTRACTS) SPEAKER LIST DEADLINE TO APEC COMM IS 11/27/19, SO ABSOLUTE ABSTRACT UPDATE/SUBMISSION CUT-OFF IS 11/25/19 TO ENABLE FINAL DECISION ON SPEAKERS (AND ALTERNATES) BY 11/27/19**
 1. “The Growing Energy Harvesting & Power IoT Ecosystem” Mike Hayes, Tyndall **VOLUNTEERED TO BE 1ST ALTERNATE AS NEEDED**

By 2025 the world will have 1 trillion IoT (internet of things) sensors, most of which will be wireless IoT edge devices. The biggest impediment to the large scale deployment of these sensors is battery life and where possible making the battery outlive the device it powers. To this end Tyndall through internal and external collaborations is providing technology and thought leadership on how to address this grand challenge by helping build a ‘power IoT’ ecosystem. Activities revolve around

bringer together researchers, industry parts supplier, integrators and users and showing how understanding energy harvesting and related technologies (energy storage, micro-power management and their system integration) when collaboratively developed and integrated can significantly extend battery life, in some cases eliminating the need for battery replacement, The presentation will mainly focus on 2 key activities

(i) PSMA's involvement in this initiative via the Energy Harvesting Committee, APEC industry sessions, publication of the power Technology roadmap (PTR) and the biennial workshop EnerHarv that was inaugurated in 2018.

(ii) Co-ordination of the EU EnABLES infrastructure project that opens up key research infrastructure in 6 leading research centres in Europe to both academia and industry to undertake free of charge 'power IoT' feasibility studies ('transnational access'). EnABLES also manages a portfolio of 'joint research activities' (JRAs) between 11 research partners showing the impact of collaborative and application driven 'power IoT' solutions.

Examples of outputs and feedback will be outlined along with a vision for further growth and impact of this ecosystem.

2. **Demo Session** (as standalone, "speaking" slot), TEAM

3. "*Silicon Integrated Supercapacitors Using Ultrathin LiPON film*" Frederic Voiron, Murata **MOHAMED TO ITERATE BASED ON FEEDBACK RECEIVED**

With emerging wireless IoT and IIoT devices during this past decade, many challenges have been raised in relation with functionalities such as sensing, communicating and more particularly efficient power harvesting and storage.

This work presents a new concept of solid state hybrid-capacitor based on a solid electrolyte. It is integrating a very thin ionic dielectric, combining ionic and electrostatic charge storage mechanisms into a unique Electrode-Dielectric-Electrode structure. Moreover, the MIM is leveraging surface enhancement techniques based upon 3D nano-structuration to further increase the specific capacitance. The component integration scheme will be presented and discussed.

Moreover, the electrical behavior of this hybrid-capacitor will be presented and discussed, including broadband transient small-signal characterization from BF to UHF and large signal analysis close to DC. Key features of such component will be detailed: High power function (50W), rapid charge and discharge (<0.1s), very low profile, low impedance, safety (no chemical reactions), easy assembly (compatible with existing standards) and long life time (little degradation over 100K of cycles).

Finally, preliminary reliability data will be covered as well, including charge retention and cycling capabilities in large signal.

Upon those electrical results, a scenarios for optimal integration of this component in the context of an energy harvester will be proposed. The benefits will be discussed in term of system efficiency and lifetime improvement of the main battery.

4. "*Large-Area Manufacturing Techniques for Reducing Energy Harvesting & MEMS Solution Costs*" Robert Andosca, AEI **FEEDBACK GIVEN ON LENGTH & CONTENT, AWAITING 2nd DRAFT, target 250 words**

It has been long envisioned that MicroElectroMechanical (MEMS) devices and sensors could supplant existing non-microscale sensor technology and introduce micro-scale energy harvesting (EH) devices to enable the micro-sensors and wireless radio communication for various 'Internet of things' (IoT) markets. Yet, this has not yet come to pass broadly across the numerous IoT market segments. The question is why?

MEMS devices are ASSUMED to be low in production cost. Yet, many MEMS devices are area dependent, e.g. piezoelectric MEMS vibration energy harvesters power generation scales with its mechanically strained capacitance $C_p^2 \sim (\text{width } W * \text{length } L)^2$. So, it is difficult to scale these devices and sensors down in size to produce 1000's or more chips per 200 mm silicon (Si) substrate as is accomplished with an accelerometer or pressure sensor chip today. For instance, a 1 cm² MEMS chip fabricated on a single 200 mm diameter silicon (Si) substrates produces approximately 216 unyielded die. In low volume, the chip with wafer-level packaging will cost \$75-100 each; in high volume production these chips could be as low as \$10-15 each. However, these levels of cost no matter high device performance and reliability is cost-prohibitive for market entry and widescale implementation without deep investment pockets. At the end of the day, the IoT needs an order of magnitude or two lower chip cost points for ubiquitous deployment.

This talk will cover all the commercialization barriers to market entry for MEMS sensors and EH devices to be adopted by price sensitive Connected Vehicle, Industrial IoT (IIoT) and consumer wearable markets. The speaker will suggest using large area fabrication techniques used to fabricate flat panel displays (FPD) to be exploited for MEMS manufacturing to lower production cost to make these devices worthy of market acceptance. Repurposing large area production equipment for large MEMS chips could be done tractably with minimal capital outlay. After converting GEN 2.0 FPD equipment to MEMS production a single 37 x 46 cm² substrate can produce 6.5X more chips

(1,404 total) than a single 200 mm wafer at only a 3X increase in overall fabrication cost. Just imagine manufacturing MEMS on GEN 4.0 (88 x 68 cm²) sized substrates or larger GEN 10.5 (3.1 x 3.1 m²) substrates in the future as adoption of low-cost chips produced in this manner becomes more and more pervasive. This could ultimately initiate a paradigm shift in the way MEMS chips are fabricated in general, even small chips sizes!

5. *"Optimizing Piezoelectric Synchronized-Discharge Harvesters"* Siyu Yang, Georgia Tech
Recommendation (senior PhD student) from GABRIEL RINCON-MORA given to Michalis

Piezoelectric energy-harvesting transducers can draw power from motion that can be used to energize a host of wireless microsystems that sense, process, and share vital information across a network. Since these tiny devices draw little power, maximizing the power they transfer is critical. Synchronized-discharge circuits are popular in this space because they can draw up to four times more power than an ideal full bridge can. Pre-charging the transducer can draw even more, but only as much as voltage-breakdown limits allow. Output power is the fraction of drawn power that the system doesn't consume. This talk will discuss how synchronized-discharge circuits can output the most power possible from tiny difficult-to-overdamp piezoelectric transducers. Measurements will show how pre-charge symmetry and energy-transfer schemes alter the power drawn from the transducer and the power lost in the system. This way, with the highest output power possible, tiny piezoelectric transducers can power more functions, and as a result, spawn microsystems that can solve the challenges that many modern and emerging applications face.

6. *"Condition Monitoring of Infrastructure Assets Using Vibration Harvesters and Solid State Batteries"* Denis Pasero, Ilika **BONUS: DEMO COMMITMENT AS WELL! NEED CONFIRMATION OF NEW CONTENT SINCE DENIS PRESENTED IN APEC '18**

The condition monitoring of large infrastructure assets such as wind turbines, oil and gas pipes, bridges, train tracks or high voltage power lines is costly and impractical due to their remoteness, their large scale and the large distance between them and monitoring centers. At the same time, in-situ measurements of these assets health are providing real time information for predictive maintenance and continuous inspection avoiding long term degradation such as delamination of turbine blades, cracks in train tracks or corrosion on oil and gas pipes. Powering sensors by cabling them to the mains is inconvenient due to the large distances of cabling involved, whilst using conventional batteries adds to the total cost of ownership when batteries die and technicians need to be dispatched to replace them. Ilika and partners have designed two autonomous sensors, combining vibration energy harvesters and solid state batteries, to monitor the health of wind turbine blades and rail tracks. This presentation will describe the design and operation of these two devices and their advantages in terms of size and extended life, avoiding to change batteries regularly.

(OLD 4). Feedback on re-vamped website – close this

Provide initial feedback by 31 Aug – ALL – BEING PROCESSED along with new PMSA logo, branding

NEW 4. White paper

Michalis Kiziroglou & Thomas Becker separately expressed interest in participating in a white paper – they will discuss offline and approach committee with a plan (table of contents). Fill gap between users and technology providers. Reach out to various groups for inputs. Consider using opinion polls, tables, etc.

PLAN UPDATE: have ToC, topics for consideration, reserve time in Dec call to discuss

TREASURE CHEST

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

5. Updated goals

- Open to suggestions.
- Consider a white paper? (Who will co-write and when?) – **REMINDER** can members please give Mike & Brian inputs offline
- Mike & Brian to revert with proposal for doing a white paper if so approved
 - OR other dedicated champion from EH Comm, **will put call out**
- 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://cmte.ieee.org/futuredirections/fd-opportunities/>), **BZ to pitch initial proposal to PELS TC6 at ECCE on 10/1/19... WILL SHARE FINAL PPT WITH TEAM**

6. Organise webinars for PSMA & PELS (FOCUS STARTING DEC MTG ONWARDS)

- We are ok for PSMA webinars (did 1 in Nov) for now but need to discuss PELS et al.
 - 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>), BZ reviewed/supports, **need Committee input. Worth reviewing seeing as Powerfilm’s abstract did well in voting but was not in top 2.**
 - Lorandt willing to do 1 – getting back up to speed (in your own time Lorandt) – Q1/2 2019? Also depends on whether Lorandt/delegate does APEC paper. **BZ TO FOLLOW-UP WITH LORANDT**
- Dan & Dusan willing to revert with suggestions – no commitment yet – Dusan thinking about an applications orientated presentation but no commitment yet.
- Brian and Raj (GeorgiaTech) gave IEEE EPS webinar on IoT with Dushan, Marc & Denis – Went very well. Can do a variant for PSMA later in the year.
- 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

7. 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**
Maevie 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.”

7. Technical forum (links, list of forthcoming events, etc.)

- Johan will review and update the list of events when he gets a chance but EnABLES project is creating a calendar of events, Mike should be able to share this (edited version) in July/Aug
 - Johan delivered updated list on 7/23/18, which MH & BZ will digest and share with group.
- Any volunteer(s) for white papers, weblinks, use cases, etc.
- Reach out to other societies/groups and cross link? – Mike & Brian to discuss.
- Note activities underway separately to re-vamp PSMA website.
- Does this add any value, should we remove??

8. AOB, actions, next meeting, etc.

- Software? Packaging/industrial design? Modelling?

**Mike Hayes & Brian Zahnstecher,
21st November 2019.**