



Setting the Standard for Automation™

Vibration Energy Harvesting



Perpetual Power for Wireless Industrial Equipment Health & Process Monitoring Applications

Standards
Certification
Education & Training
Publishing
Conferences & Exhibits

Keith J. Abate Sr.

- Director of Business Development for Perpetuum.
- B.S.E.E. and over 25 years of international technical, sales, marketing and business development experience.
- Market expertise includes Semiconductor, Industrial, Aerospace and Energy market verticals.
- Extensive experience in the definition and deployment of wired and wireless dynamic sensor monitoring systems.
- Successfully managed and deployed measurement and monitoring solutions in the industrial, power and energy market segments.
- Prior to Perpetuum, has held ranking positions with Meggitt, Teradyne, Fairchild, Schlumberger and Hewlett Packard.

Core Product Description

FSH

Free Standing Harvester



- Vibration Energy Harvester (VEH)
- Converts waste vibration into usable power for WSN's
- Electromagnetic – Coils & Magnets
- Industrially robust & reliable
- Hazardous Area Certified

Capable, Simple, Reliable, Robust ... Forever

What Does a VEH Provide?



In-exhaustible power
for “battery” powered Industrial WSN’s

A New Disruptive Paradigm

- ❖ Batteries introduce a new and additional disruption to already burdened maintenance staff & operational logistics.
- ❖ The disruptive logistics of finite battery life, replacement and disposal can be minimized or eliminated with Vibration Energy Harvesters.
 - **Unplanned maintenance is disruptive and costly**
 - **Unnecessary maintenance is just bad business**
 - **Energy Harvester Payback = One Battery Change**
 - **How many Batteries are you planning to change?**

Resistance to “Battery Only” Power

- Unpredictable or limited life span in WSN applications
- Added unnecessary disruptive maintenance logistics
- Replacement Logistics: Remote, un-safe and hazardous locations. Hot work permits.
- Non-optimized maintenance & scheduling logistics
- Increased demand on skilled labour reserves
- Stocking - Costs of replacement and spares
- Disposal & Environmental - Lithium related

Why use an Energy Harvester?



Lithium Thionyl Chloride
D-Cell - 19,000 mA-hour

- Finite energy storage capability
- Delivers 1.0mA @ 3.6V for approx. 2 years
- Fast update rates drastically reduce life span
- Unnecessary maintenance logistics.

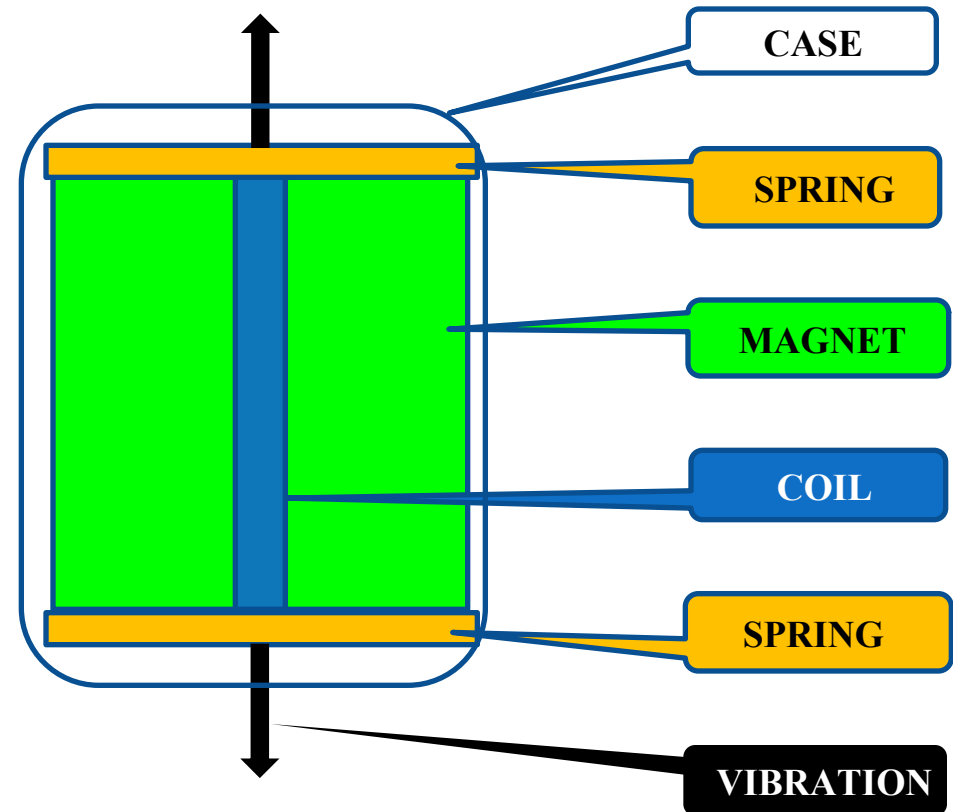
Energy Harvester
(FSH)



- Perpetual power generation
- Delivers at least 1.0mA @ 3.6V indefinitely
- In many cases Duty Cycle independent
- Maintenance Free - Fit and Forget

VEH Construction & Operation

- VEH Construction:
 - Magnets, Coils & Springs
 - Power management
 - Temperature compensation
- Vibration moves magnet up and down relative to coil.
- Based on Faradays law, an AC current is generated
- AC current rectified to produce a DC output.



