



# Energy Harvesting: Ready for real Applications?



PM°DM is:

- Part of the Japanese Minebea Group (56.000 employees worldwide)
- The biggest R&D center of Minebea
- Development center of BLDC Motors for:



Industrial



Automotive



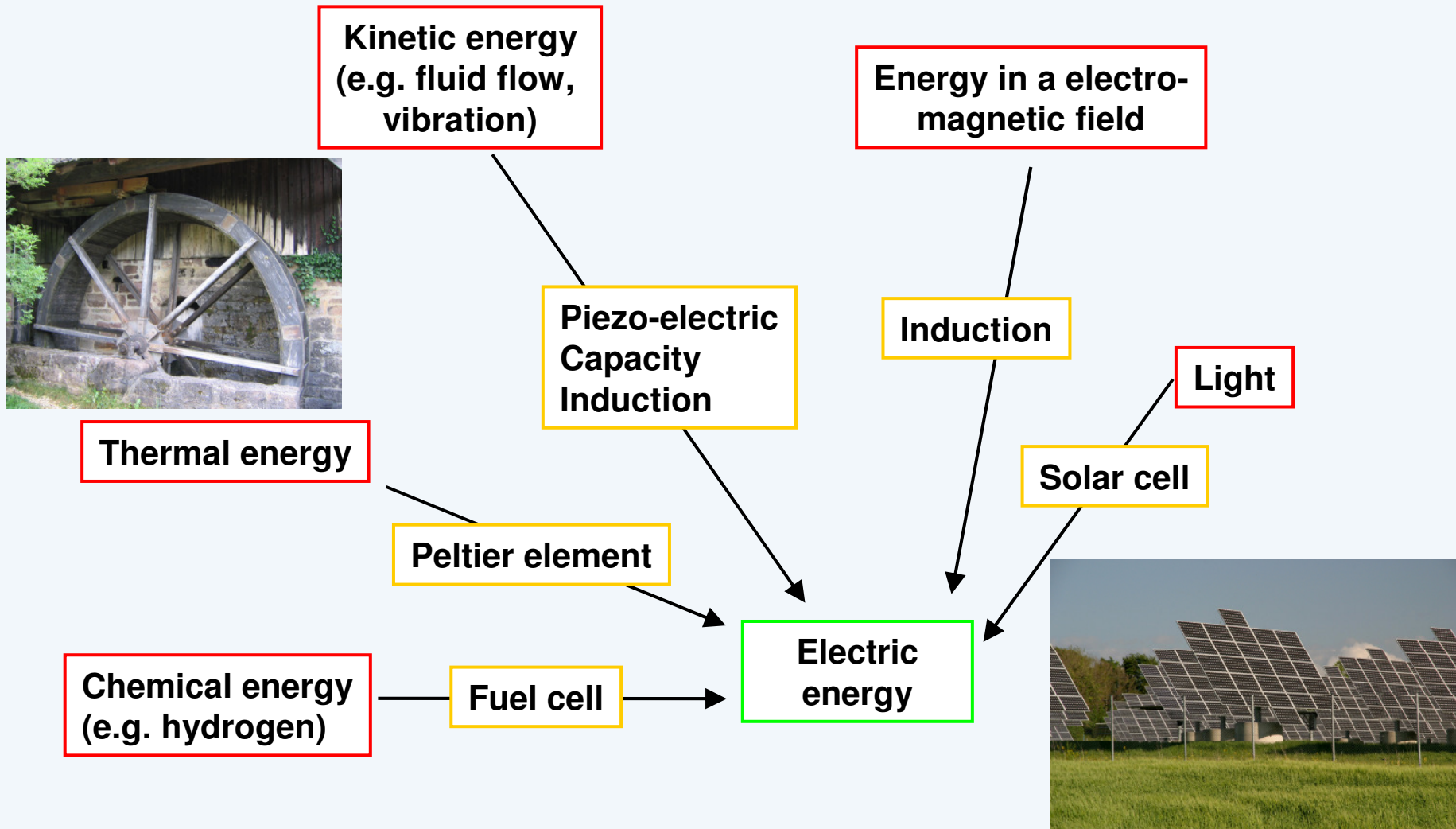
Air Mover (Computer) Hard Disk Drives



- you can find us:

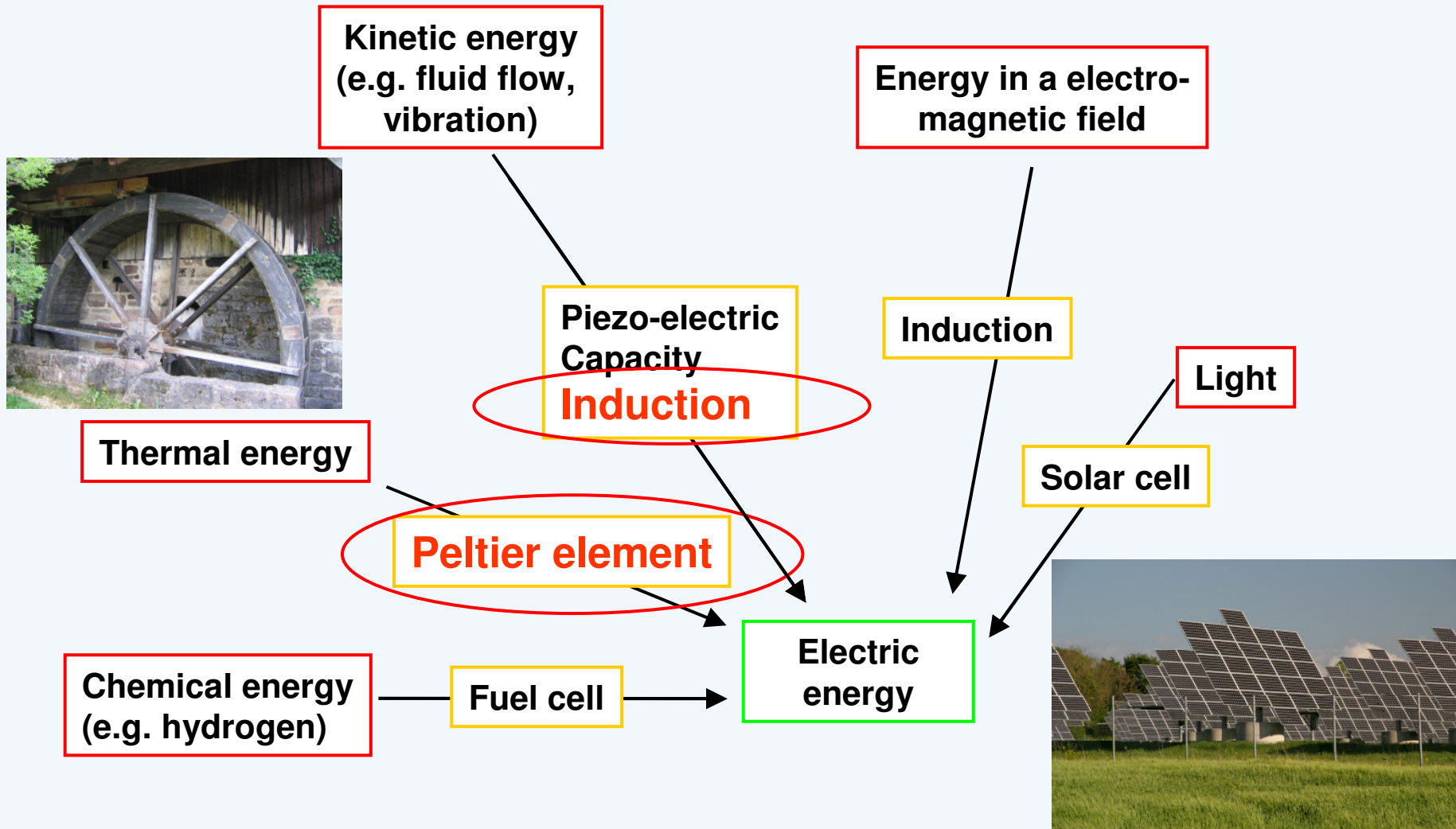
Precision Motors Deutsche Minebea GmbH  
Auf Herdenen 10  
78052 Villingen-Schwenningen  
[www.pmdm.de](http://www.pmdm.de)

# Examples of available Energy



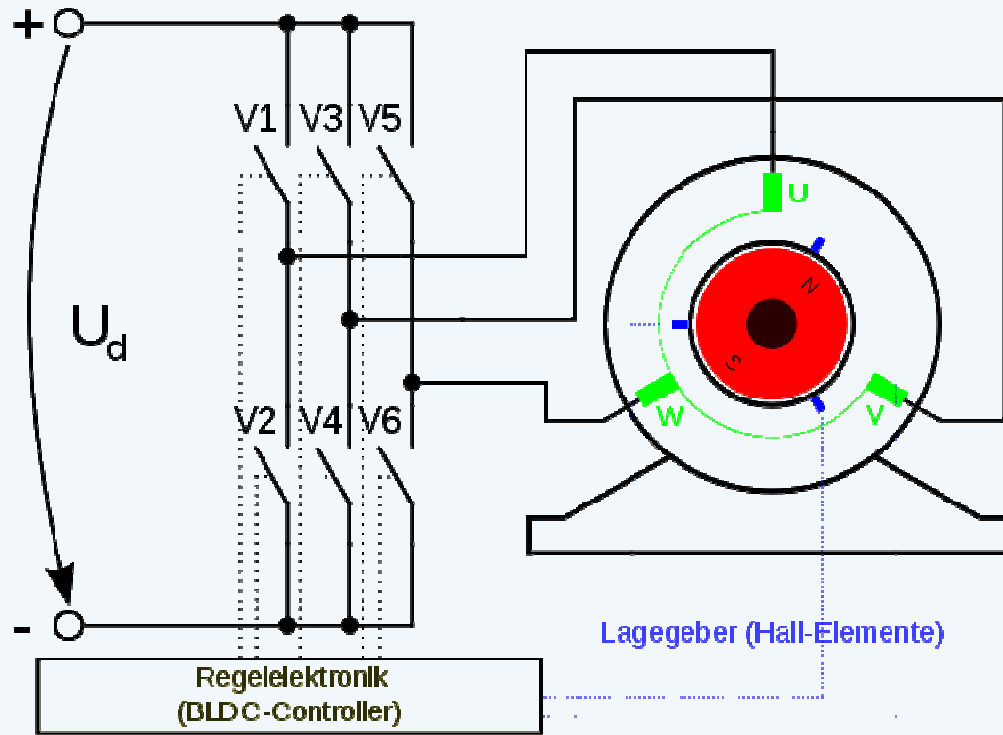
Freely adapted from: Prof. Woias – IMTEK Uni Freiburg

# Examples of available Energy

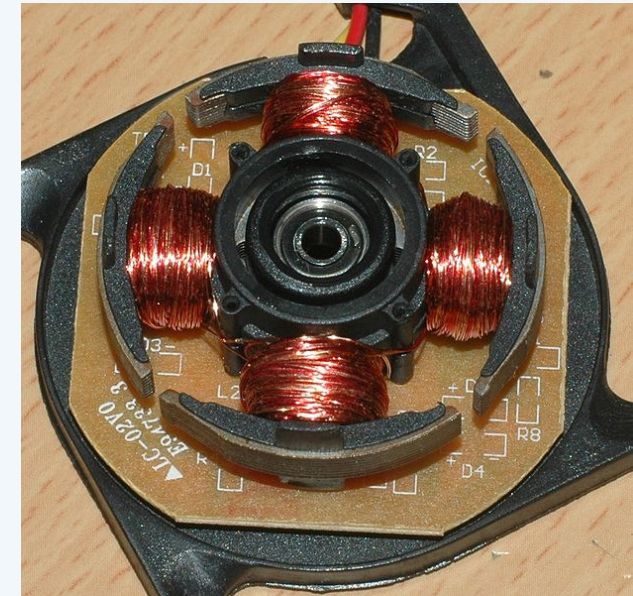


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## Principle of a (brushless) electric Motor



Source: Wikipedia



Reluctance Motor for Fan (Stator only)

Efficiency of Energy Conversion today: **Up to 95%**



Company Bosch (ca. 1930)



