Applications

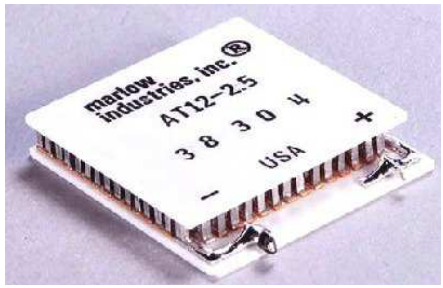
Advantages / drawbacks of thermoelectric converters

+

- Solid state unit, no moving parts,..
- Long lifetime with minimal maintenance
- Compact, functionality independent of the position, easy adaptable,..
- Simple instalation
- No greenhouse gases,..
- In case of temperature management precise temperature control
- Possible to be used in reversible mode
- Recuperation of waste heat

-

- Low performance
- Price

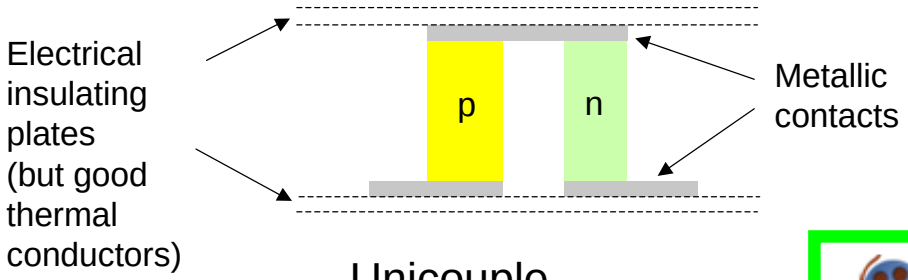


Key element- TE MODULE

Module

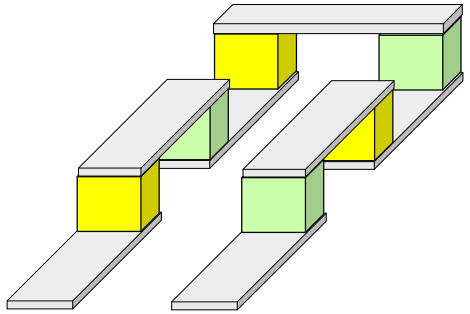
TE modules: technological aspects

Materials: n and p types with high ZT and similar properties
Aditional conditions for applicable materials: chemical stability, temperature stability, good thermal stability, mechanical resistance, acceptable price, not complicated synthesis, resistivity to thermal schock,…
Assembling : targeting of metallic material suitable for contacts (both electric and thermic – low resistance, compatible thermal dilatation coefficient, analysis and control of interfaces ➔ i.e. to lower the contact electrical resistance and increse the thermal resistance,….



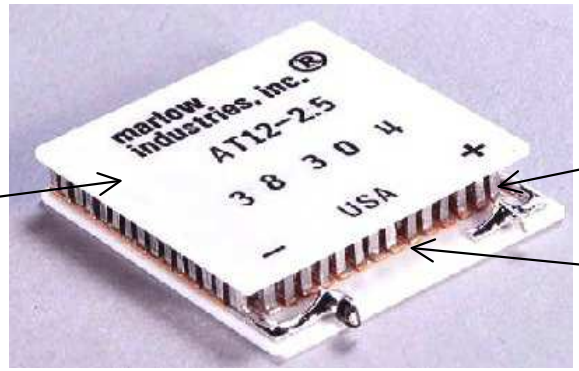
Unicouple

Assembling



3-leg couple,..