FSH at a Glance

Free Standing Harvester (FSH)

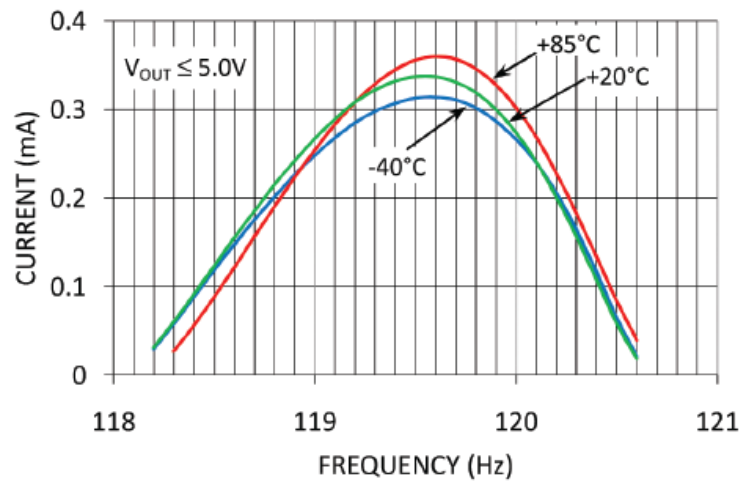
- 20mW max Power output (5.0V * 4mA)
- 4mA max current output
- ~ .3mA output with as little as 0.025g vibration level
- Current drive independent of load voltage up to 5V
- 2 standard Voltage output levels (5V & 8V)
- 316L stainless steel, hermetically sealed case
- ATEX, IECEx, CFM Zone 0 certified
- Full industrial temperature zone operation (-40C to +85C)
- Standard IEC connector interface



Sources of Vibration

Narrow Band

Figure 4. Current versus Frequency at 0.025g_{RMS}

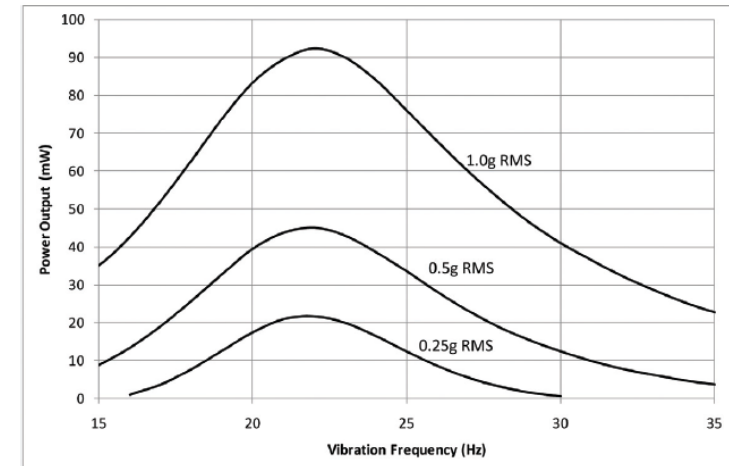


- Repeatable periodic / resonant frequencies
- Low vibration levels
- i.e. – Line / Mains powered motors



Wide Band

Figure 2. Power Output vs. Vibration Frequency



- Non-repeatable randomized frequencies
- High vibration levels
- i.e. - Train / Rail Cars



