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Energy Harvesting in Practical Applications

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Getting it out of the Lab

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Experiences from taking energy harvesting concepts to successful, practical applications

rtt

- Need basic research
- Need to keep focussed on Laws of Physics
- Need to assess source of energy to be harvested
- Do NOT need
  - Taxpayers money spent on impractical human power
  - Ridiculous claims - RF Harvesting to recharge mobiles
  - Unrealistic Energy Source Expectations – 4g @983Hz
  - Misplaced faith in Moore's Law to increase power

Requirements for EH Power

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- Sufficient Power as/when needed
- Adequate lifetime - No/low maintenance
- Easy low cost installation
- Flexibility
- Meet application specification requirements

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Sufficient Power as Needed

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- Does power source produce enough average power from actual energy available?
- Power Source Output depends on
  - Energy Source
    - Vibration- Frequency, Amplitude
    - Temperature – Gradient, Airflow
    - Battery Capacity, Temperature
  - Size
    - Mass, Number of Devices, Area of solar panel

More than Enough Power

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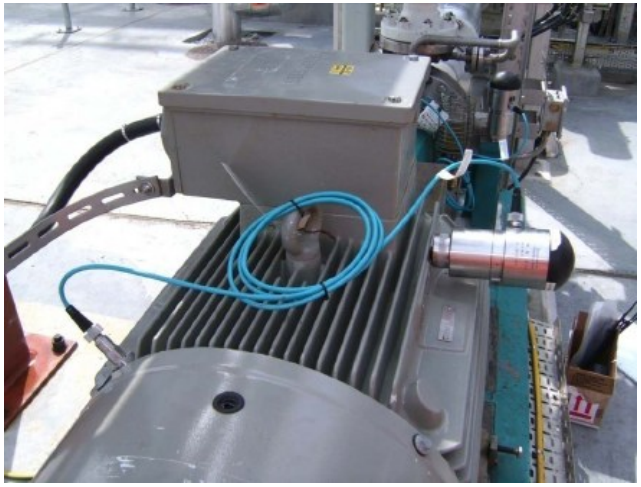
First System
One harvester powers
WSN with **One** sensor



GE Bently Nevada Insight.Mesh

New System
One harvester powers
WSN with **Four** sensors

Pump in Power Station

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MW of power but much cheaper and easier to use mW generator to power WSN

Sufficient Power – Everywhere?

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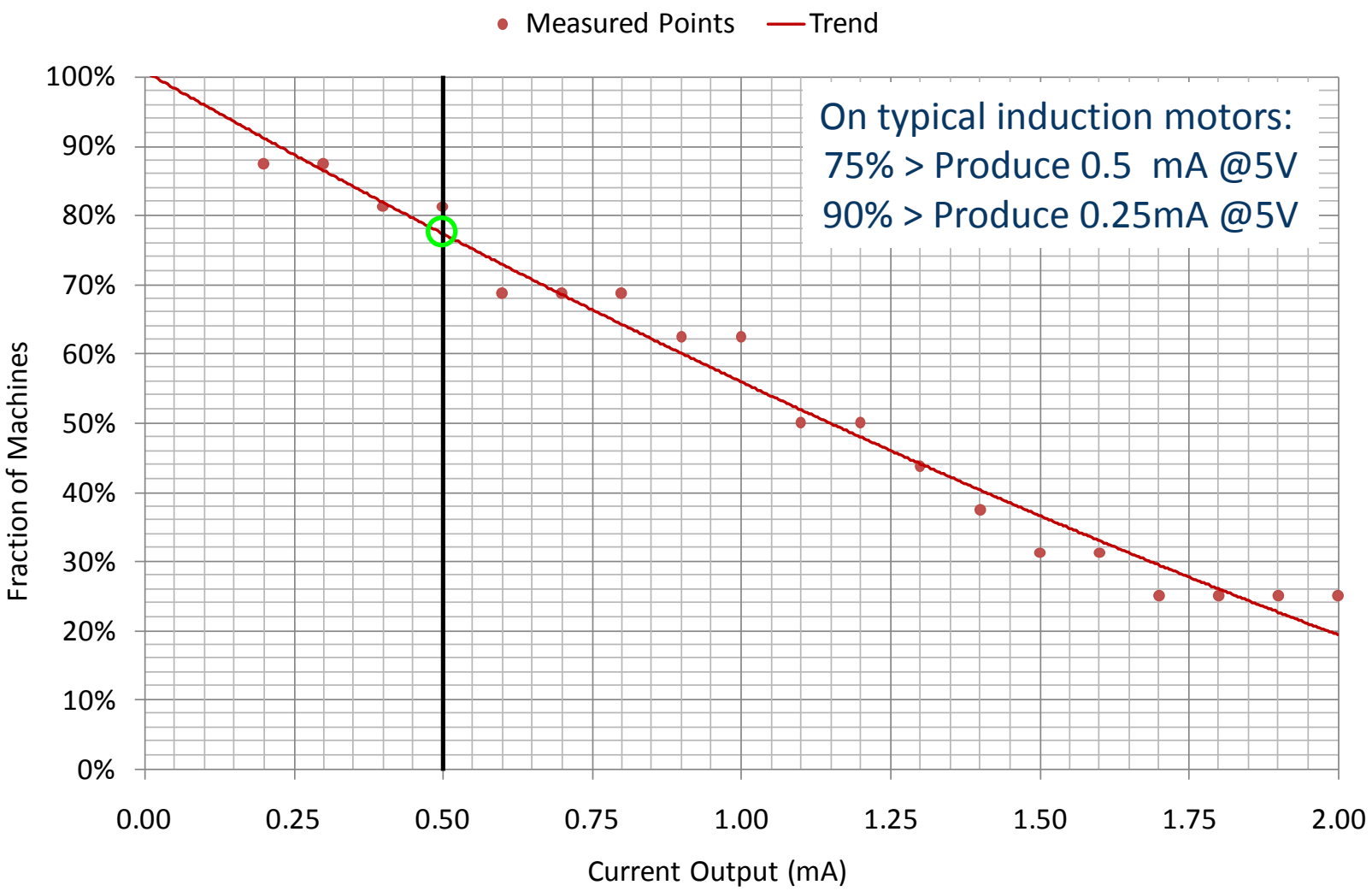

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Lifetime – No maintenance

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- Power Source to exceed equipment life
  - Harvester designed for high reliability -890 yrs MTTF