Commercial module



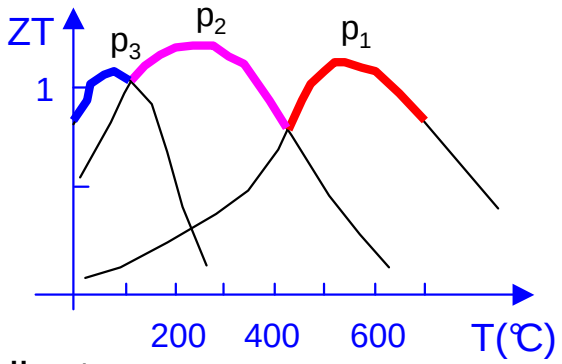
Alumina

Leg n or p on a base of Bi_2Te_3

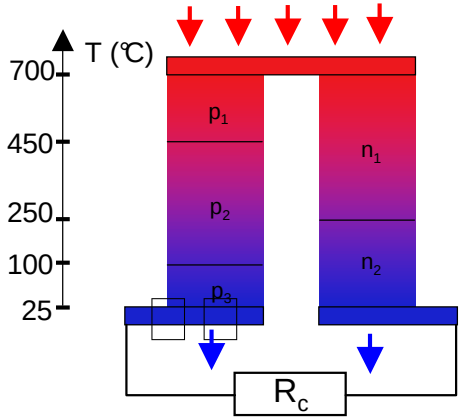
Copper+brazing,. PbSn ou BiSn

Module

TE modules: technological aspects

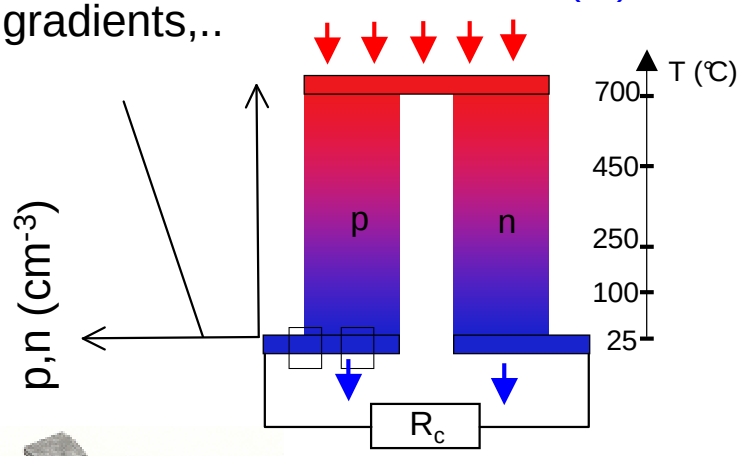


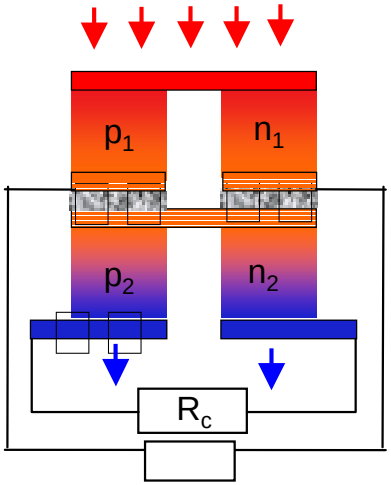
✓ segmented materials



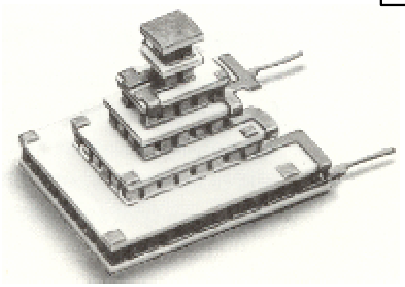
✓ Materials with concentrations gradients,..

Possible architecture of the module with high temperature gradient (due topeaking ZT…) :





✓ Cascaded module…



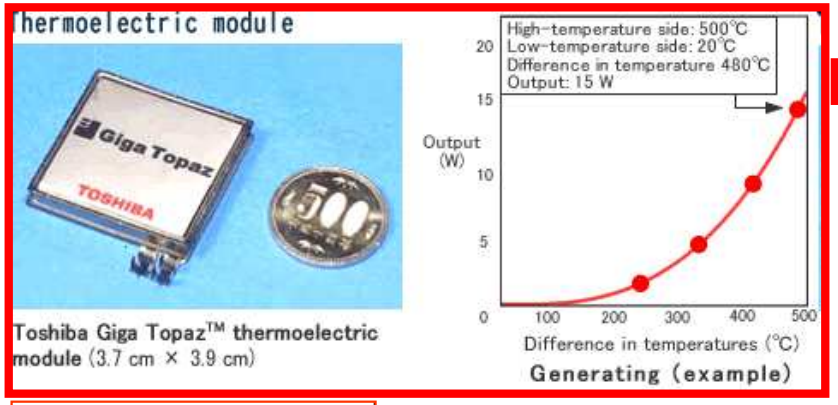
Heat pipes (dimensionality, thermal resistance,…), electronics behind,…

➡ Many interfaces : $\Delta T_{real} < \Delta T_{material}$(cooling)

$\Delta T_{real} > \Delta T_{material}$ (generation)