Battery Powered WSN's



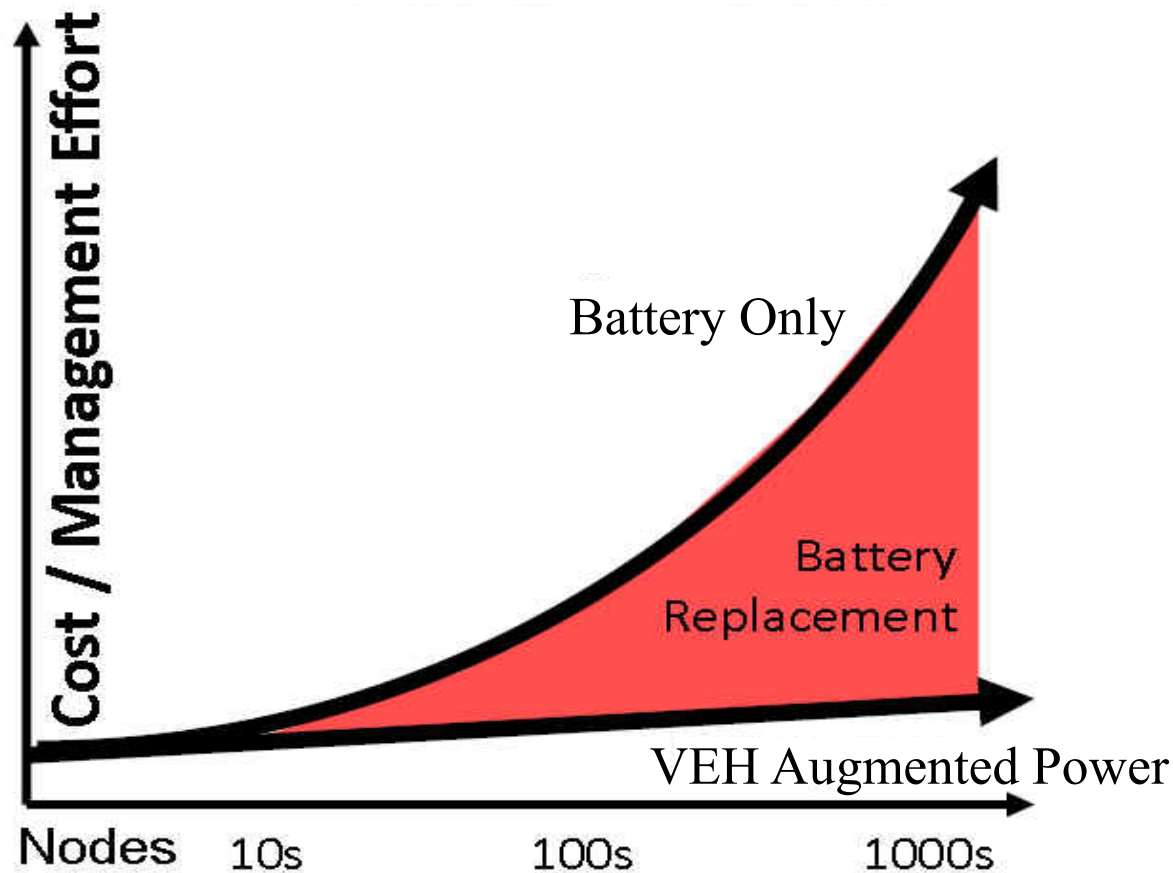
True Cost of Changing Batteries

Cost of Changing Batteries for Deployed WSN's:	
(Time): Identify & locate	30
(Time): Paperwork & Logistics	30
(Time): Pull repair stock items	15
(Time): Traveling to & locating, devices	30
(Time): Change time per Power Module	5
(Time): Number of Power Modules to change	1
(Time): Added travel time for multiple WSNs (5 mins/ea)	0
(Time): Power Module Change time - Total	5
(Time): Return & Verify operation	40
(Time): Disposal of old batteries	15
(Time): Total Time in minutes	165
(Cost): Burdened hourly labor rate	\$85
(Cost): Hourly Rate Cost	\$233.75
(Cost): Consumables / Other costs	\$15.00
(Cost): Replacements	\$150.00
(Cost): Inventory cost of spares	\$45.00
(Cost): Lost Labor Productivity	\$58.44
Total Costs	\$502.19

Simple, close proximity, non-safety restricted case

Cost of Scalability

Wireless Sensors Networks can not scale using batteries only



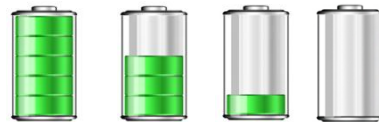
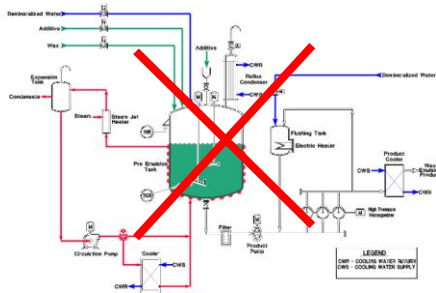
Industry will need to manage wireless sensor nodes involving thousands of nodes with their own power. These can not be visited without great expense and labor and some can not be visited at all.

