Energy Harvesting application

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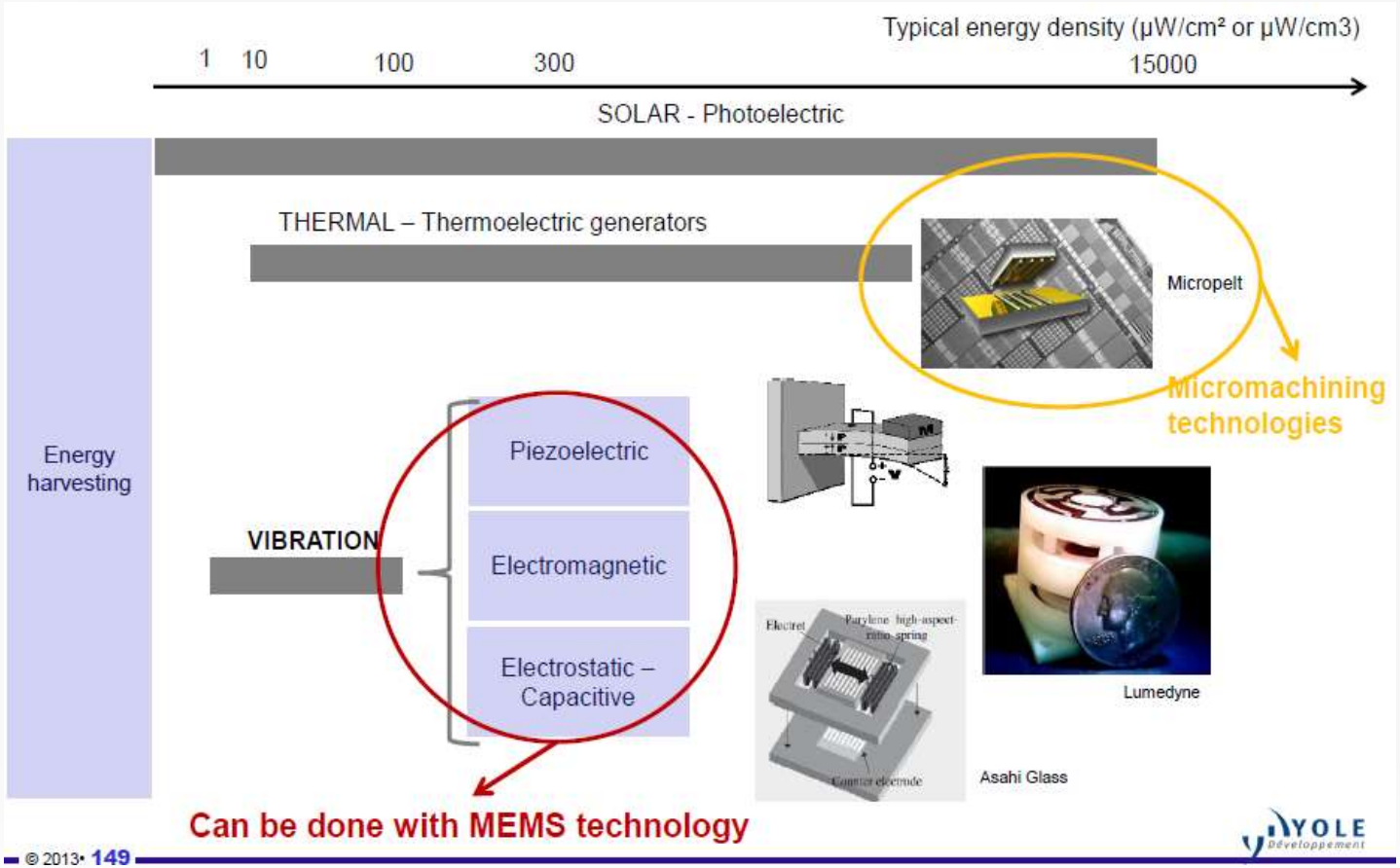
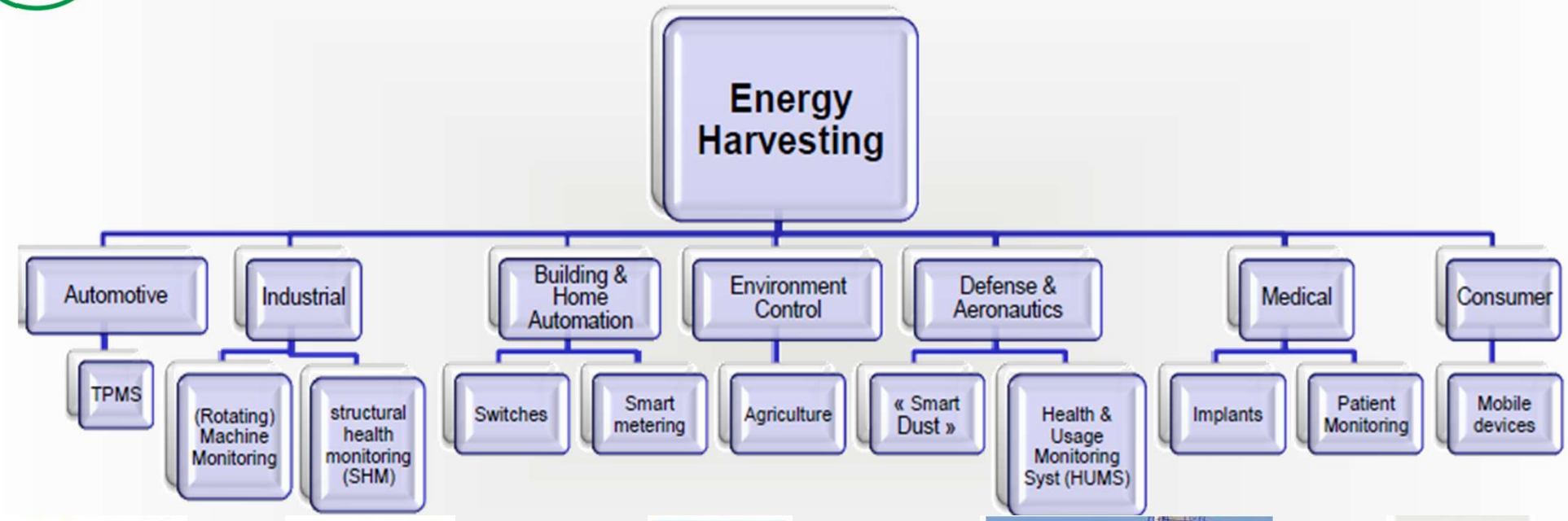
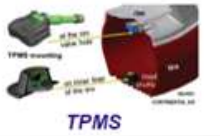
Energy Harvesting Technologies