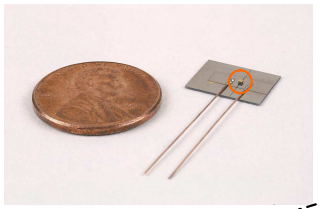
➡ Lowered performance

Modules

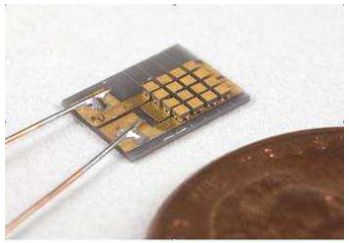


TOSHIBA
Leading Innovation

1 p-n couple
P ~ 0.055 W

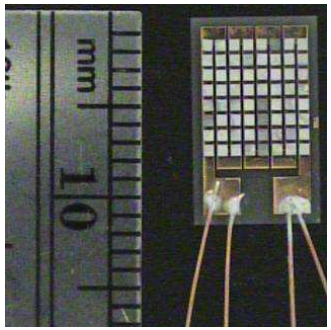


4x4 module
P ~ 1 W

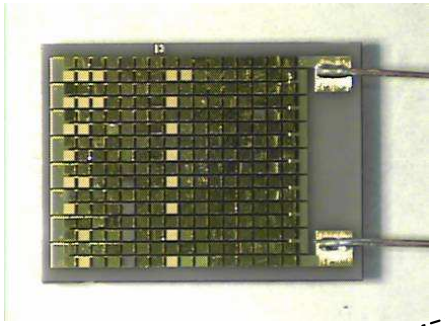


6x6 module
P ~ 2.1 W

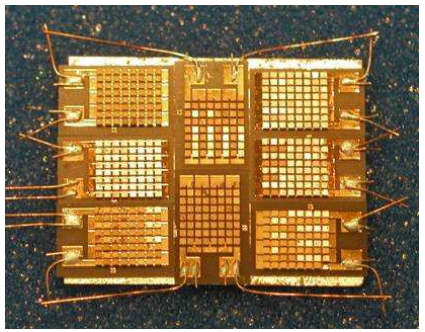
8x8 module
P ~ 3.4 W



16x16module
P ~ 10W



Multi-Module-Array
P ~ 14.6 W



Comparison of Newly designed laboratory modules with Commercial ones

	Units	RTI Bi_2Te_3-SL Module	Toshiba Giga Topaz™ module	Modules currently on the market		
		State-of-the-art	Giga Topaz™	Compact type	Midsize type	Large type
Temperature on high-temperature side	[℃]	157	500	230	230	230
Temperature on low-temperature side	[℃]	57	20	30	30	30
Voltage	[V]	11.2	3.6	3.3	1.7	[3.8]
Current	[A]	1.3	4.2	0.8	8	5
Output	[W]	14.6	15.0	2.5	14.0	19.0
Width × height	[cm]	2.3 x 2.0	3.7 x 3.9	2.9 x 2.9	6.3 x 6.3	7.5 x 7.5
Weight	[gm]	2.5*	40	14	82	115
Output per unit of surface area	[W / cm^2]	3.2	1.04	0.30	0.36	0.34
Output per unit of weight	[W / g]	5.8	0.38	0.18	0.17	0.17

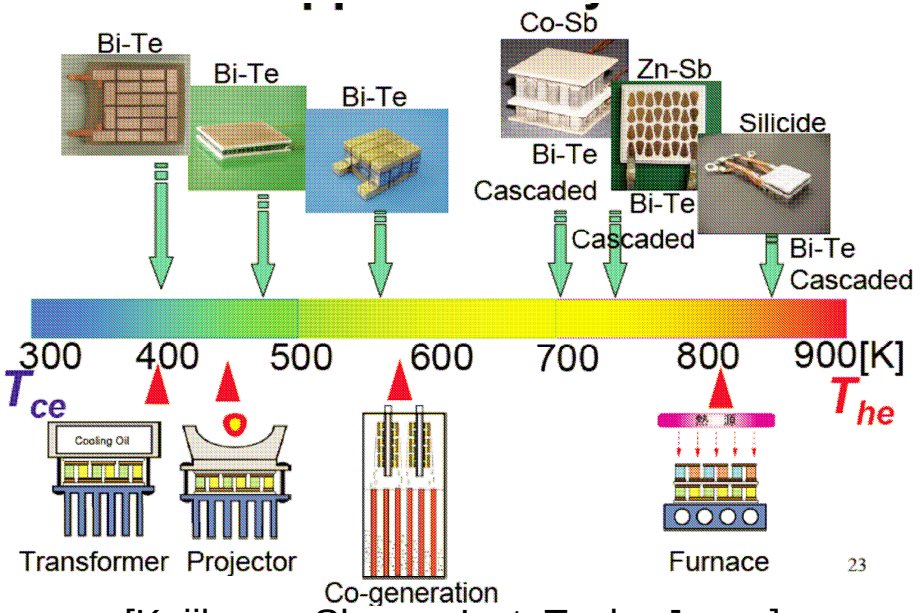
Ref: http://kagakukan.toshiba.co.jp/en/06energy/newtech141.html

*** Includes heat-sink carrier and all wire harness**

Japanese Programs- capturing high temperature waste heat

NEDO – New Energy and Industrial Technology Development Organization

- US$24M over 5 years
  - Transportation
  - Co-Generation
  - Industrial waste heat
- Goal:
  - