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Thermal **Energy Harvesting**

Ready to compete with batteries?

by

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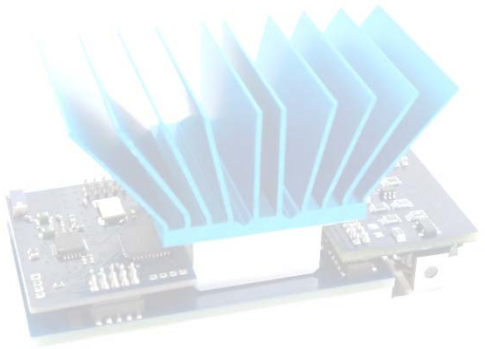
Outline



- Introduction
  - Why Wireless?
  - Power for Wireless
  - Energy Harvesting
  - Harvesting System View
- Thermoharvesting
  - Thermoharvesting Basics
  - Implementing µTEGs
  - Power & Energy Budgeting
- Technology to Applications
- Conclusions & Outlook

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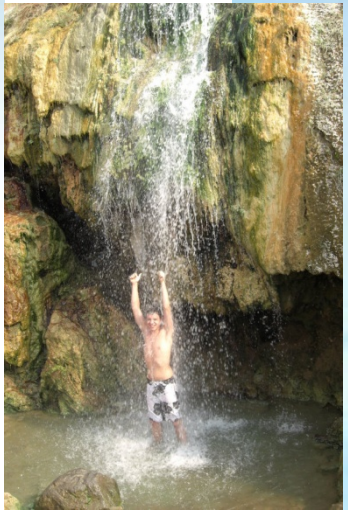
Take a little bit from available energies…



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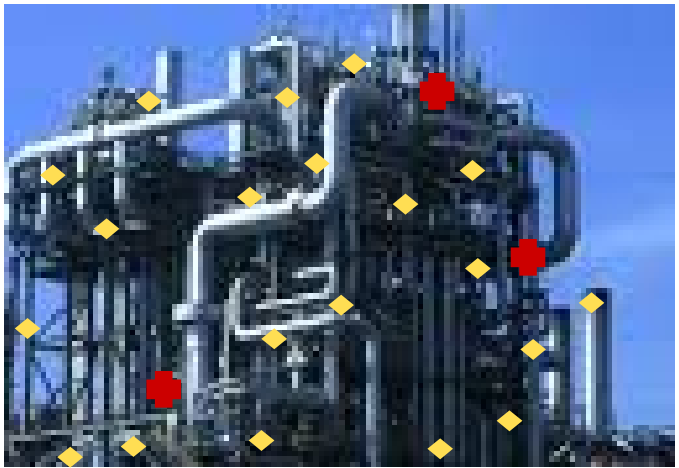
The Utility of Wireless

- Process & machine health *monitoring*
  - Process efficiency improvement margins undisputed (but also unnumbered)
  - 50% to 75% of each maintenance € is spent in vain
- Much better insight through extensive sensing
  - Improve productivity, reliability and control,
  - Reduce cost, risk and resource utilization.
- Automation to preserve energy @ home and office
- Big time savings at both corporate and private bottom lines?
  - Enabling new levels of energy preservation, and other ‚green' missions…



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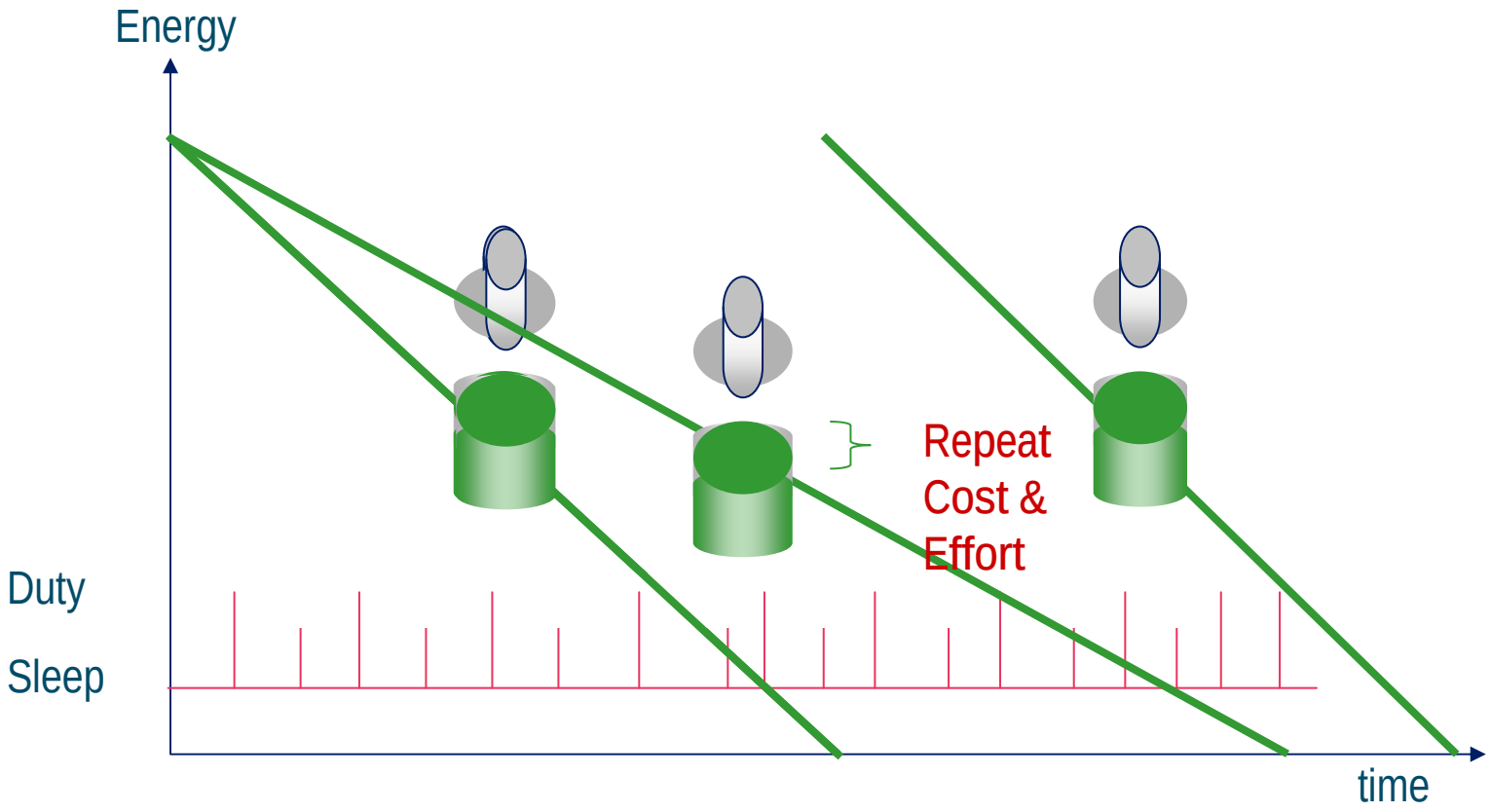
Duty Cycles and Batteries

- The battery issue
  OnWorld market research: 70% of potential users rate batteries as a critical inhibitor to WSN implementation

What can we do?

- Increase battery size
- Skip duty cycles
- Improve power management
- Use latest ULP hardware



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It‘s Time for Energy Harvesting

- Because of **Technology Convergence** (driven by mobile applications)
  - Microelectronics and MEMS integration leading to Ultra Low Power (ULP)
    - MCUs
    - RF ICs
    - Power conditioning ICs
    - Sensors
  - Duty cycle schemes save battery life
- ‘Micro’ power supply increase
  - Energy harvesting technologies
    - Emerging & maturing
    - Acceptable power densities

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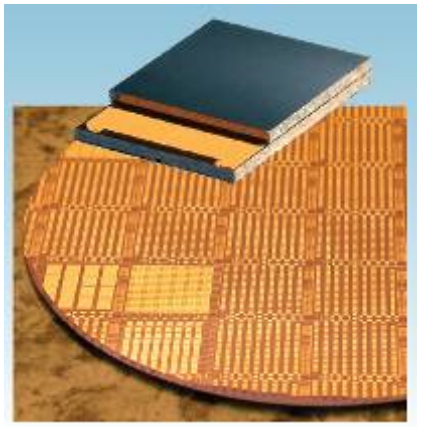
Introducing Micropelt

- 8+ years thermoelectric R&D, starting 1998
- VC backed Spin-off in Jan 2006 from:
  - *Infineon Technologies &*
    Fraunhofer IPM, Freiburg, Germany
- Headquartered in Freiburg, Germany
  - *20 full-time employees*
- Patented thin film thermoelectric technology
- Products:
  - *Thermogenerators (TEG), TE coolers (TEC)*
  - *Fast delta-T & calorimetric sensors*
  - *Prototyping & engineering services*
- Volume production starting 2011
  - ***Capacity:***
    10+ million units p.a.



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New Thin Film Deposition Equipment

TEG volume prices from < 5€

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Applications in Process and Condition Monitoring, Building Automation…

Heating / HVAC / off-grid combustion control

Bearing condition monitoring

Pressure valves & steam traps monitoring

Hydraulics monitoring

Process control / sensing

Wireless cooking sensor

Machine & structural health

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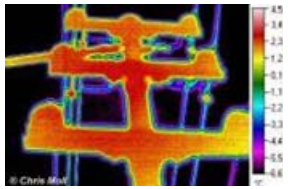
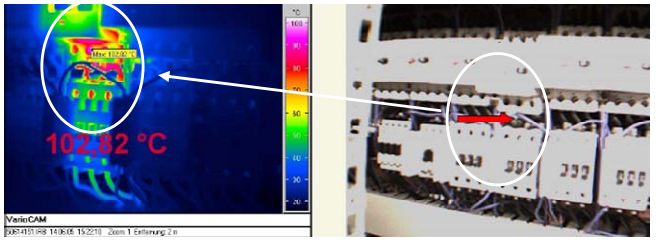
Ubiquitous '*Free Primary Energy*' Sourcing

'Every technical process produces waste heat'

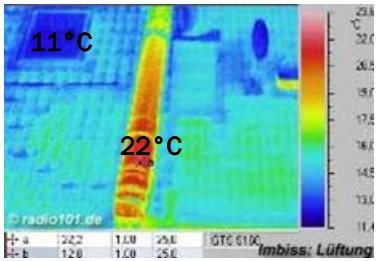
Electrical tower*1



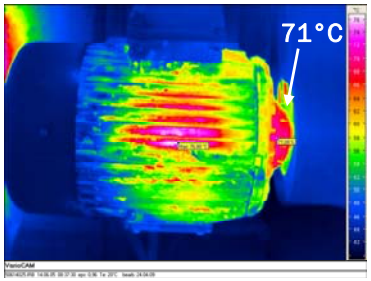
Switchboard*2



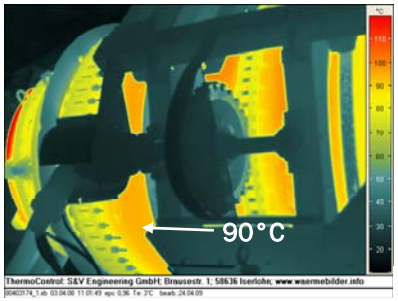
Vent pipe on roof*1



Electric motor*2



Forge*2



Quellen/Source:
*1 www.radio101.de
*2 www.waermebilder.info S&V Engineering, Germany

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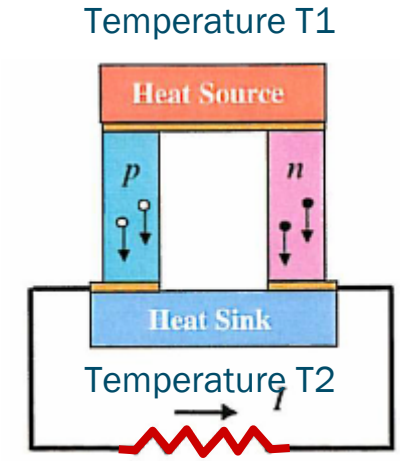
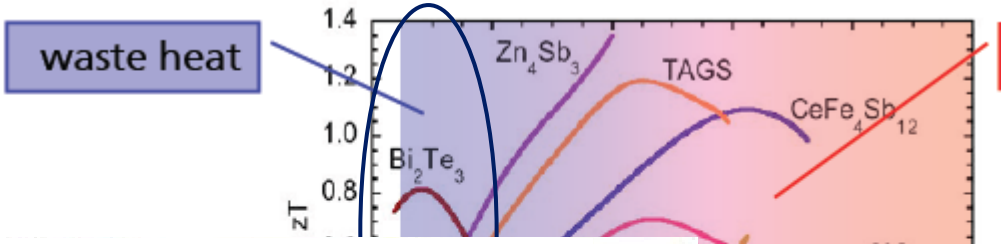
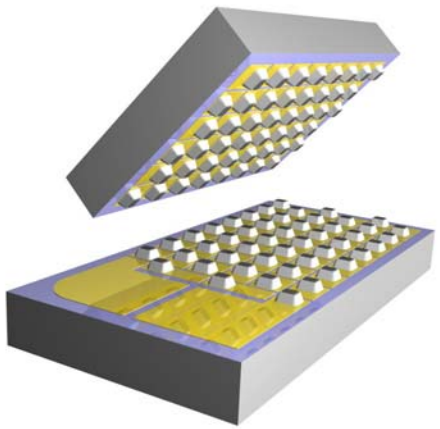
Thermoelectric Basics

The thermogenerator's (TEG)
and TE Cooler's (TEC) basic building block :
Thermocouple

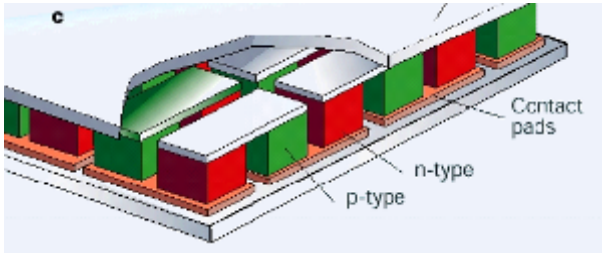


Material system: Bismut-Telluride (Bi_2Te_3) with best properties between 25°C and 150°C





Manual or semi-automated assembly



TE Element = multiple thermocouples:
Thermally in parallel,
electrically in series

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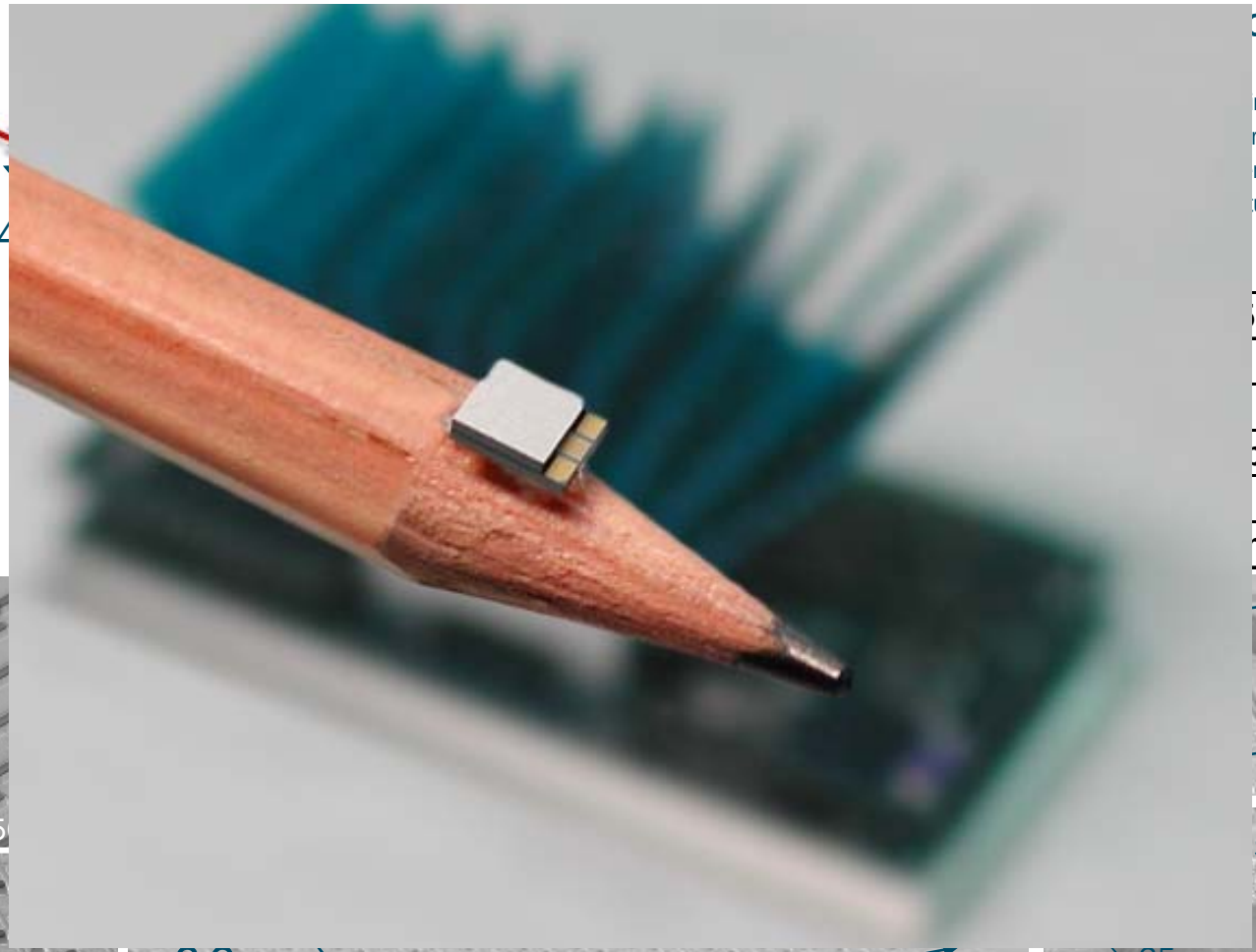
Thin Film vs. ‘Bulk’ Thermogenerators

Legacy:
128 thermo-couples
50 mV/K

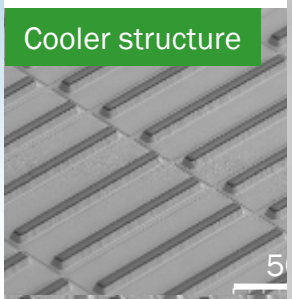


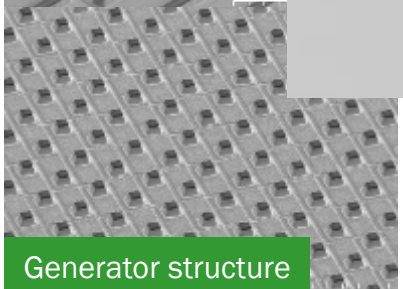
ocouples

n Volt open circuit
rs
nt Volt per Kelvin
ure difference

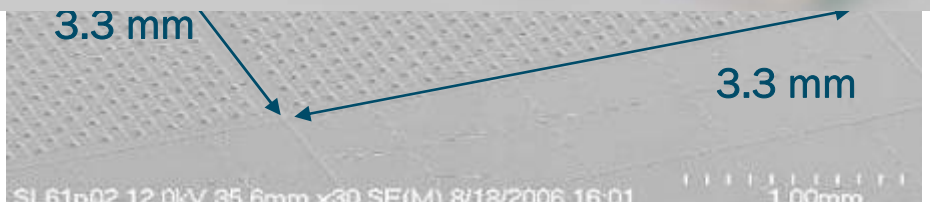
1
per cm²
²

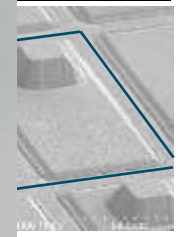
Cooler structure

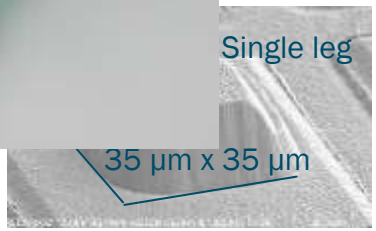




Generator structure







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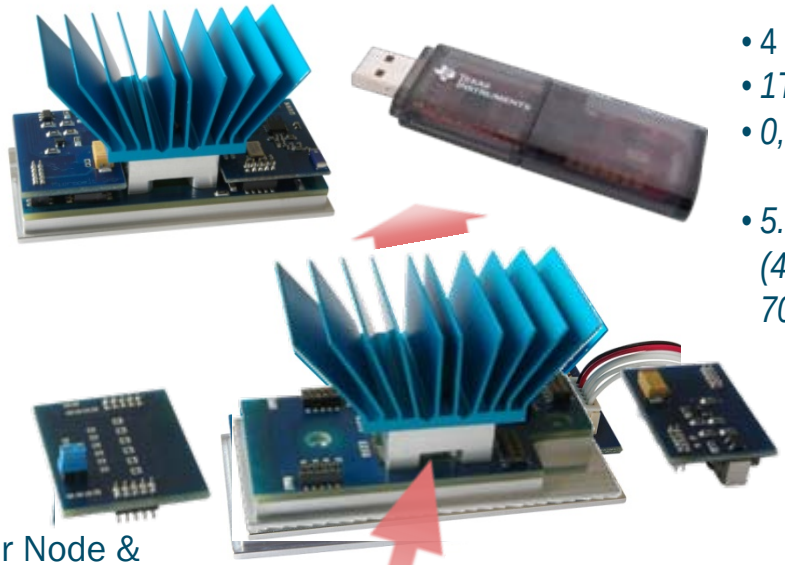
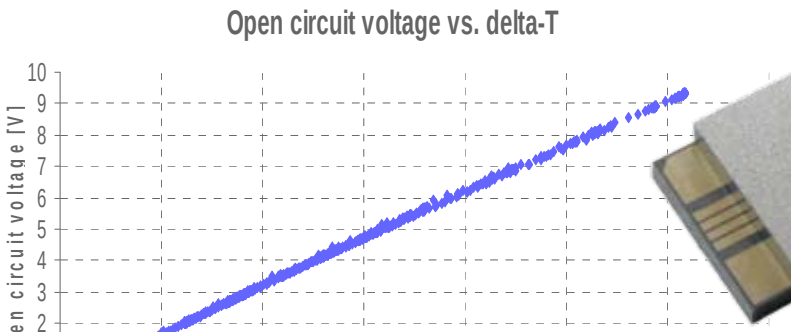
Approach Practical Implementation

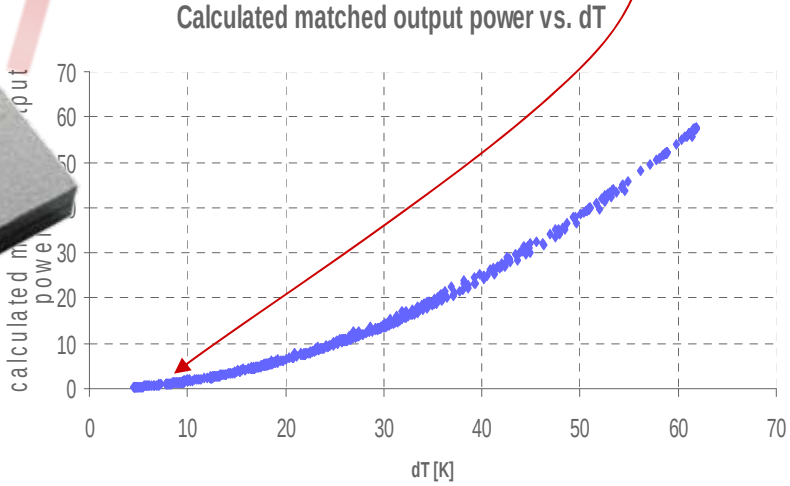
e.g. modular wireless thermoharvesting evaluation system

- TE-Power ONE
  Gross Harvesting
  power source
- TE-Power PLUS
  Net harvesting
  1.6 V – 5 V DC
  Adjustable voltage &
  capacitor extension
- TE-Power NODE
  Harvesting Wireless Sensor Node &
  Power Budget Explorer



- 4 Channels - I²C interface
- *1Tx/sec @ 3 Knet*
- *0,2% Duty Cycle*
- *5.600 mAh p.a. net*
  (4k hrs, 7K dT across TEG
  70% boost eff.)





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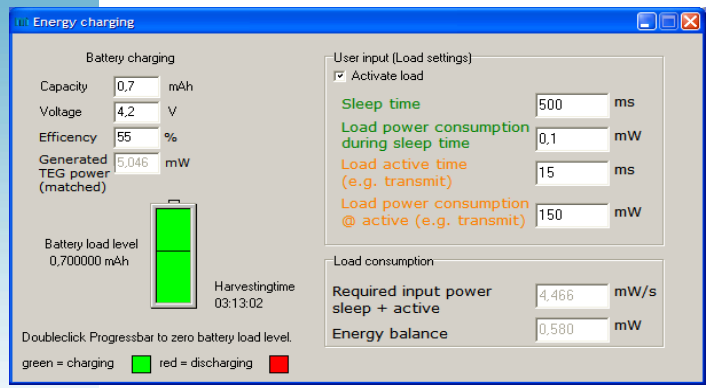
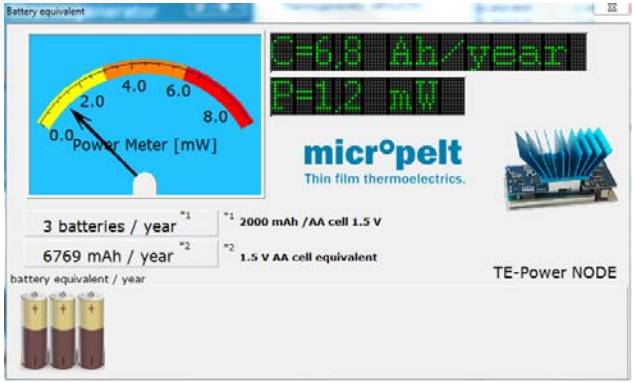
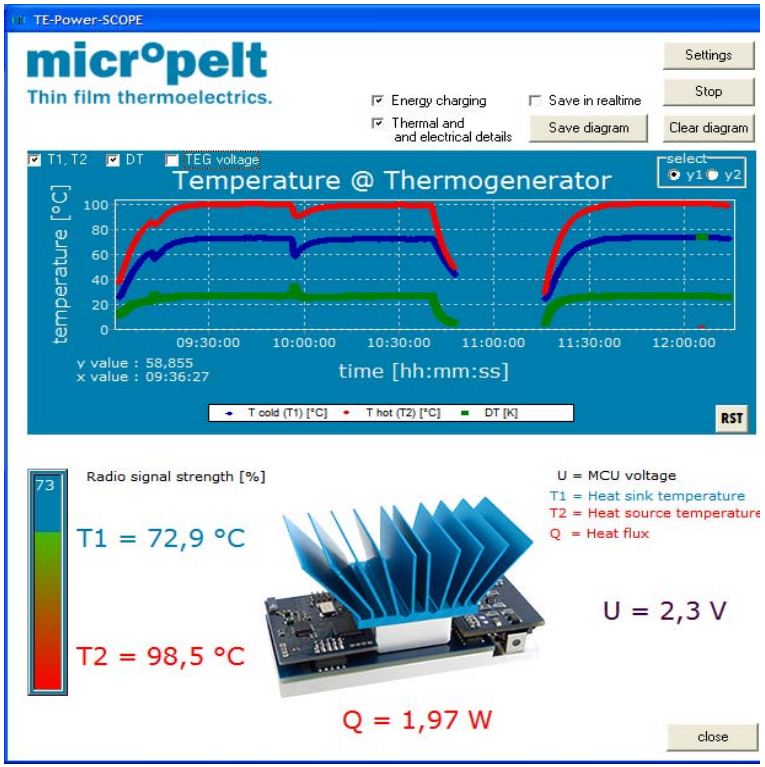
Approaching Real Life Applications

Practical Exploration & Energy Budgeting Software

- Flexible, long term histogram for themal budget field studies
- Real-time harvesting conditions and electrical output
- Parameterized energy storage and device power budget analysis
- Battery Benchmarking







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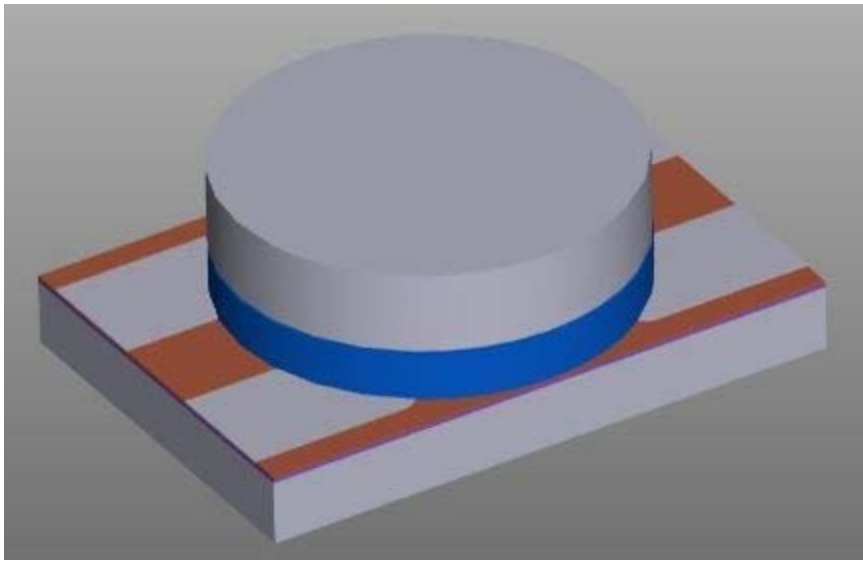
Facilitated TEG Assembly

- New standard product from Micropelt:

Packaged TEG = **GiP**
(Generator in Package)

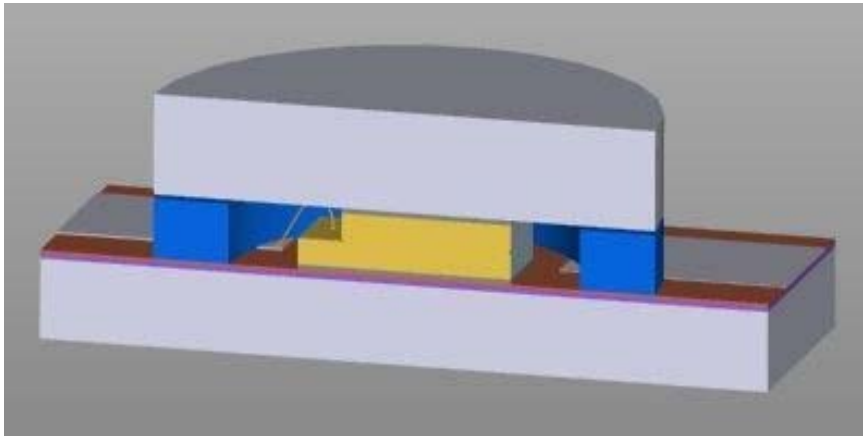
- GiP7 -> MPG-D751
- GiP6 -> MPG-D651



Protected TEG die

- Shear, torque, pull, pressure
- Impact
- Environmental

- SMD processing compliant
- RoHS compliant



- Samples from Q2/2011
- Volume production from Q4/2011

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GiP & DC Booster Integration