Market application

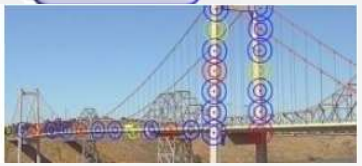




TPMS

Wireless sensors for machine monitoring

Switches



Structural health monitoring

Medical

Market driver

Maintenance reduction and access in harsh environments

- Maintenance 'free' device:
  - deployment of thousands of sensors
  - implementing sensors in remote places
  - potentially infinite lifetime allows for convenient battery-less sensor nodes.
- Harsh environment:
  - Batteries are not so efficient in temperatures over 80°C (industry)
  - Engine temperature - thermal energy harvesting.

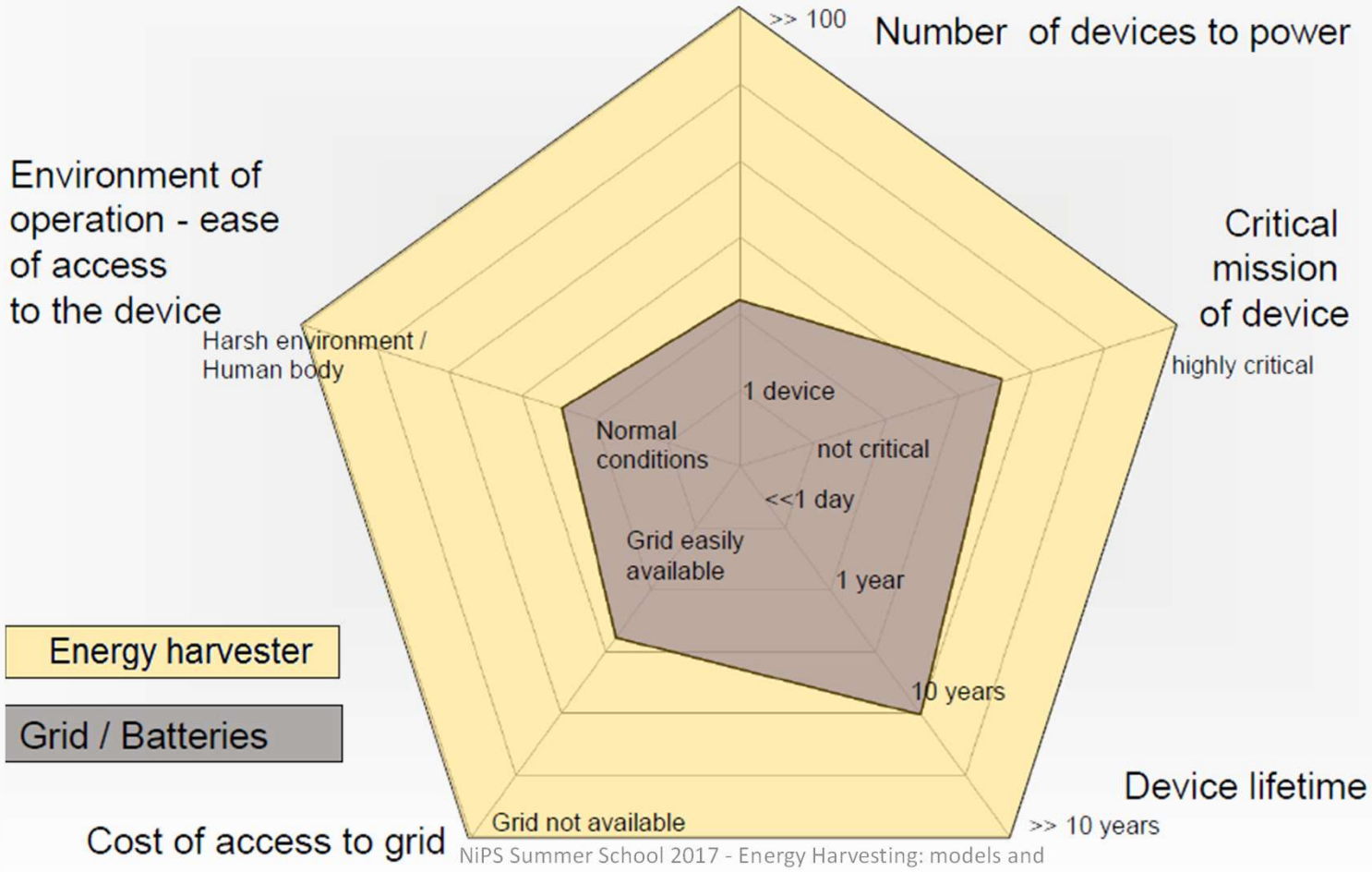
MEMS-based energy harvester

- Size and weight reduction (harvested energy is proportional to the harvester's mass ⇨ physical limit on the amount of power captured by a small device)

Environment

- Avoid throwing millions of toxic batteries each year into the environment

Market potential determination



Industrial, buildings, infrastructures, automotive and transportation applications.

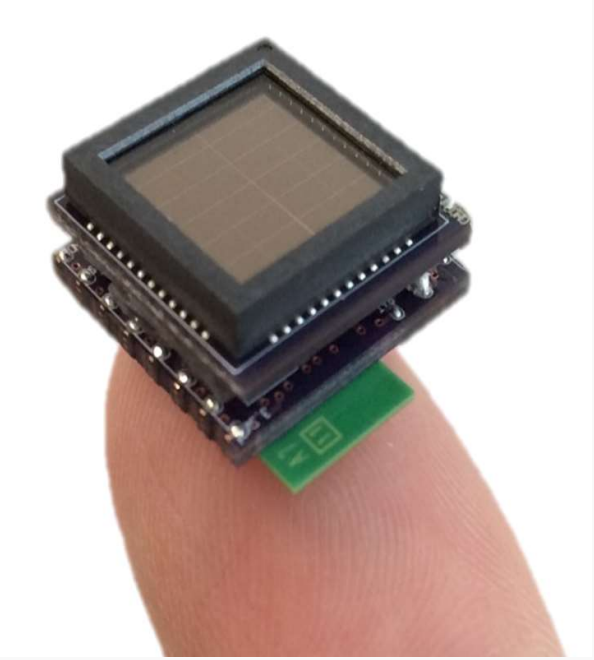
Industrial

- **Process control sensors in industrial environments need reliable long life power supplies.**
- **Most of the machinery vibrates at 50 or 60 Hz.**
  - **Very low level (10's of mG) vibrations, but very consistent and stable frequency**:
- **Possibility of profit of thermal gradient.**
- **Industries:**
  - Oil and gas
  - Chemical manufacturing
  - Waste water treatment
  - Food
- **Vibration Energy Harvesting works well and has been in use for several years.**

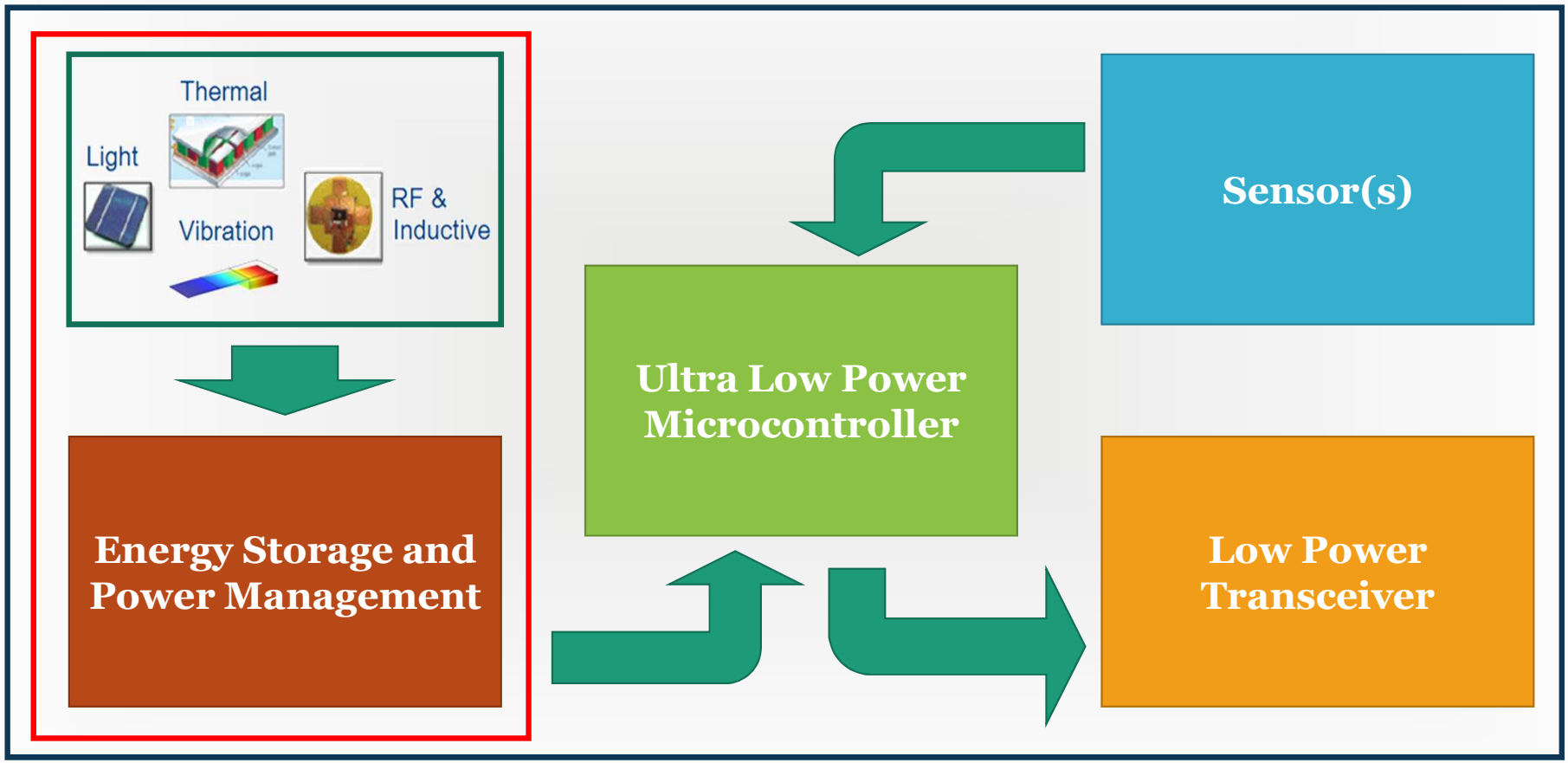
E.H. Approach

Power Supply

Sensor Node



E.H. Approach


Thermal
Light
Vibration
RF &
Inductive
Sensor(s)
Ultra Low Power
Microcontroller
Energy Storage and
Power Management
Low Power
Transceiver

Industrial Vibration E.H.

Perpetuum (www.perpetuum.com)

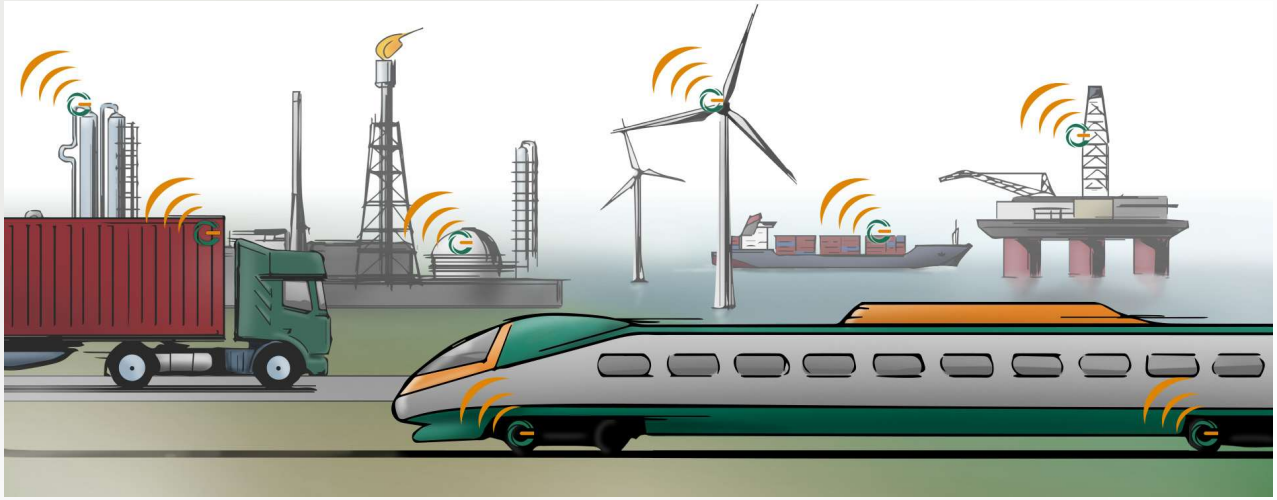
https://perpetuum2016.files.wordpress.com/2016/09/perpetuum-ltd-vibration-energy-harvester-data-sheet-21october2013.pdf

"We can eliminate the cost, disruption and downtime caused by the need to change batteries. Our harvesters are designed for use in demanding environments, are hazardous zone certified and operate from -40 °C to 85 °C."

Industrial Vibration E.H.

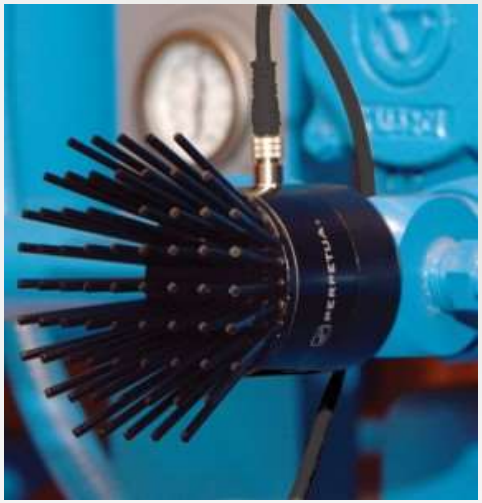
HiPER D
(www.kinergizer.com)

http://kinergizer.com/energy-harvesting-products/motion-energy-harvesting-device-2-



Industrial Thermal E.H.

Perpetua Power (www.perpetuapower.com)



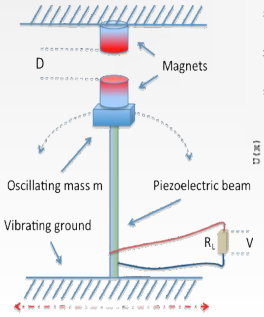
Common Heat Sources

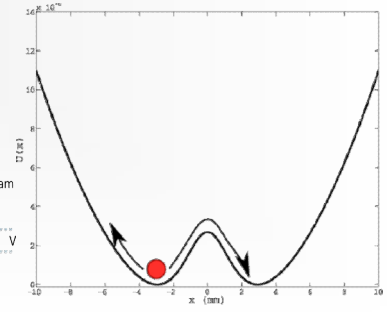
http://perpetuapower.com/wp-content/uploads/2016/07/00601-01-Perpetua-Power-Puck-EH-CSI9420.pdf

Industrial Hybrid E.H.

Wisepower (www.wisepower.com)

VIBRATION	ACCEL g_{RMS}	RMS POWER LINEAR	RMS POWER NON-LINEAR
BICYCLE	**0.848**	**0.718 mW**	**1.187 mW**
CAR (HYGHWAY)	0.180	0.008 mW	0.024 mW
CAR (URBAN)	0.307	0.215 mW	0.259 mW
WHEEL AXLE	**0.844**	**0.304 mW**	**1.134 mW**

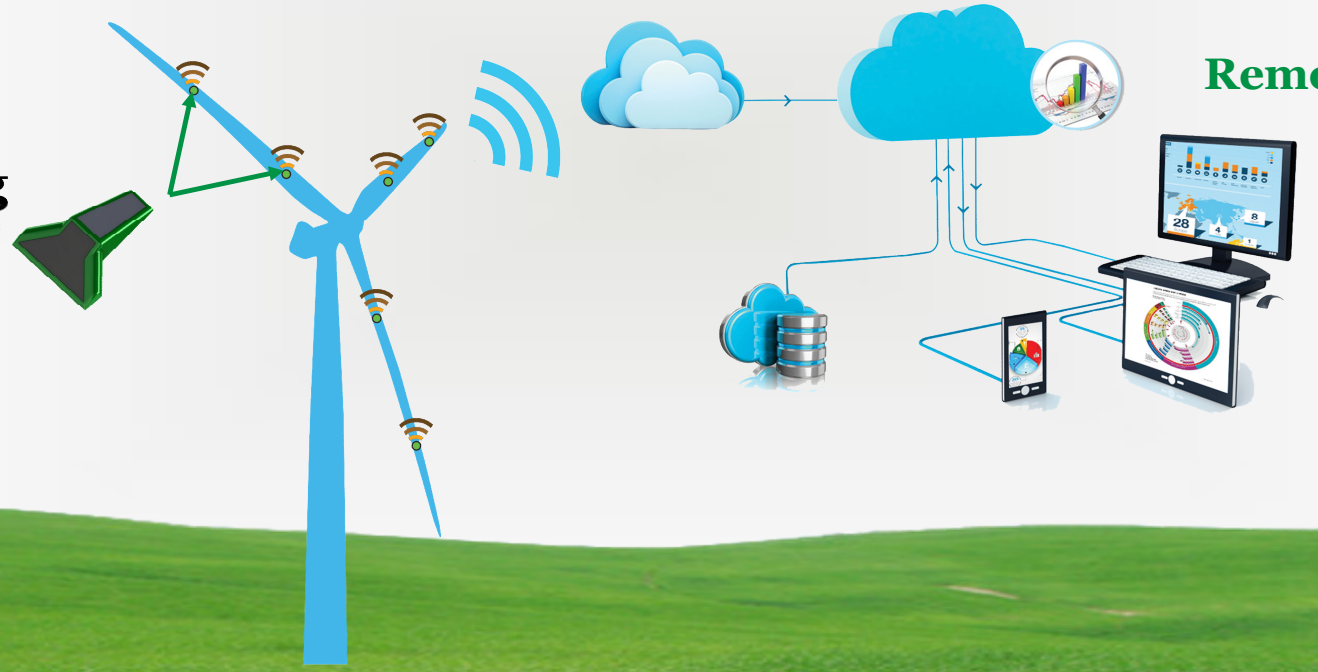




http://www.wisepower.it/HAT

Industrial Hybrid E.H.

MONITORING → DATA COLLECTION → CLOUD SERVER → ANALISYS → USER INTERFACE



WiseSensing
powered by WISEPOWER

Remote Monitoring Service

Building

Building: Light Switches

Why Light Switches?

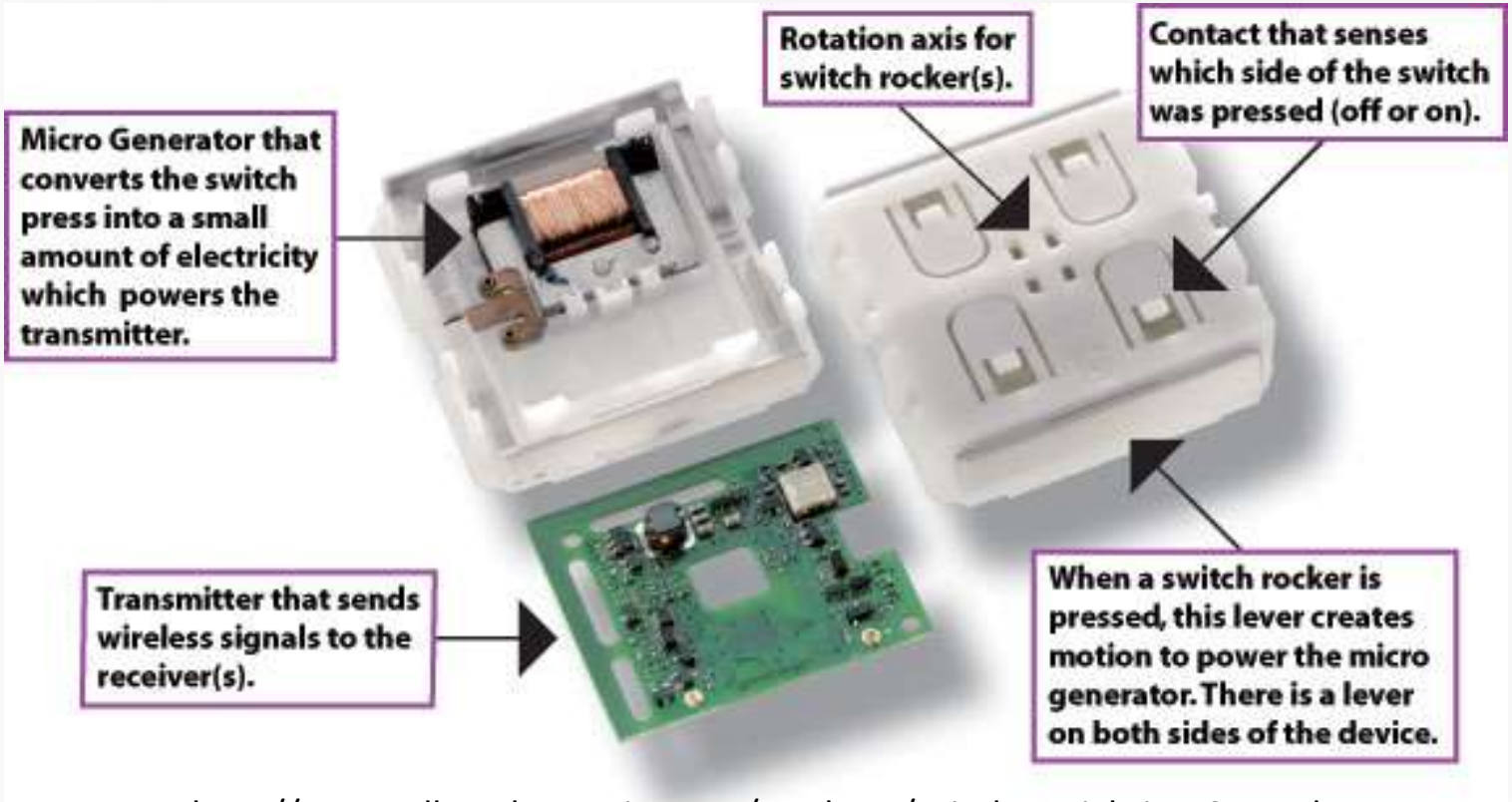
- It is expensive to wire light switches for new and retrofitted buildings
- Wireless light switches can be moved based on users' convenience without rewiring
- Changing batteries in light switches in large buildings with many switches is a significant maintenance cost and headache
- Light switches can integrate into smart building control schemes

Light Switches

EnOcean (www.enocean.com)

Fixed amount of energy input, very roughly 4 N x 1 mm = 4 mJ max.
Use Enocean's radio and communications protocol
Needs somewhere around 100 uJ for a transmission
- Efficiency is closer to 10%
- Note, early designs were piezoelectric

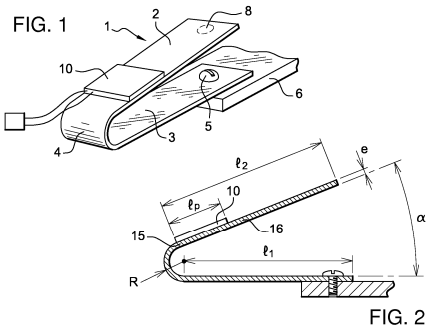
Light Switches

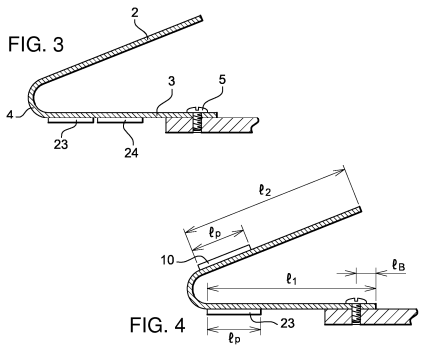


http://www.adhocelectronics.com/Products/Wireless-Lighting-Control

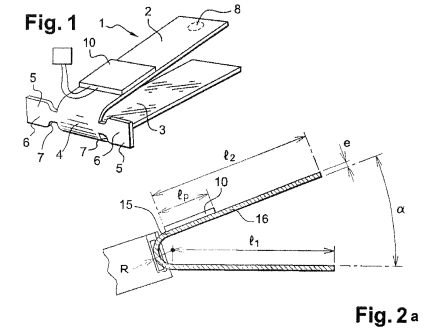
Light Switches

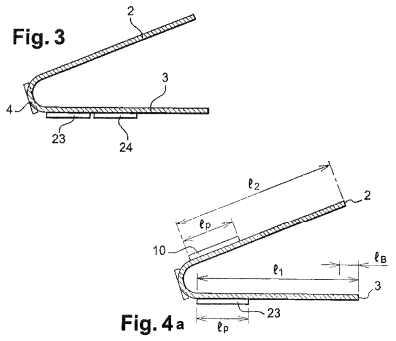
Arveni (www.arveni.fr)





PCT/FR2008/050082





PCT/FR2009/051399

Automotive solutions

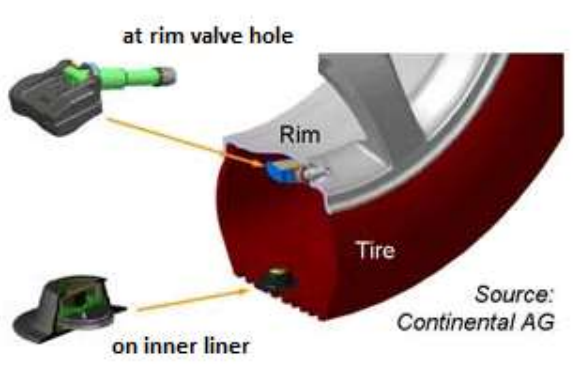
Automotive solutions

Passenger stop button using miniaturized harvester for buses & wireless stop pulse to the bus drivers computer.
In a bus with 40 buttons, eliminates the need to install 230 meters of cable:

- reduce weight (hundreds of kg)
- fuel consumption (tons of CO_2).

Automotive solutions

Tire pressure monitoring system (TPMS)



Correct pressure in tires leads to:

- Optimal rolling resistance between tire and road;
- Lower fuel consumption
- Lower CO_2 emissions;
- Longer lifetime of the wheel;
- Decreased total no. of car accident by 0.8-4%*

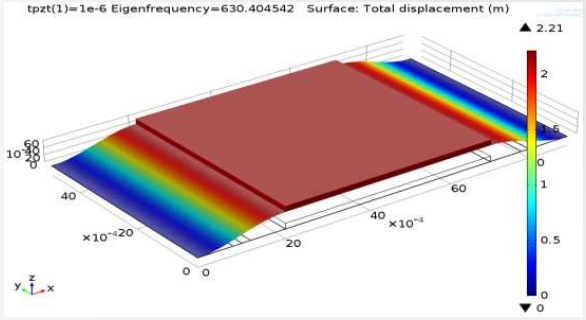
Standard TPMS device:

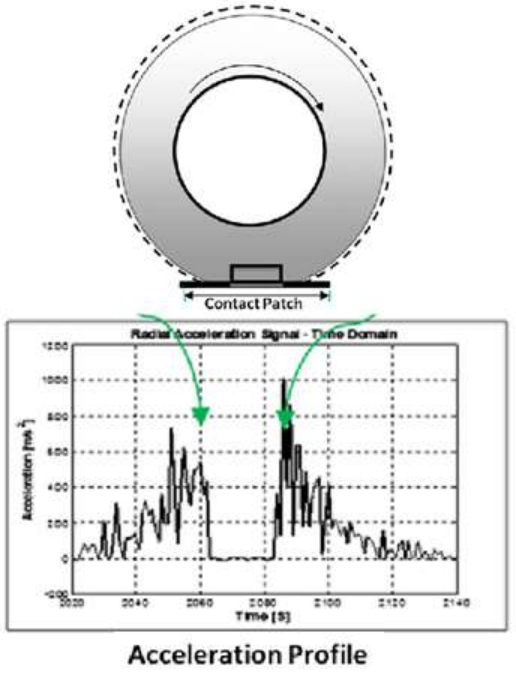
- Lifetime: 8 years
- Total weight: 7g
- Power consumption: about 3µW
- Shock accelerations: up to 2000g

Automotive solutions

Goals

- Piezo-MEMS material and fabrication technology (**Silex**)
- Simulation, modelling, design and testing of Piezo-MEMS energy-harvester (**Acreo Swedish ICT**)
- Design of the integrated power management system (**Linköping University**).





Acceleration Profile

K. B. Singh et. al., *Piezoelectric vibration energy harvesting system with an adaptive frequency tuning mechanism for intelligent tires*, Mechatronics 22 (2012) 970–988.

Novel Bridge design:

- **Significant improvement** as standard cantilever designs
- **Average power output 11 µW** @ 60km/h @2um PZT

E. Trabaldo, E. Köhler, H. Staaf, P. Enoksson and C. Rusu, Simulation of a novel bridge MEMS-PZT energy harvester for tire pressure system, Journal of Physics: Conference Series, 2014, vol. 557, p. 012041

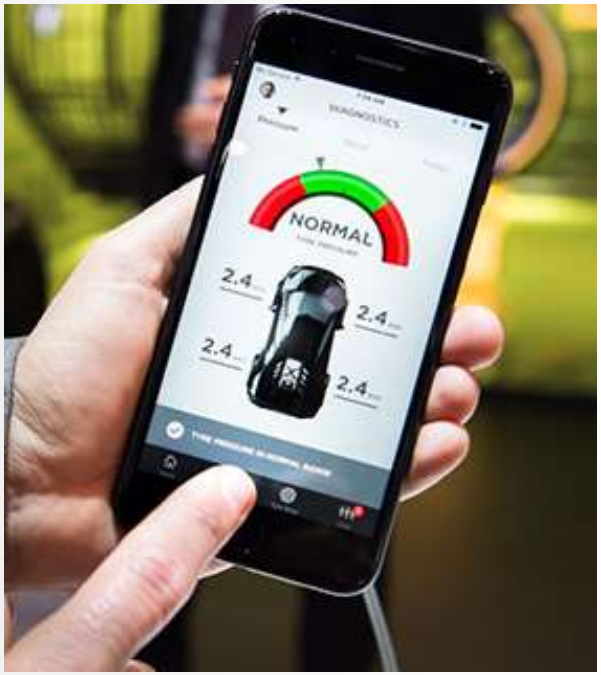
Automotive solutions

"Smart Tire" - could monitor temperature, friction, wear and torque;
- assist with optimal tracking and engine control;
- send all information wirelessly.

This would a major change in the supply chain - TPMS module would be sourced by tire manufacturers and not car makers.

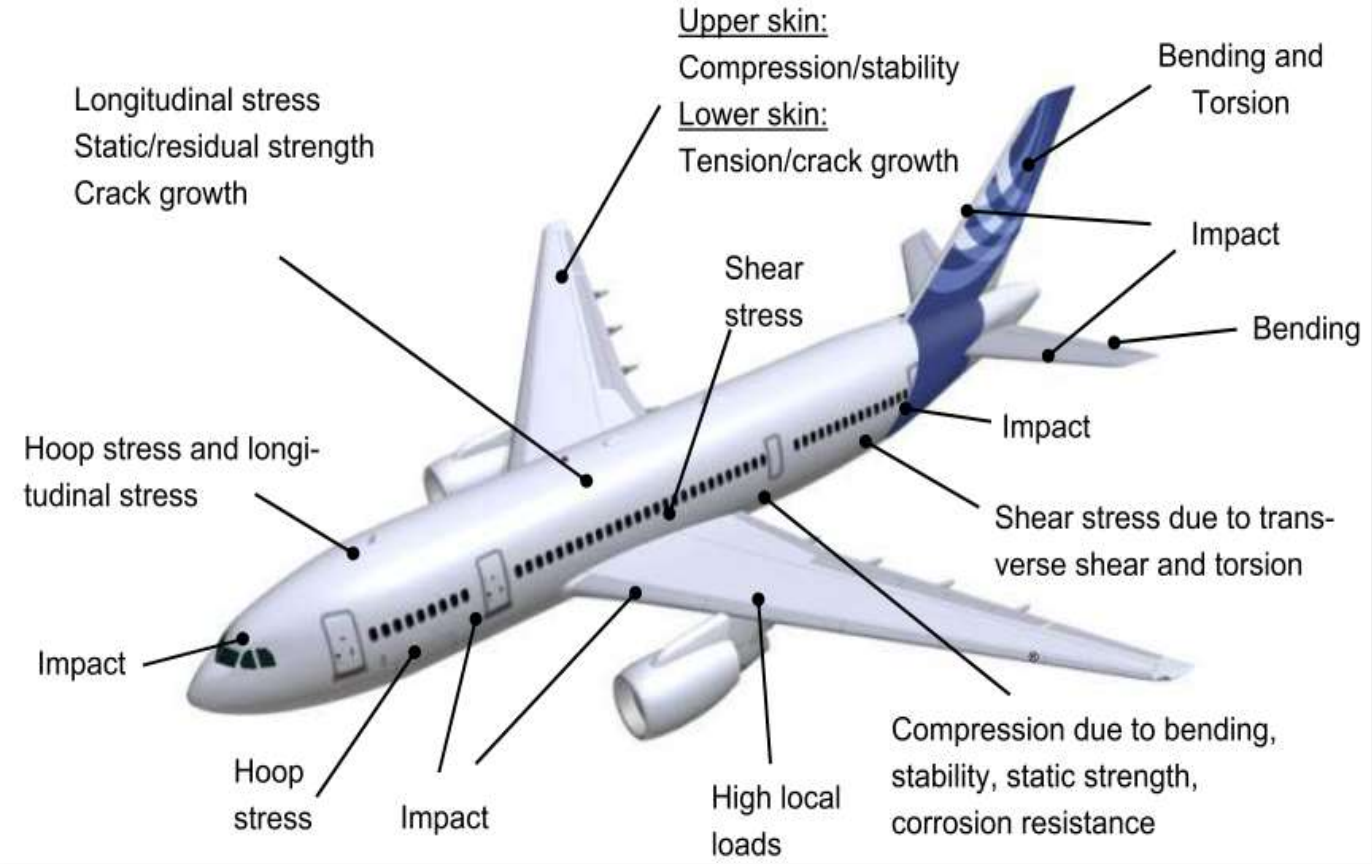
- **Trucks:** first to implement TPMS through smart tires,
  - strong advantages in embedded ID, drive monitoring and usage monitoring.
- **Cars**: If the cost of EH is really reduced.

- **TPMS with EH + batteries**: EH cost is even further reduced, a combination of EH + batteries could be adopted.



PIRELLI CONNESSO

Transport applications



CHALMERS

Linköping University

silex MICROSYSTEMS

Fraunhofer IZM

SPINVERSE Capital & Consulting

LivaNova Health innovation that matters

SWEDISH ICT ACREO

aixACT

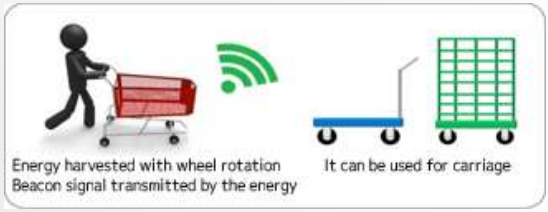
vermon

Transport applications

http://www.star-m.jp/eng/products/develop/de03.html

Miniature Technology, Infinite World

http://www.star-m.jp/eng



Feature

- Energy harvested with wheel rotation without battery inside the device
- Solution tool for Shopping cart Tracking System at wide area like Shopping mall

Item	Specification
Model	EB30
Wheel dimensions	Dia.100 x 32mm Dia.125 x 32mm
Signal transmitted	1 signal / 2 wheel rotation
Wireless protocol	BLE