Staggered Battery Life Disruption



**At
\$500-
\$1000+
Per
Battery
Change!**

“Battery Only” powered WSN



Battery Power



Transmit Data



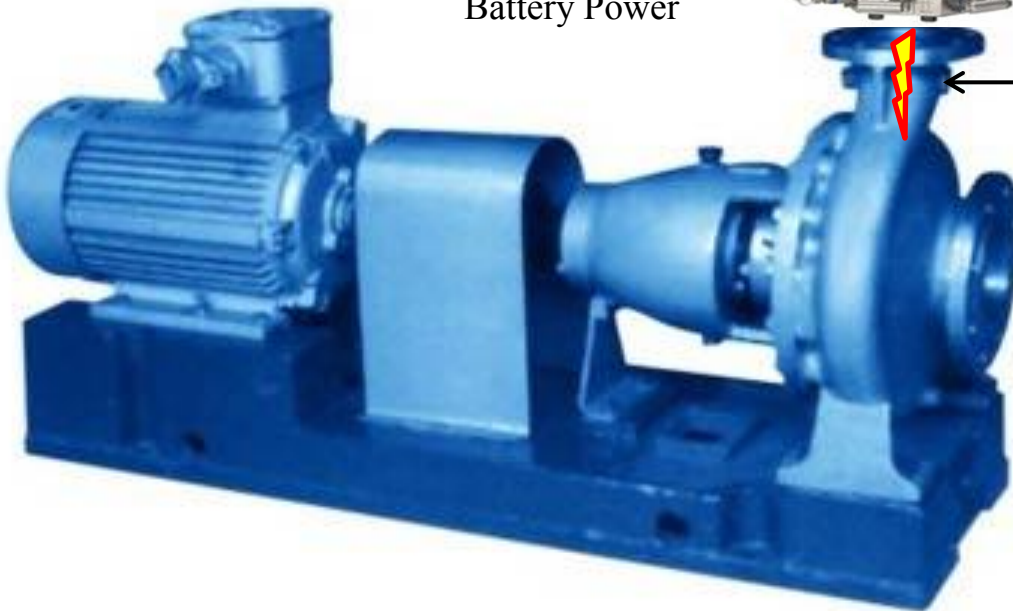
Processing



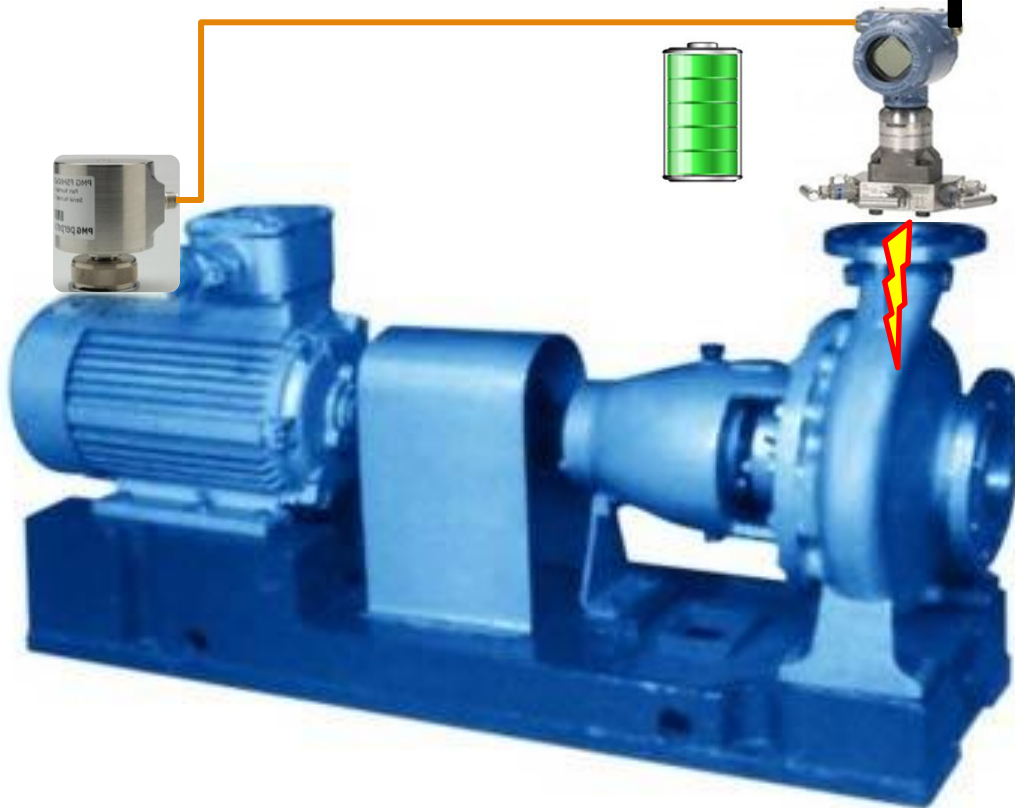
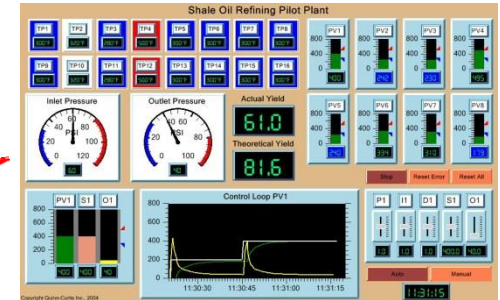
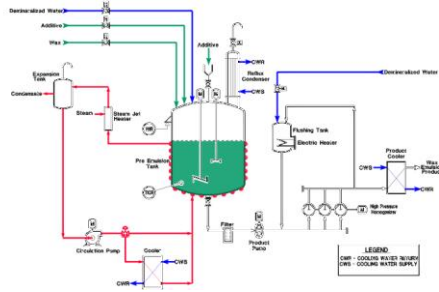
Control Panel

CAUTION

Costly, Disruptive
and Unnecessary
Maintenance Logistics
Ahead



VEH Powered WSN



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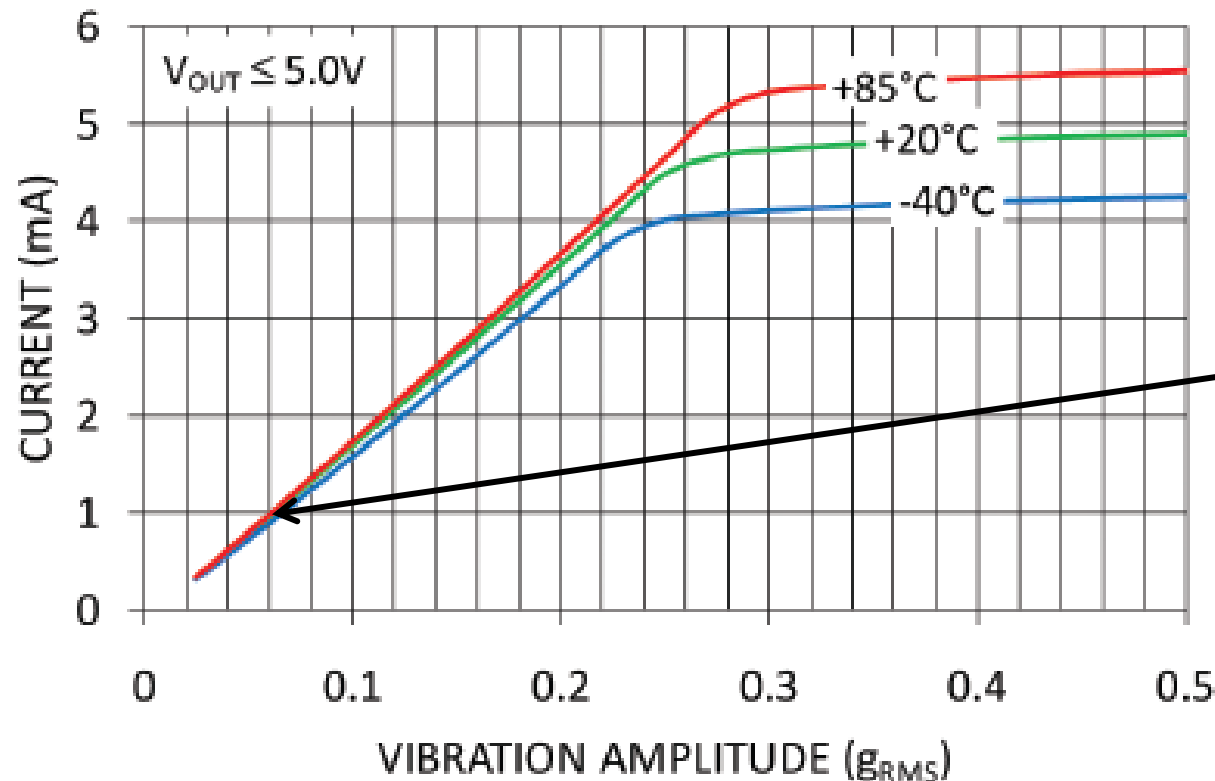
Energy Harvester
(FSH)



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VEH Performance vs. Vibration Level