- Embedded Thermoharvesting Power Module

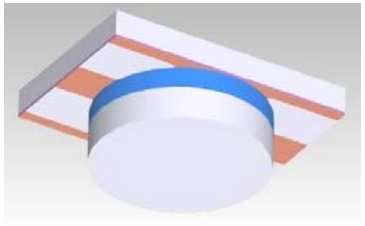
  TE-Power CORE

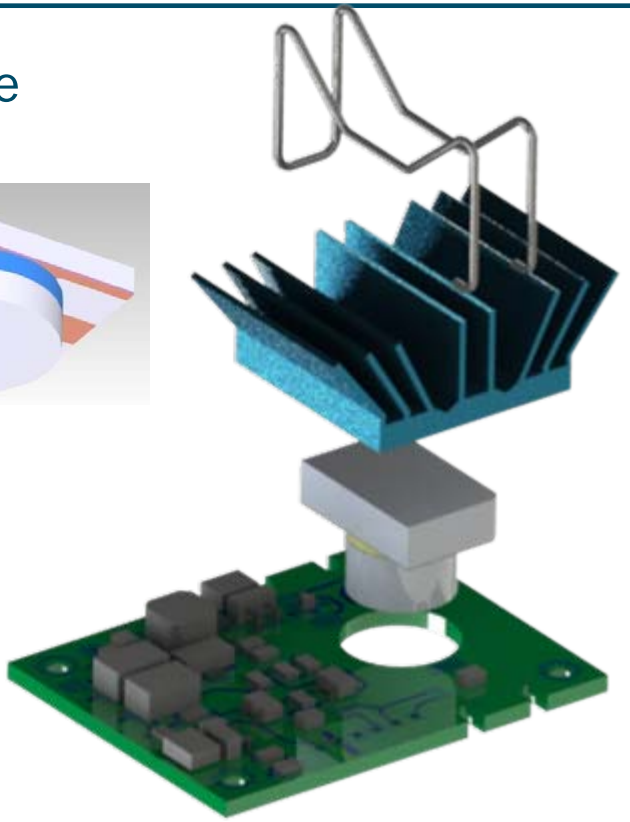
  - Fully regulated DC Output
    - 1.9 V, other voltages optional
  - Minimized thermal design effort
    - Force-fit heat source attachment
    - Flexible heat sink mount

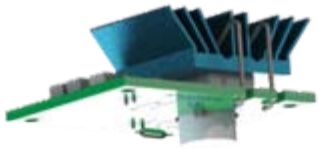
- Embed as module or integrate design IP

- Samples from Q2/2011

- Volume production from Q4/2011







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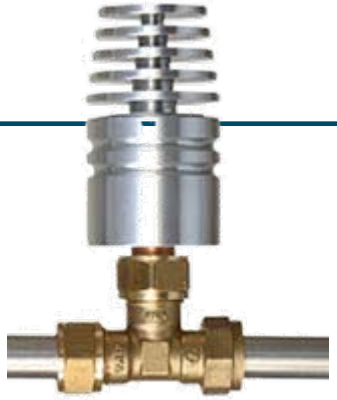
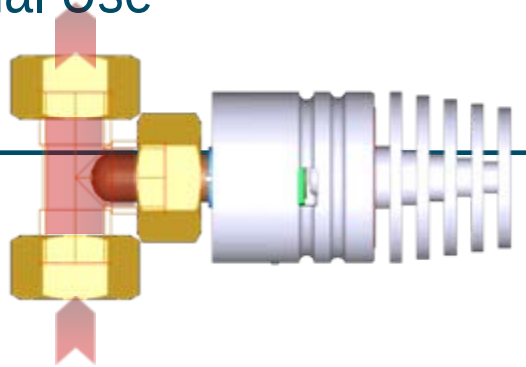
‚Historical' Thermoharvester Devices for Industrial Use

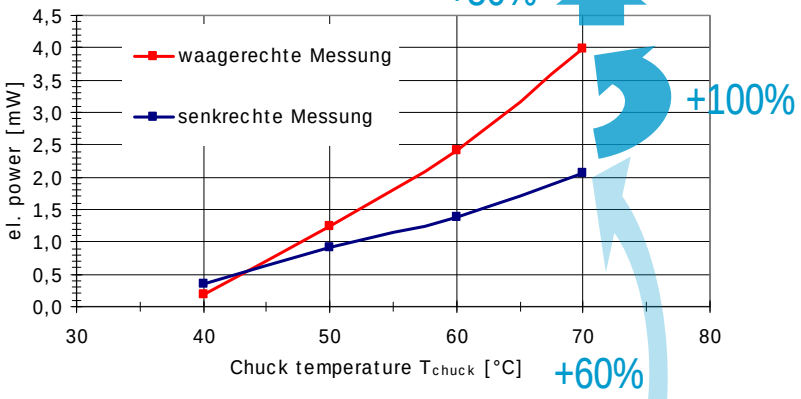
TE-Power BOLT (2008):

TE-Power PROBE (2009)





power at matched load; natural convection

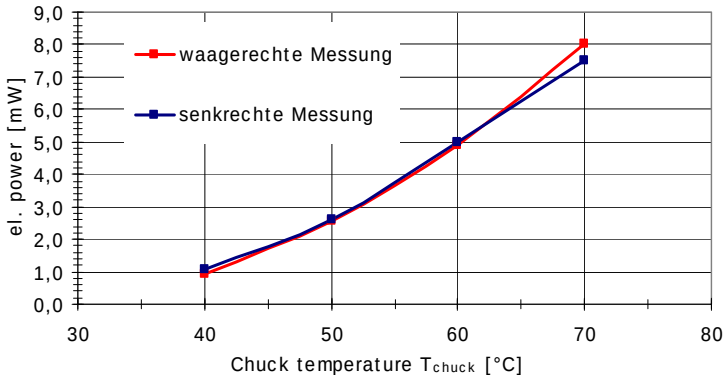


+50%

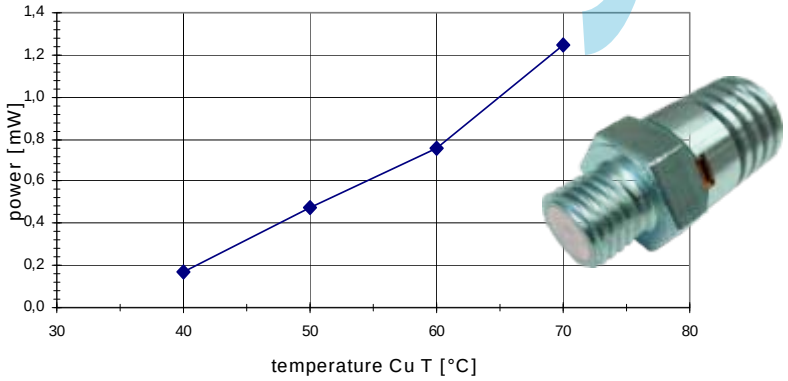
+100%

+60%

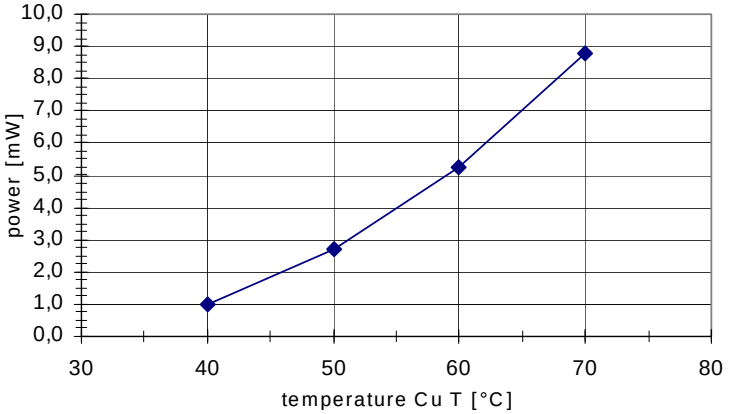
power at matched load; forced convection



power at load matching with natural convection

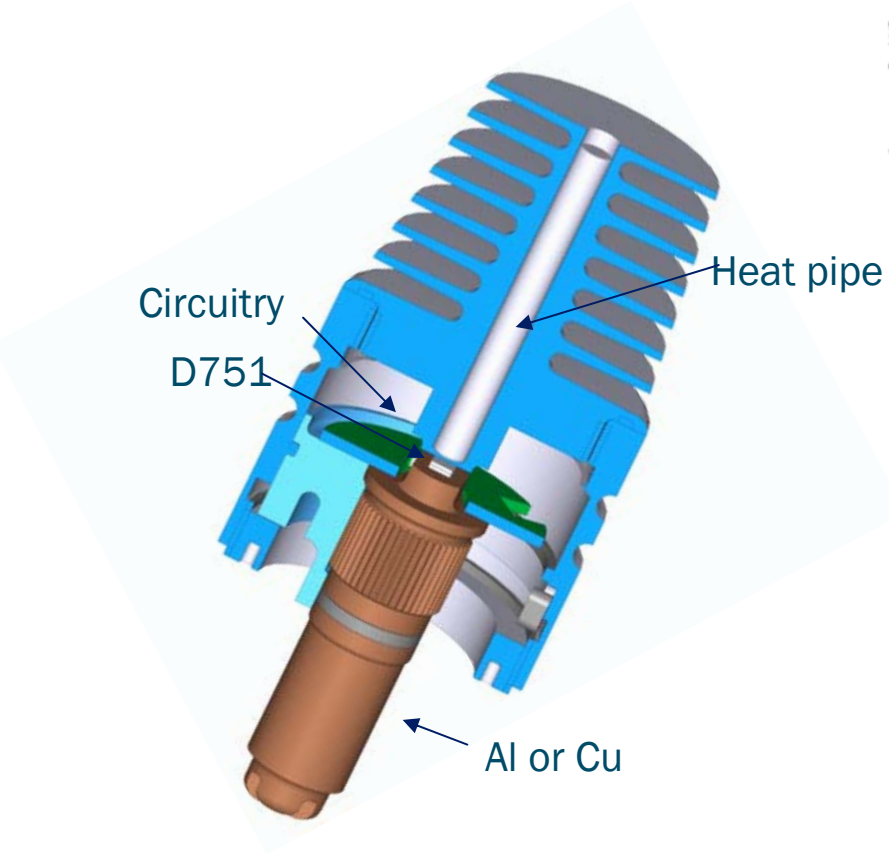


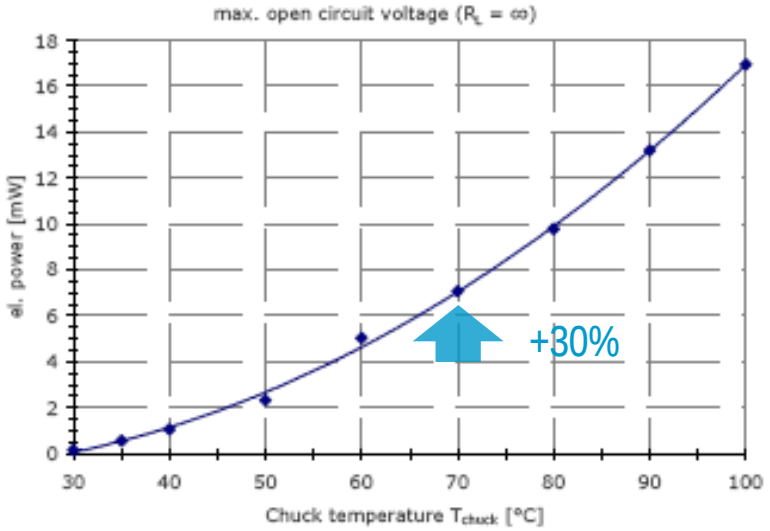
power at load matching with forced convection



TE-Power PROBE Re-Design

- 30% more output





Maximum output power (load matching $R_i = R_L$)
versus hot side temperature Tchuck @ Tambient about 25 °C

2nd Design Release

- Generator MPG-D751
- Hermetically sealed
- Improved mechanical stability
- Optimized heat sink
- Certification (CE, EX,...)

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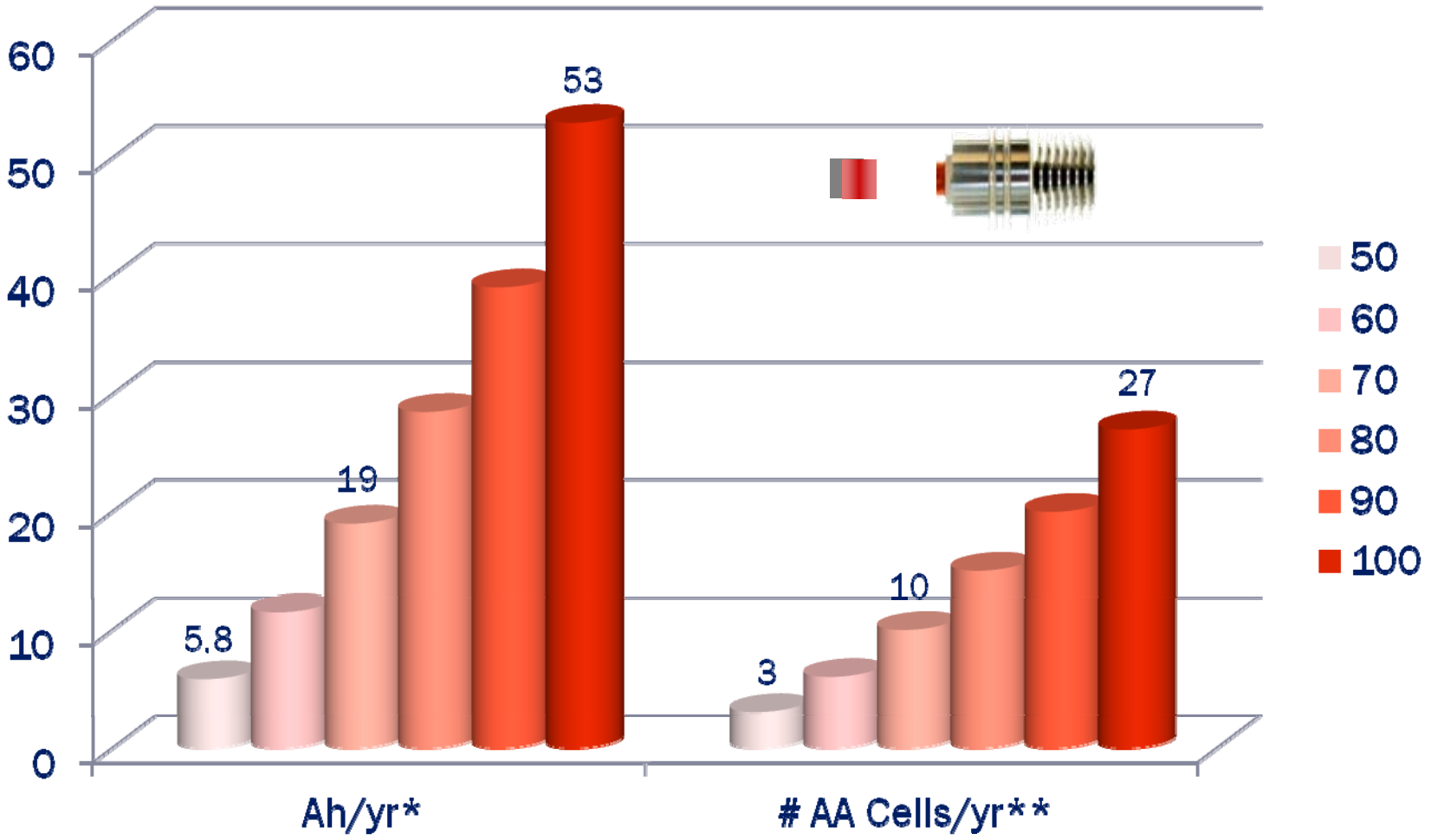
TE-Power PROBE @ 24/7 Constant Harvesting

Can Thermoharvesting Compete?



* System voltage: 3 Volt
** Cell capacity: 2,000 mAh

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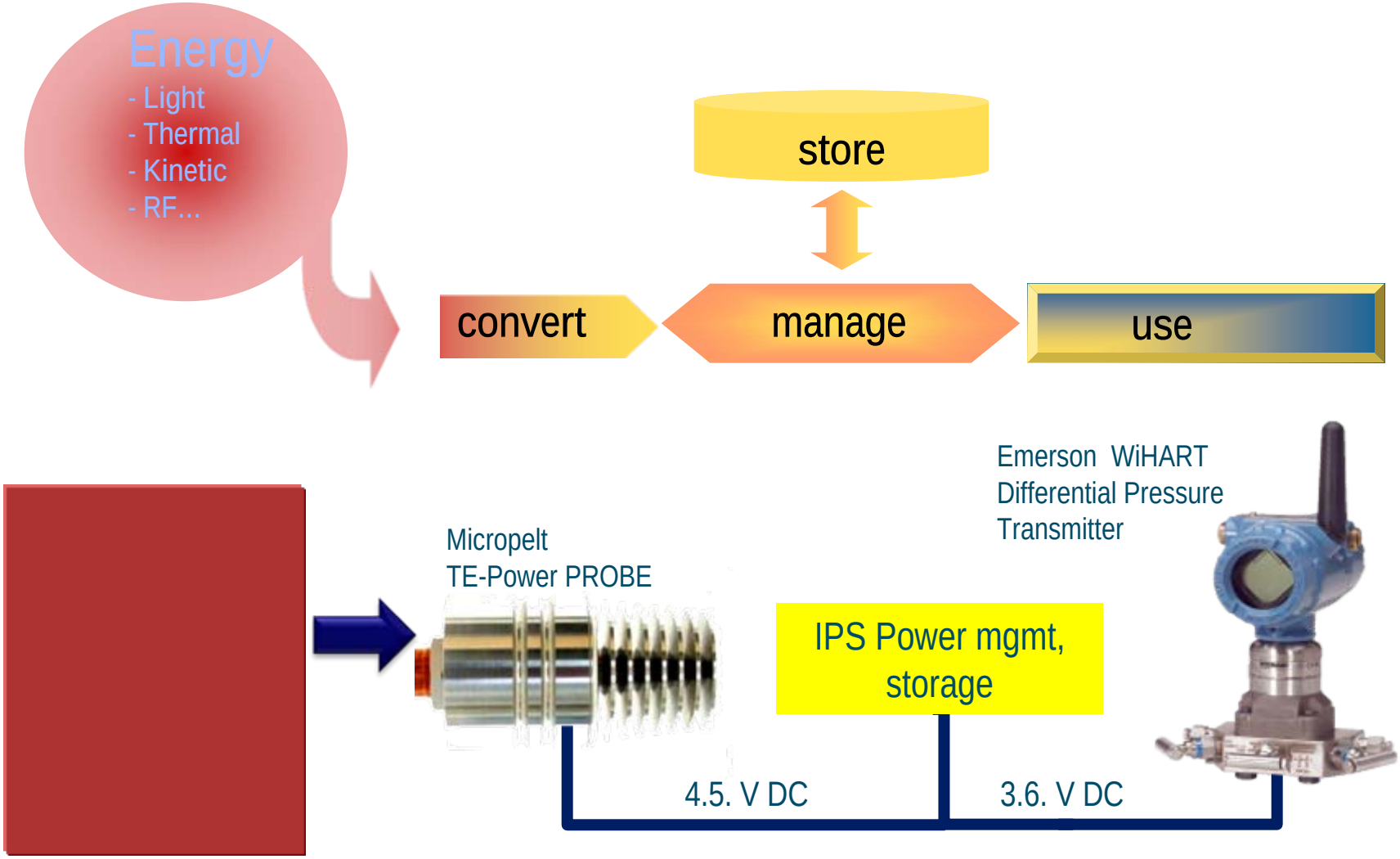
Proof of Concept

Shell Field Trial (Den Helder, The Netherlands)



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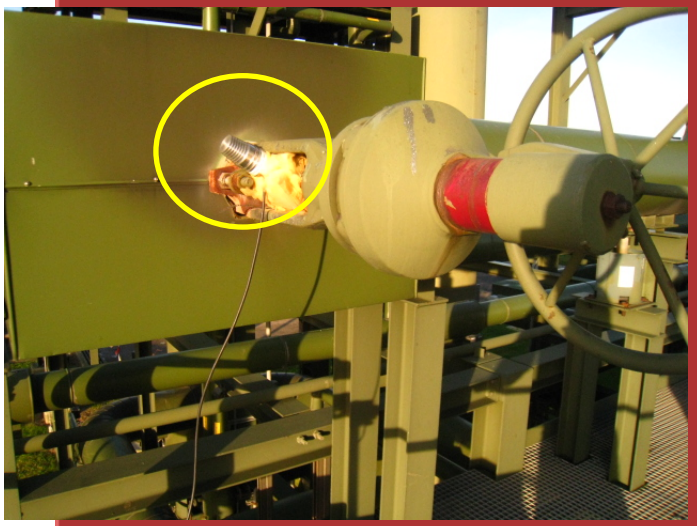
Utilizing Energy Harvesting To Power The Pressure Measurement

- Installation location identified with thermal camera
- Trial purpose:
  - Proof of concept
  - Integrate technologies
  - Identify field requirements
  - Project for university student's thesis



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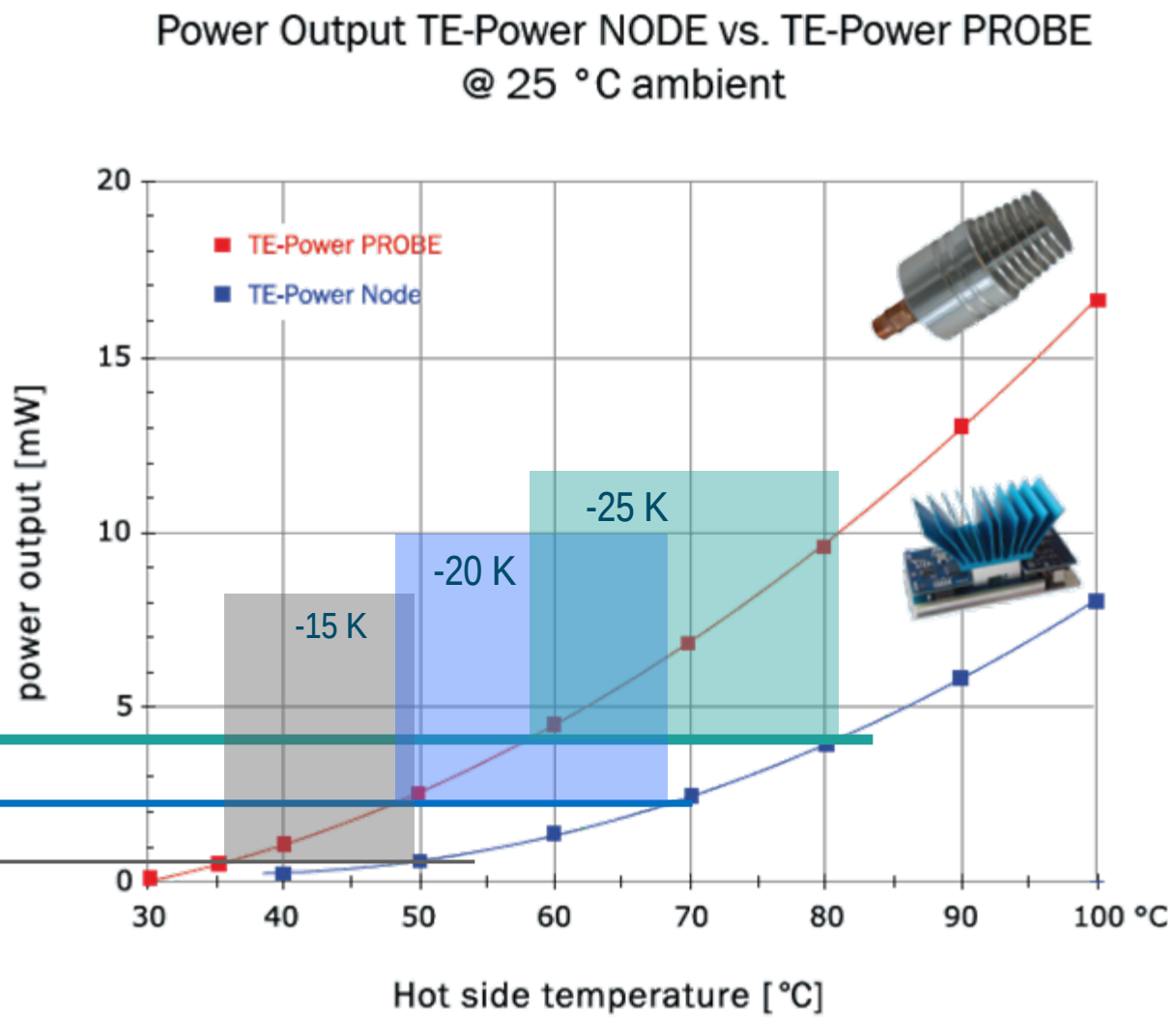
TE-Power NODE vs PROBE