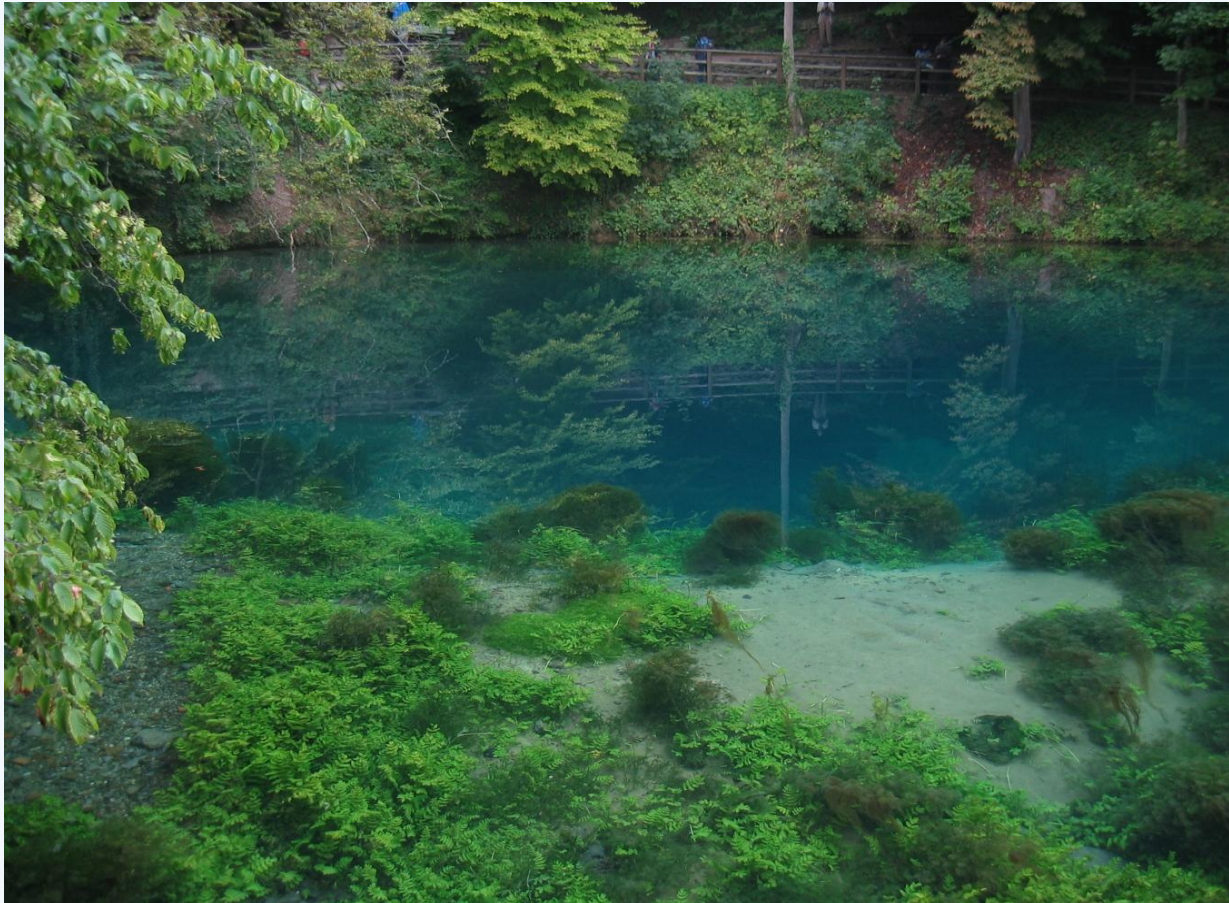
Source: Wikipedia

**Continuous rotating EM-Generators are very well understand and working since many decades with very high efficiency.**

**But the problem is:**



Where is the continuous rotation?