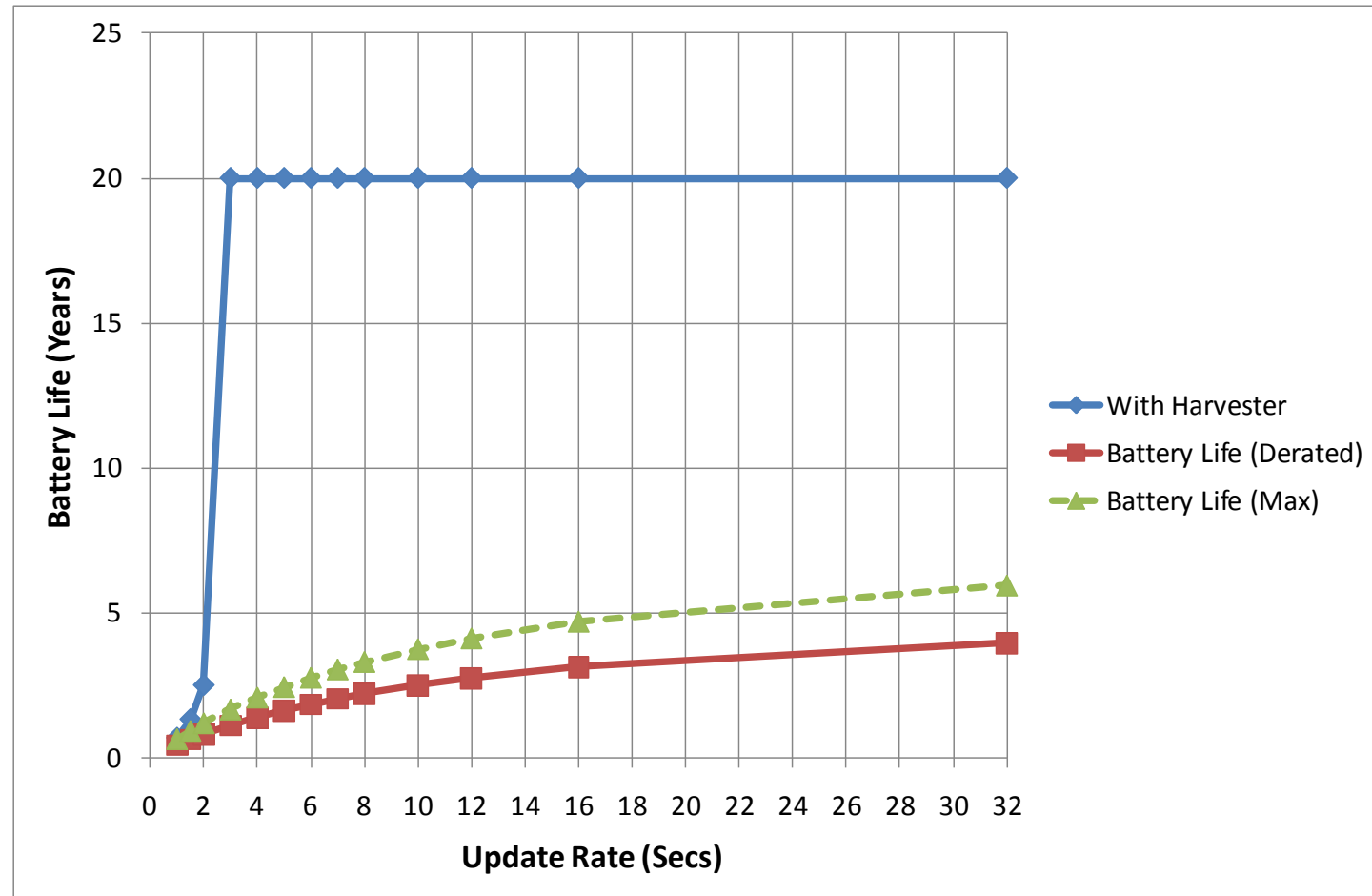
Figure 1. Centre-band current output



Typical Avg. Power output
for Industrial WSN's