Application scenarios @ different tasks & duty cycles

Available at Mouser.com

PEPPERL+FUCHS

EMERSON
Process Management



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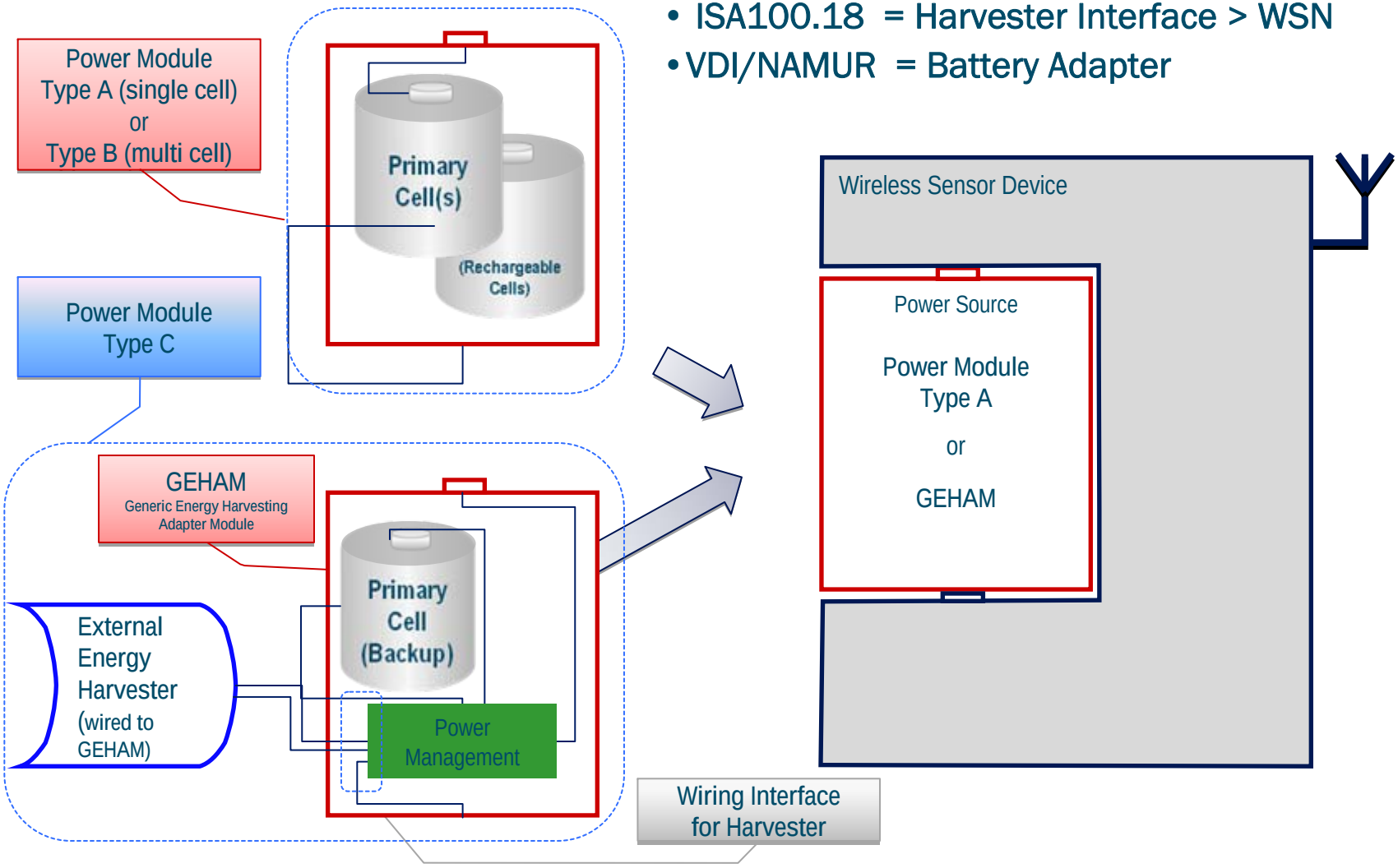
Standardizing Harvester Interfaces

- Committees:
  - ISA100.18 = Harvester Interface > WSN
  - VDI/NAMUR = Battery Adapter



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Award-Winning Integrated Transmitter

IDTechEx

Winner

Best Technology Development of RTLS/WSN

EUROPE 2010

ENERGY HARVESTING & STORAGE EUROPE

WIRELESS SENSOR NETWORKS & RTLS EUROPE
ACTIVE RFID APPLIED

- ABB Technology Demonstrator
  - *Self-powered Wireless*HART temperature transmitter
  - Fully integrated thermogenerators
  - Powered by Micropelt TEG & boost technology

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Thermo-Powered Applications

- Home & Buildings
  - Improve heating control
  - Optimize energy flow & consumption
  - Increase comfort & ‚design' flexibility
  - Reduce operating cost

- Process & Condition Monitoring
  - Reduce
    - Energy consumption
    - Materials utilization
    - Cost & risk
  - Improve (greatly) operational results

- ... Human ‚Condition Montoring'
  - Training & activities
  - Heath indicators
  - Assisted living

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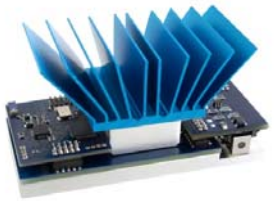
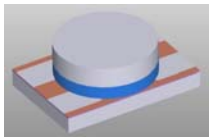
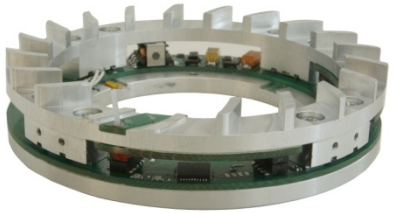
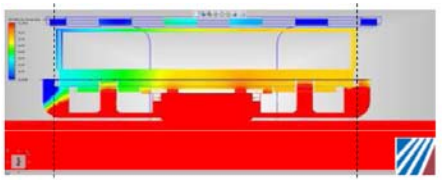
Summary

- Most of the desirable WSN will NEVER be deployed if battery-based
  - Energy harvesting is a key enabler for ‚unlimited sensing'
- Harvesting often outperforms batteries
  - No need to ‚save' energy for extended life
- Target applications in most technical environments
  - Except real-time control
- Thermoharvesting is easy to explore and quantify
  - Off-the-shelf solutions available
- NEW - Embedded harvesting devices and modules
- Emerging interface standards
- Custom designs for specific applications









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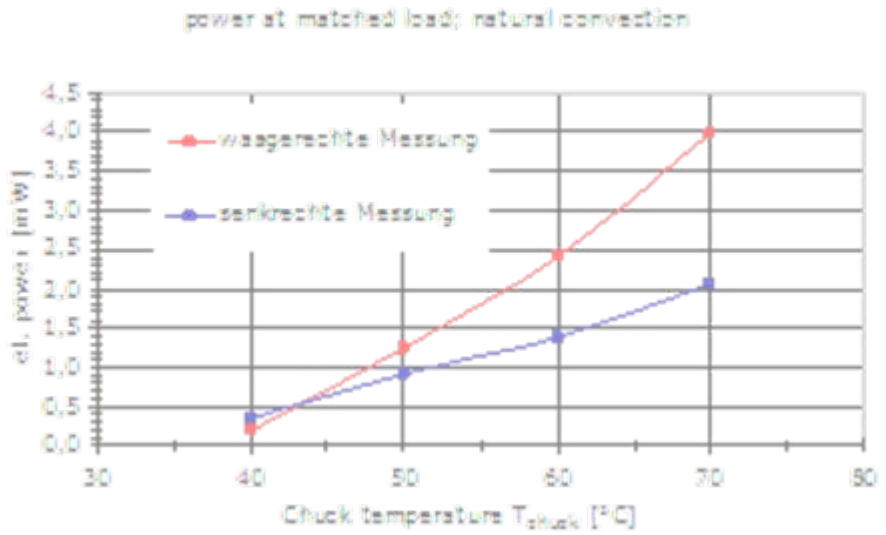
Power generation.

Thank you for your attention.



Your questions, please!

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