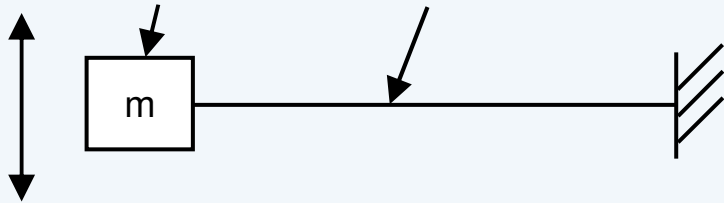


Blautopf in Blaubeuren (east of the Schwäbische Alb) Source: Wikipedia

**Continuous rotation is not a natural motion but everything is swinging.**

# Basics of Oscillators

Excitation Mass      Bending Spring      Fixed-point



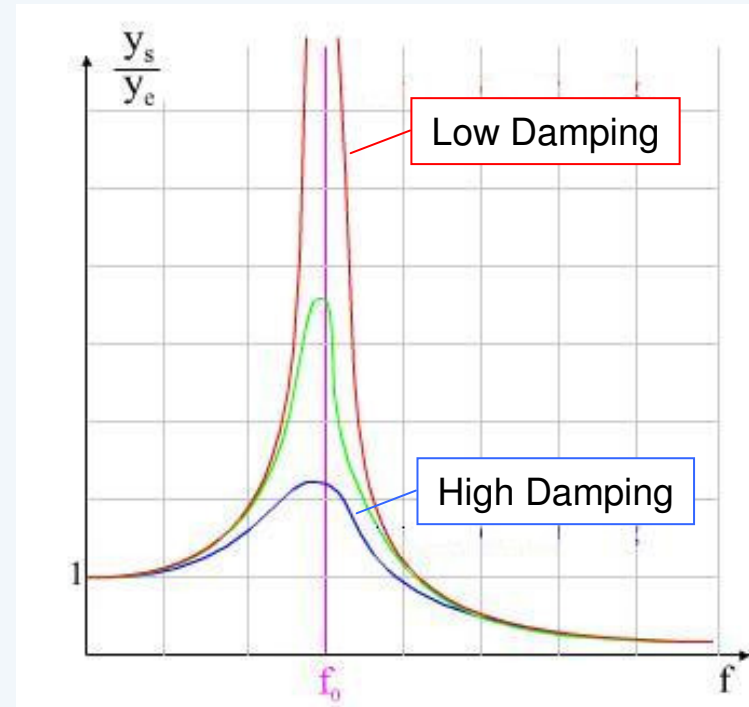
Acceleration Force      Spring Force

$$0 = m \cdot \ddot{x}(t) + d \cdot \dot{x}(t) + c \cdot x(t)$$

Damping Force

$$U_{ind} = \mu \cdot \frac{N^2}{l} \cdot A \cdot \frac{dB}{dt}$$

Amplitude vs. Frequency





Harvester for low vibration amplitudes  
and random vibrations



EM-1D-09

Harvester for shock events with push  
button

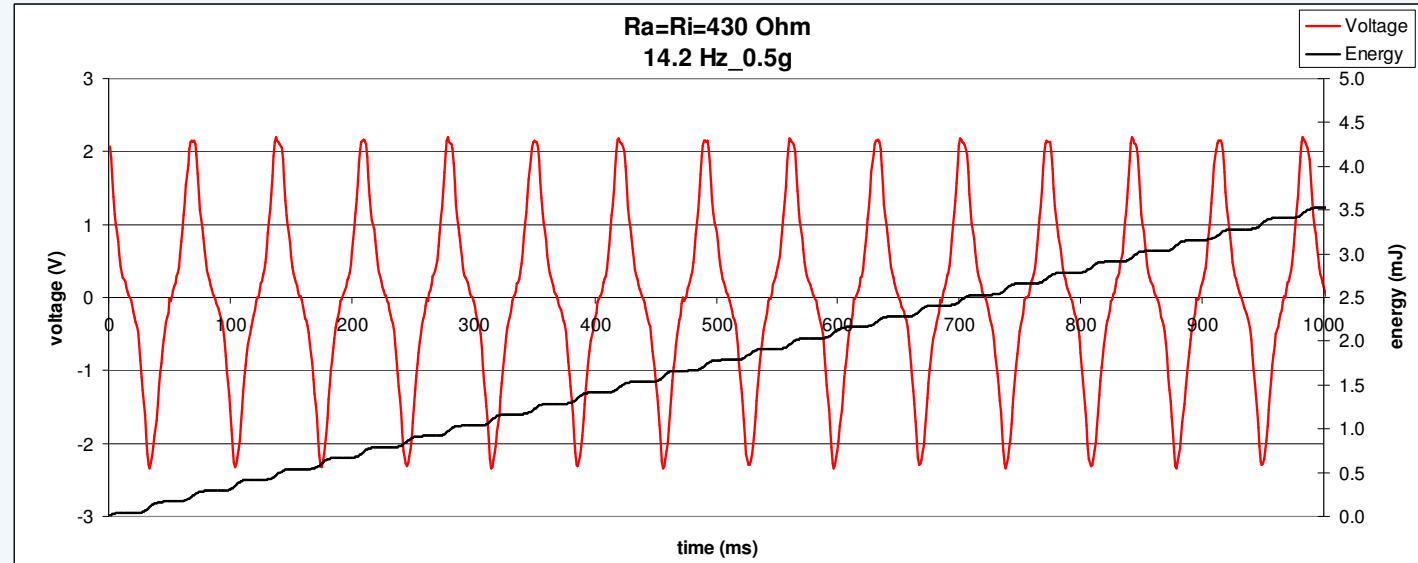


EM-1D-10

## Results EM-1D-09 Voltage and Energy

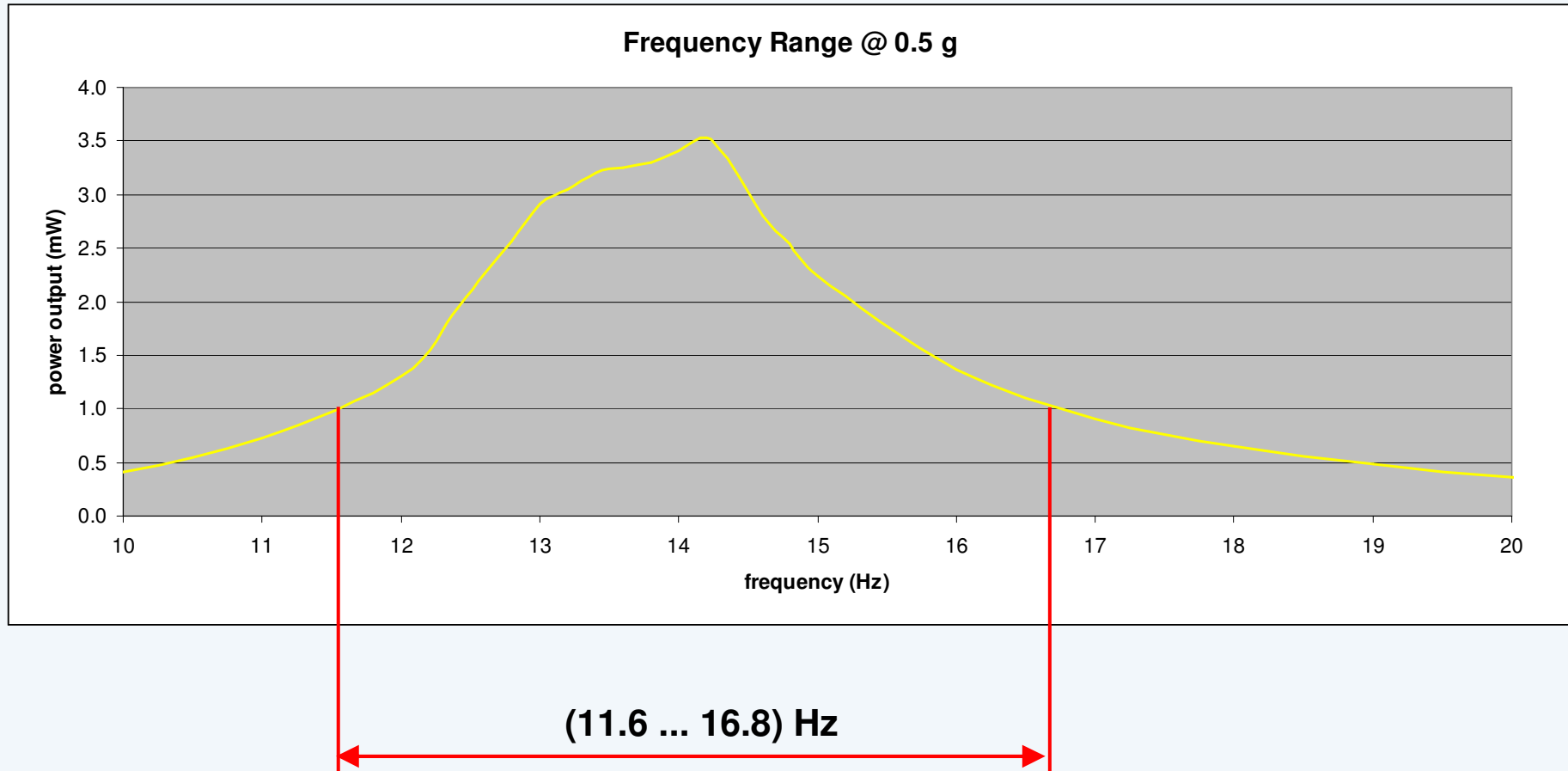


EM-1D-09



### Generator Data

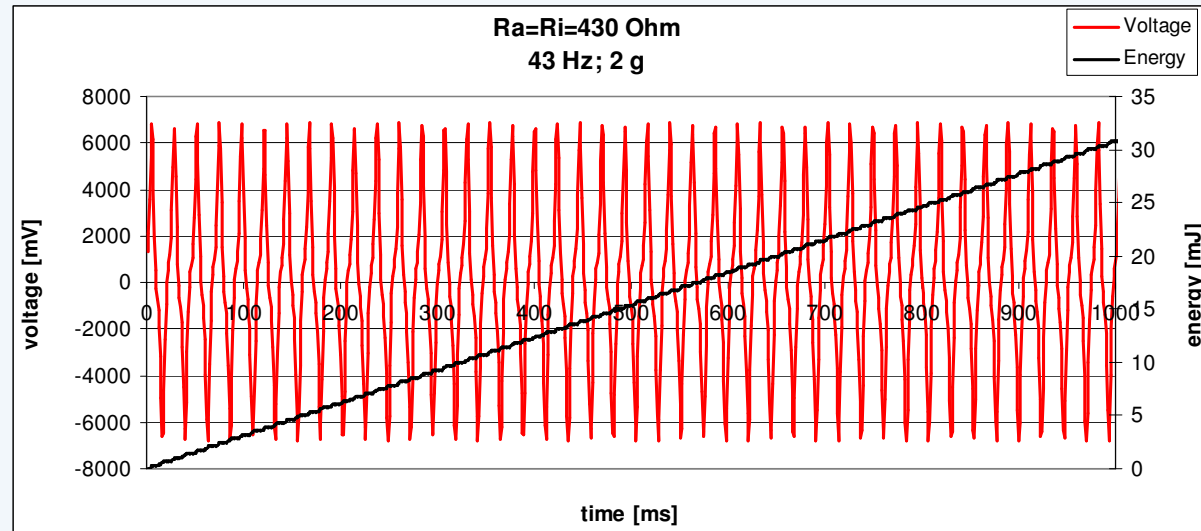
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm <sup>3</sup>
Mass	42	g
Inner Resistant	430	Ω
Resonant Frequency	14.2	Hz
Power Output (0.5g continuous)	3.6	mW
Power Density	0.11	mW/cm <sup>3</sup>
Specific Power	85.7	mW/kg
Frequency Range of 50% Power	12.4 - 16	Hz