  - Rejected materials with 200m cycles:- <7 weeks @50Hz
- Maintenance :-
  - Difficult, undesirable, impossible
  - Battery change issues
- Power Solution must be “Fit and Forget”

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Easy, Low Cost Installation

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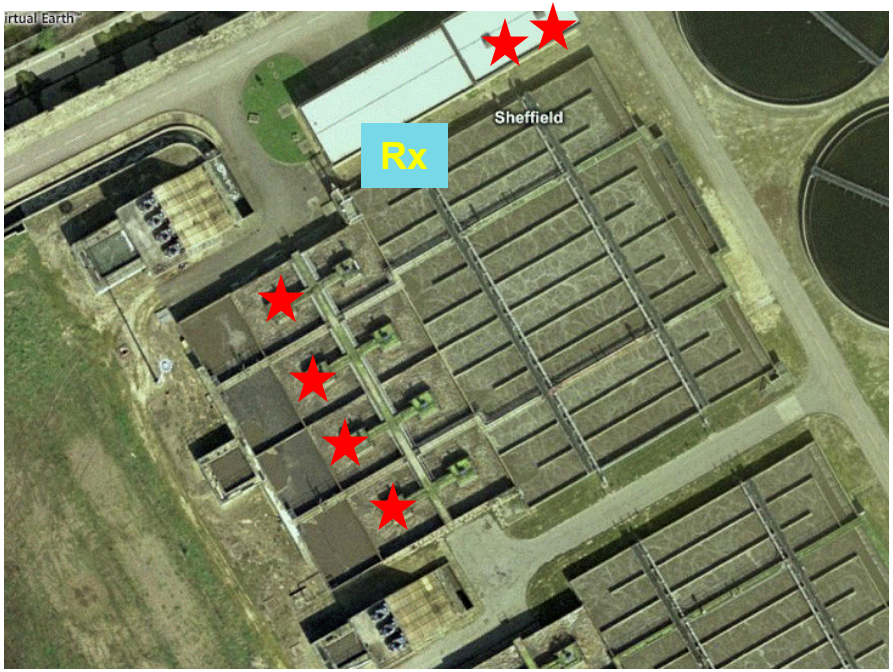
Pruftechnik GmbH