~ 5 mW or 1mA

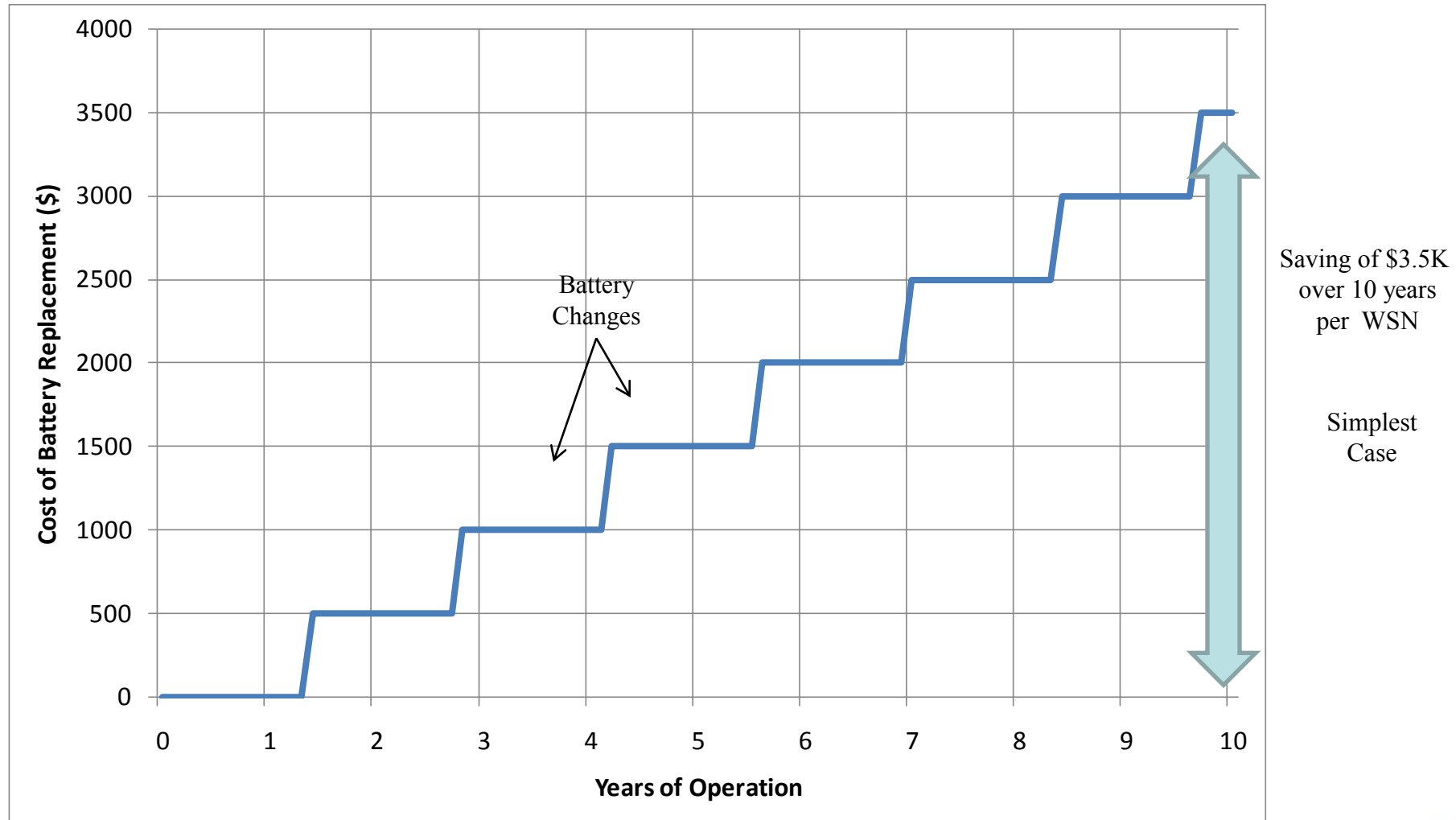
Harvester delivers full operational
performance from -40C to +85C

Impact of Using Harvesters

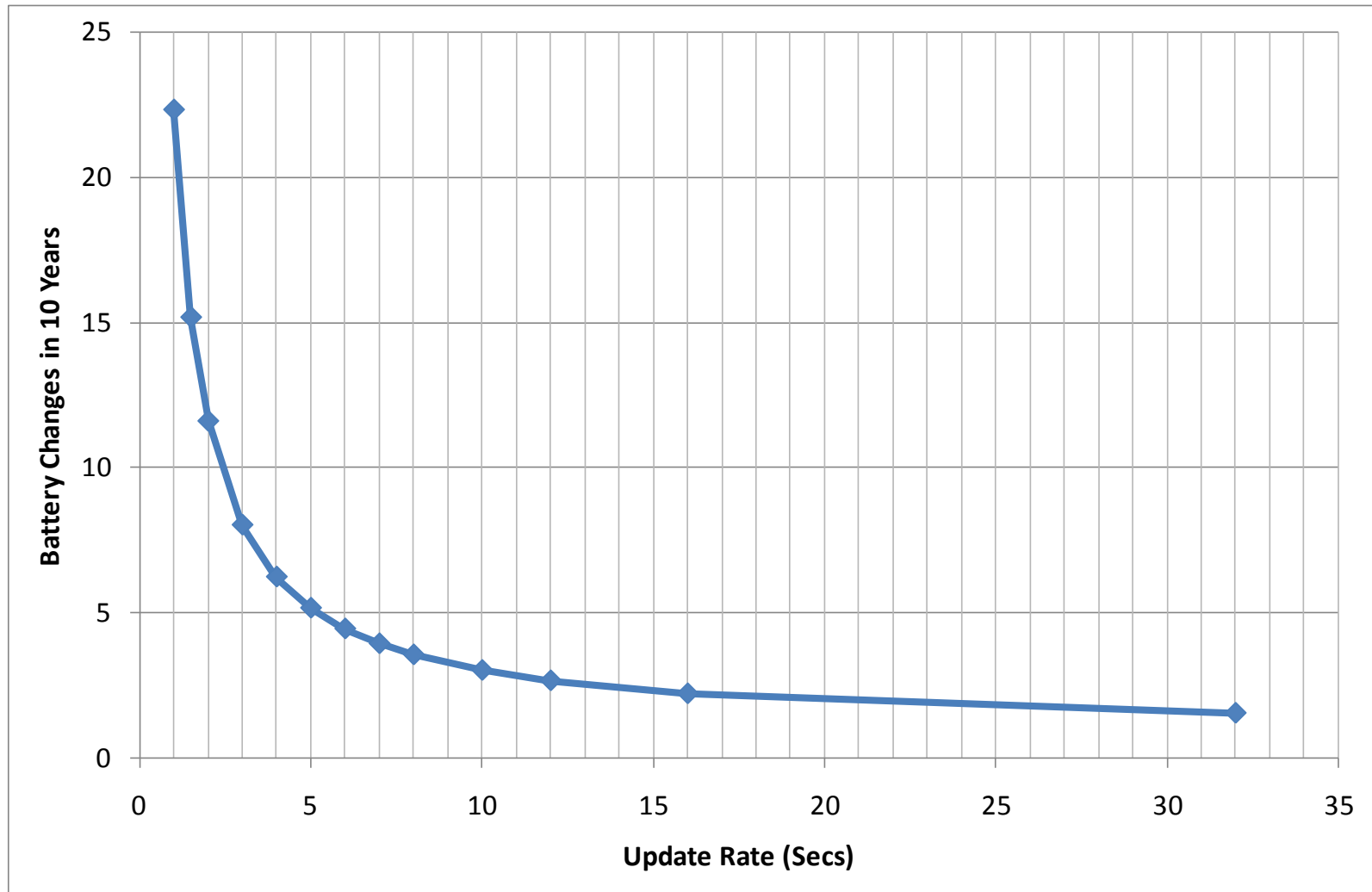


Dramatic Improvements using Energy Harvesters

Business Case per Node (4 Sec)



How Many Battery Changes?



Rate of Battery Change (No Harvester)

Update Rate (Sec)	Total Battery Voltage	Ideal Ah rating of Batteries	Actual Ah of batteries	Total Wh of Battery Power	Avg Power required by WSN at update rate (mW)	Total Wh batteries can deliver	Total years before battery change required
4	7.2	8.5	6.375	45.9	4	11,475.00	1.31

# of Nodes Deployed	Years in operation (X)	# of replacements required in (X) years	Avg. # of battery changes per day
500	10	7.6	1.05

At \$500 a battery - each day

\$500/day (cost of battery change) X 365 days/year = \$182,500.00

Spent just on changing batteries !

Market Vertical Examples

Industrial

- Oil & Gas
- Power Generation
- Petrochemical
- Polymer
- Water / Waste water
- Paper & Pulp
- Mining



Transportation

- Rail
- Wheel bearing monitoring
- Cargo / Environmental
- Location Tracking



Applications: Industrial

Equipment Health Monitoring (EHM)

VEH Powering GE Bently
Essential Insight.mesh
Wireless vibration
transmitters.



Applications: Industrial

Process Monitoring

- VEH powering **Emerson 408** wireless transmitter.



Applications: Rail



Attach
Wireless
Sensor Node
to Wheel
bearing casing

- Key Features:
 - ✓ Vibration & Temperature Sensors > Early Identification of Failure
 - ✓ Microprocessor > Simple Measure of Bearing Condition
 - ✓ Wireless Communication > No Wires
 - ✓ Energy Harvester > No batteries
 - ✓ Robust design for harsh environments

Perpetuum is applying Industrial Condition Monitoring Techniques to Rail Industry

Installation

Simple site installation logistics

Measure the current with a multi-meter or Vibration Power Puck during installation.

Verifies the current that will be supplied to WSN when connected to FSH.

- The FSH has a current drive output.
FSH connected to multi-meter



Power Puck

Summary

- ❖ VEH convert waste vibration into free usable electrical energy
- ❖ Significant power output at low machine vibration levels
- ❖ Well suited to provide the power of current WSNs
- ❖ Designed into multiple leading OEM WSN's
- ❖ Exceptional Reliability: MTBF of 100s of years
- ❖ Temperature compensated across industrial range
- ❖ Hazardous area / zone certified
- Can solve “battery only” power logistics & concerns
- Harvesters are a key enabler for WSN growth



Vibration Energy Harvesters are a true “Fit & Forget” Wireless Power Solution

Vibration Energy Harvesting

*Perpetual **Power** Solutions for Wireless Sensing & Automation*



Who's *Harvesting* Your Success?