## Results EM-1D-10 Voltage and Energy

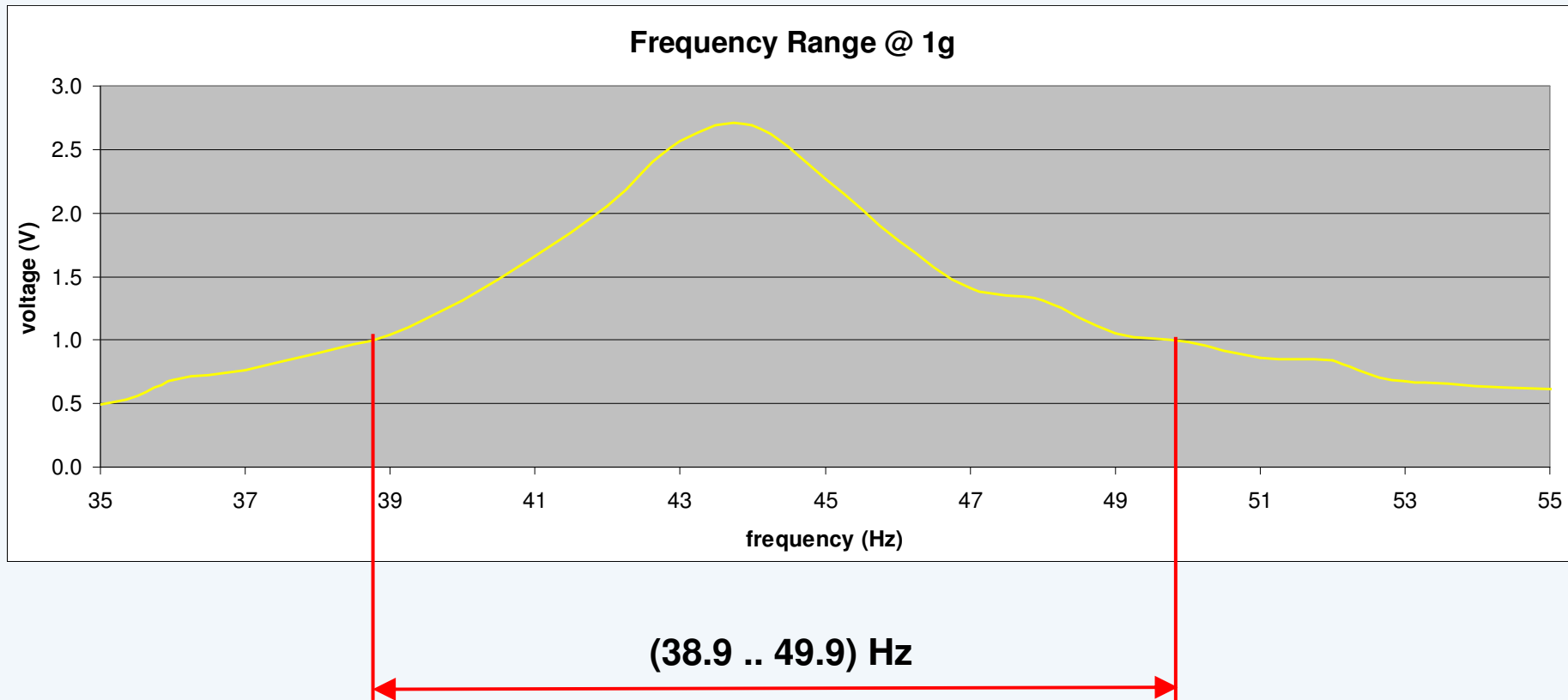


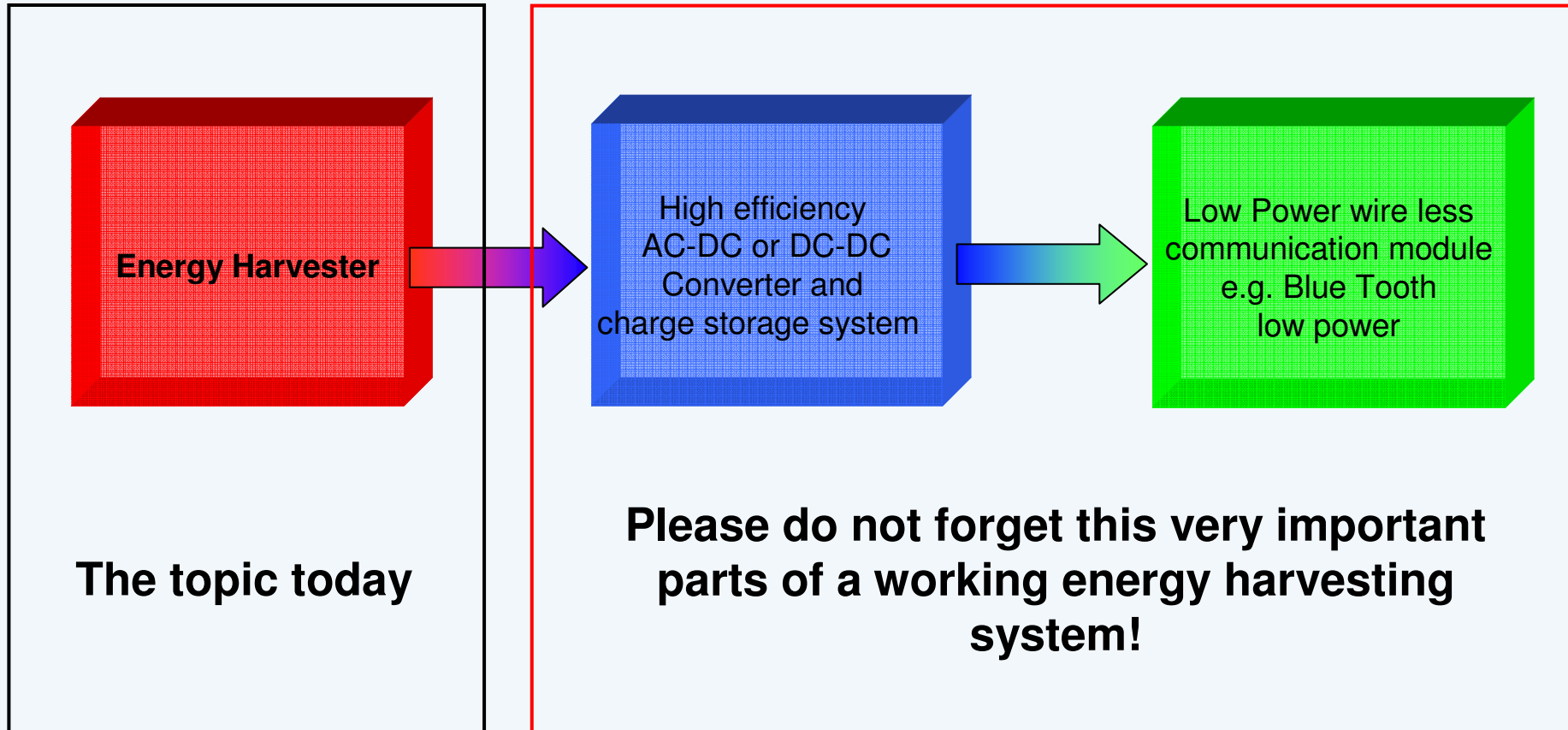
EM-1D-10



### Generator Data

Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm <sup>3</sup>
Mass	46.5	g
Inner Resistant	430	Ω
Resonant Frequency	43	Hz
Power Output (2g continuous)	30	mW
Power Density	0.96	mW/cm <sup>3</sup>
Specific Power	660	mW/kg
Energy Output (1x Push Button)	1.5	mJ







**PM DM**

Precision Motors Deutsche Minebea GmbH

 **Minebea**

**Energy Harvesting: Ready for real Applications?**

**We think: Yes**

**Thank you for your attention**