Wireless Condition Monitoring System
At Water Treatment Plant



- 6 units installed in 40 minutes
- Wiring would need 6-8 man weeks and plant shutdown
- Unhealthy Working Environment

Easy to Install

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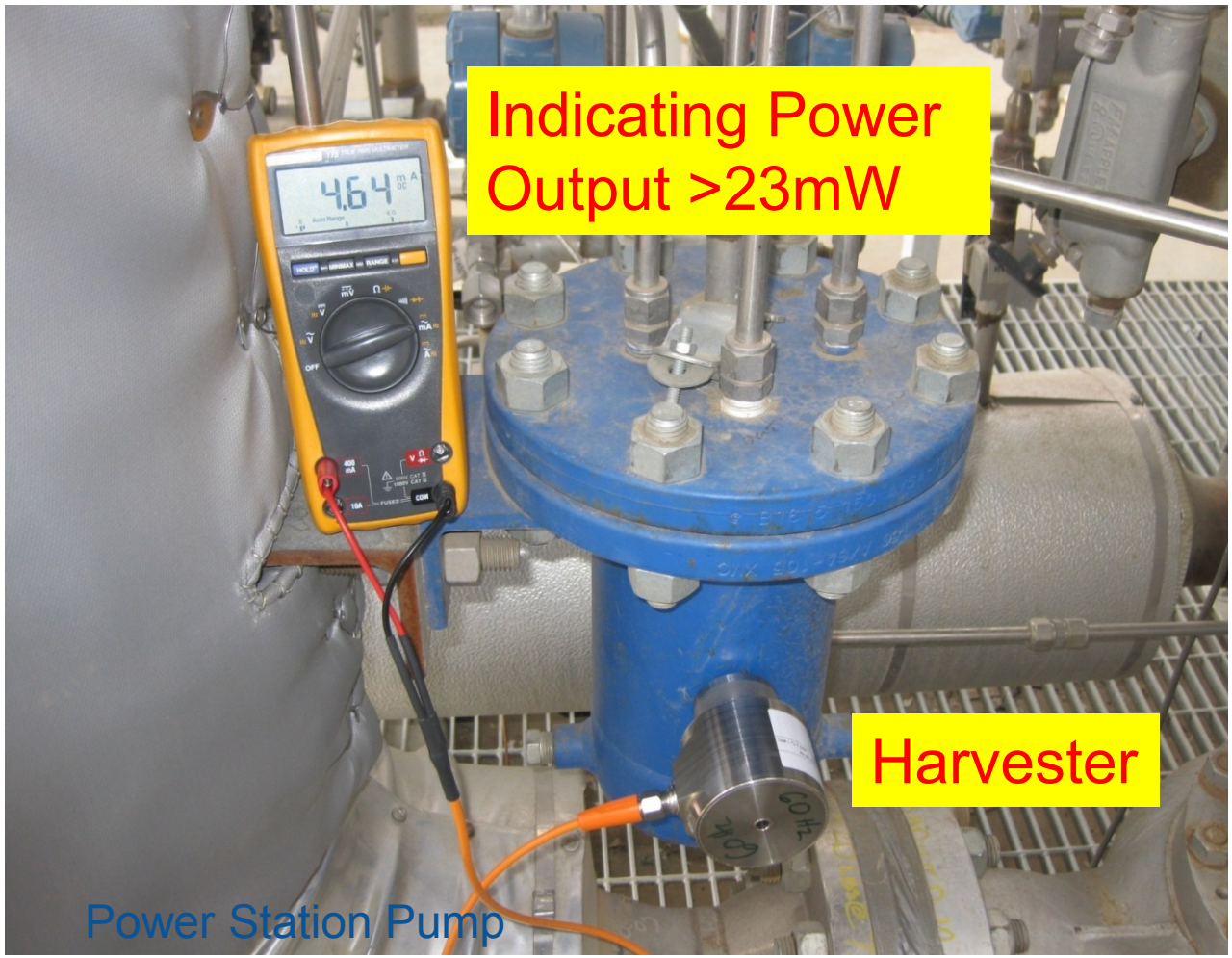
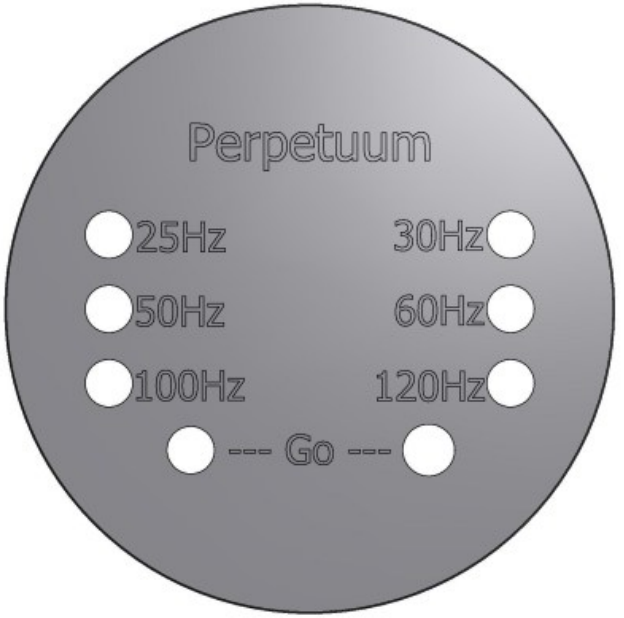


- Power level seen immediately
- Non – intrusive Installation

Installation Tool

- Place on machine and press button
- Lights illuminate to indicate frequencies available
- Optimum stays on longer



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Flexibility – one size does not fit all

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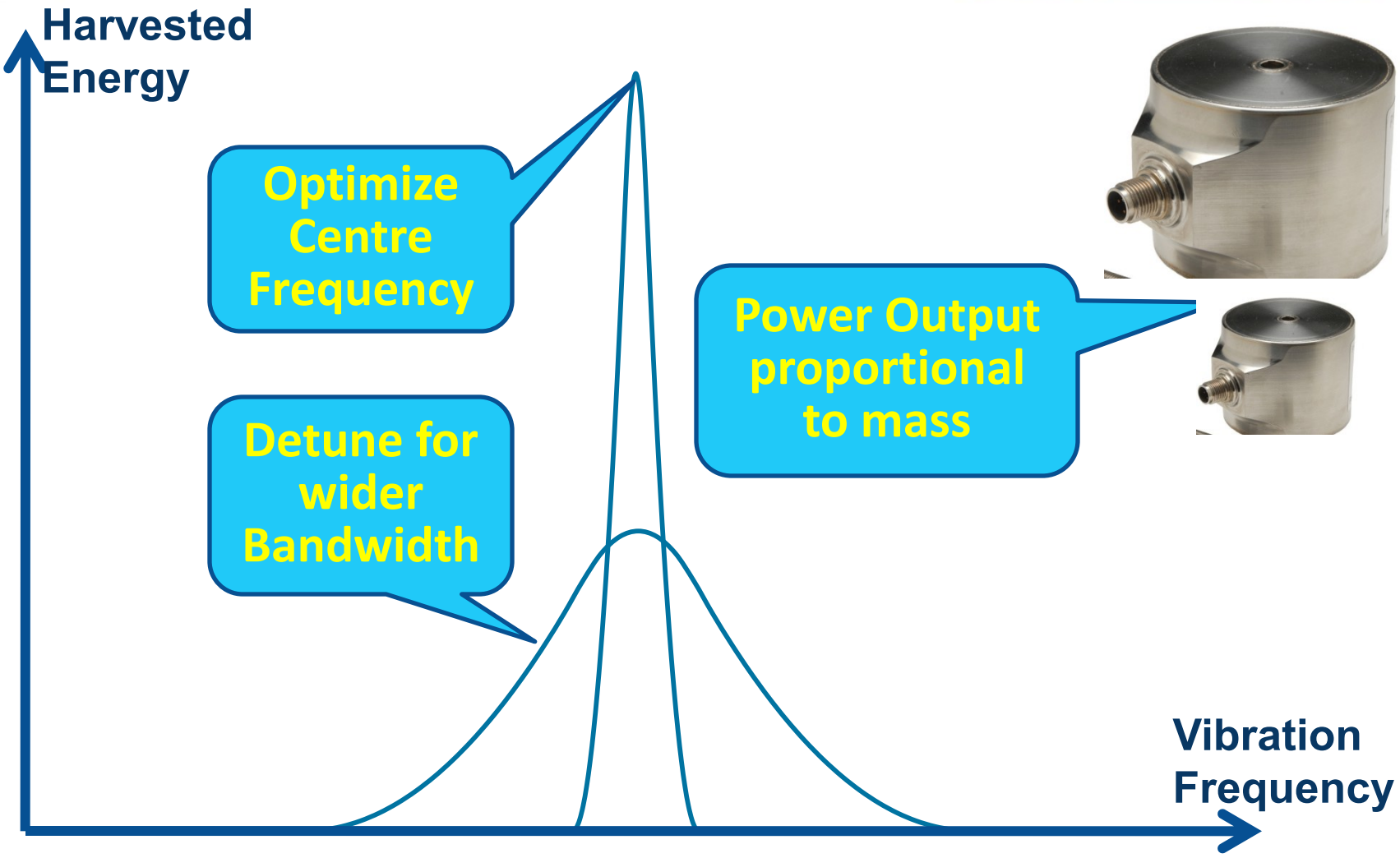

Flexibility

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National Instruments Wireless Sensor Node

- Pressure, Temperature
- 4AA batteries
- Vibration Energy Harvester
  - Integrated Power Conditioning including Capacitor
- Solar Power Unit

http://zone.ni.com/devzone/cda/tut/p/id/12128

ISA100.18 Power Sources

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Mission

The ISA100.ps Working Group mission is to develop standards to enable users and suppliers to compare, specify and interface power/energy sources for “non line powered, low power, wireless sensor nodes (WSN)”.

- **Objectives**
  - Develop and Publish standards that permit **interchangeability** of Power Modules for WSN’s.
  - Develop and publish standards for specifying performance of power/energy sources

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Meet Application Specifications

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- Environmental/Regulatory/ standards

  E.g. CE, EMC, UL, FM, Train washing
- Temperature range
  - E.g. -40 to +85
  - *Warning – Energy Storage Devices may not give adequate performance over full temp range and for required lifetime*
- Shock
  - E.g. 100g for rail
- Hazardous Zones
  - E.g ATEX/IECEx/CSA Certification, CSA,

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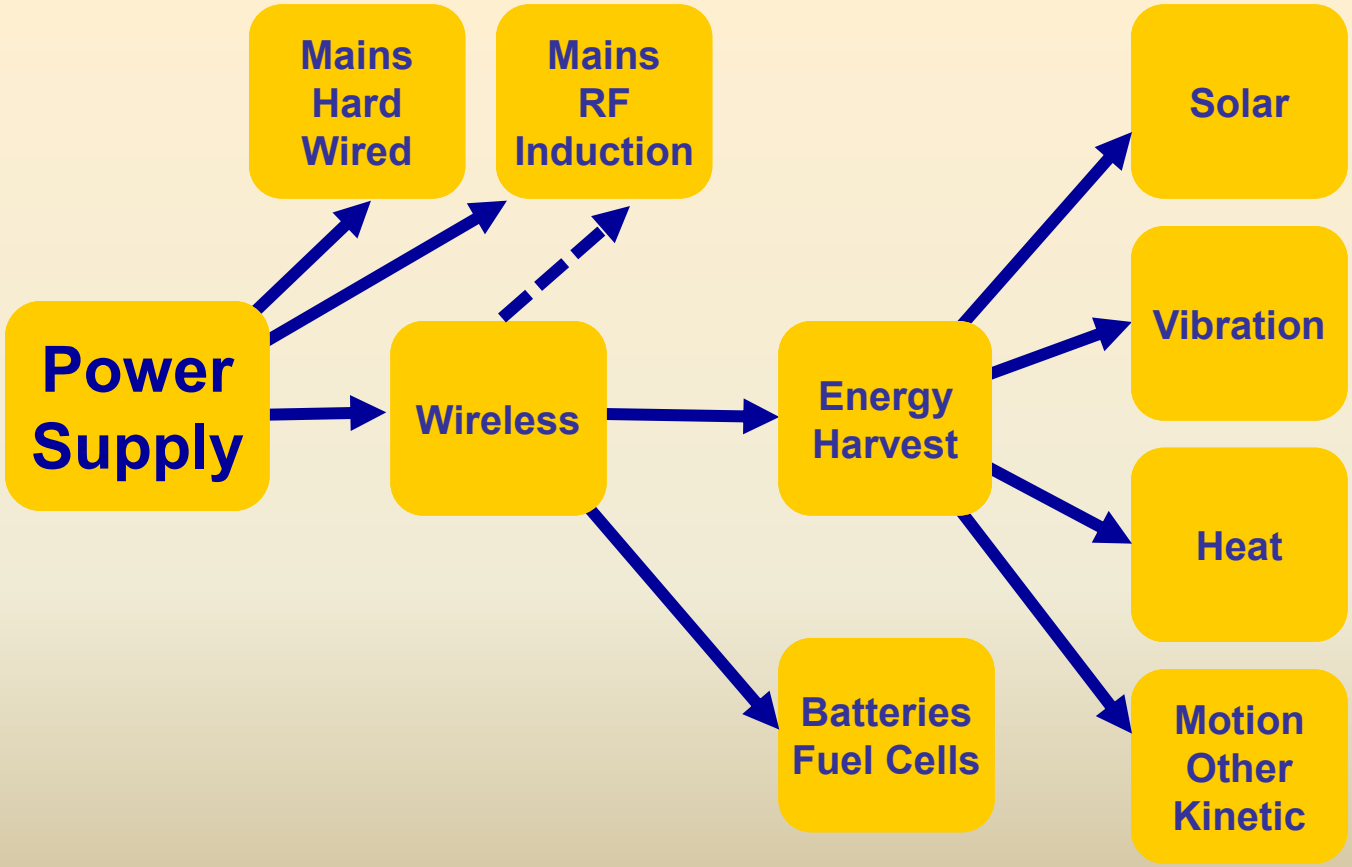
Power Supply
Mains Hard Wired
Mains RF Induction
Wireless
Energy Harvest
Batteries Fuel Cells
Solar
Vibration
Heat
Motion Other Kinetic

Power Source Options Comparison

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- Example Use Case - WSN with average power of 3mW

  Typical for

  - Either a frequent reporting requirement (such as several times per min)
  - Or a high data requirement (such as complete vibration spectra).

- Options for Wireless Power

  1. Battery
  2. Vibration Harvester
  3. Thermal Harvester
  4. Photovoltaic Harvester
  5. RF Transmitted Power

Power Source 1. Battery

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- Theoretical life of standard sized cells from leading Lithium battery supplier
  - Theoretical capacity is reduced by
    - Intermittent high currents for RF transmission
    - Self discharge
    - Low temperatures.
    - Some newer designs perform closer to theoretical capacity, may include energy storage to help with the peak power requirements of WSNs

Battery size	Nominal capacity	Life at 3mW (3.6V)
AA	2.4 Ah	Less than 3 months
C	8.5 Ah	Less than 10 months
D	19 Ah	Less than 2 years

Power Source 2. Vibration EH

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- Uses ambient vibration from rotating machinery or vehicle motion
- Example: **Perpetuum** vibration harvester
  - 3mW from about 40-50mg of vibration
  - Depends on frequency and amplitude
  - High bandwidth important to ensure adequate coverage of a wide range of machines

Power Source 3. Thermal EH

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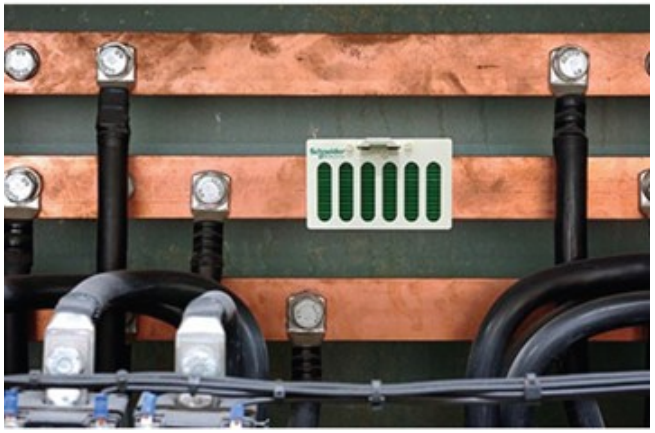
- Requires Heat Source and
  good heat transfer
- Example: **Micropelt** thermal harvester
  - 3mW with heat source at about 55C assuming ambient temperature of 25C
  - Rate of heat transfer is important
  - Installing a probe which impedes convection or heat flux increases the required temperature differential.



Power Source 4. Photovoltaic EH

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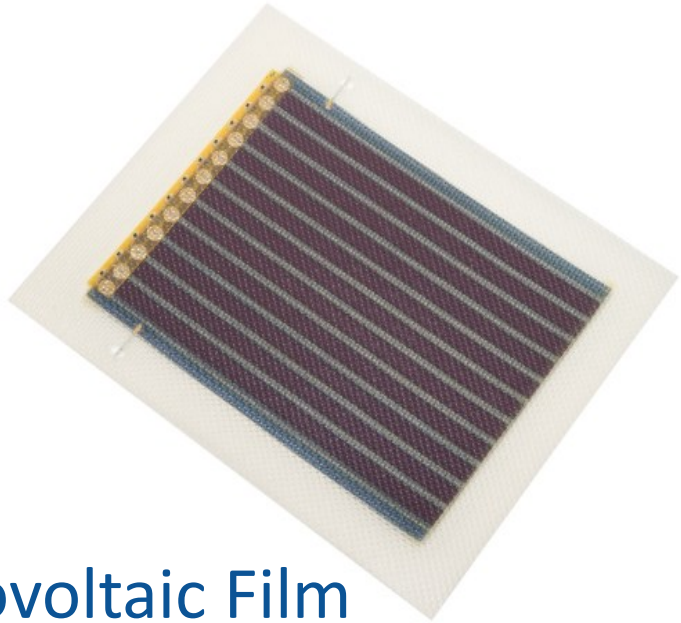
- Photovoltaic uses ambient light externally or inside buildings



- Example: **G24 Innovations** Photovoltaic Film
  - Dye sensitized thin film photovoltaics
  - 3mW from area of 233mm x 135mm in typical industrial indoor environment with a light level of 500 lux.
  - Light source dependent and cleanliness issues

Power Source 5. RF Transmission

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- Needs Powered Source
- Example: **Powercast** RF transmission system
  - 3mW of usable power at a range of (4ft) from a 3W transmitter
  - Multiple transmitters or receivers can produce 3mW at longer range.
  - Wireless power transmission rather than energy harvesting
  - Range Limitations

Conclusions

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- Energy Harvesters are key enabling technology for wireless sensing
- Harvesters must supply sufficient power from immediately available energy sources and meet the full operating condition requirements
- Energy Harvesting is now a practical reality with choice of solutions offered by leading global businesses

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Thank You for Listening

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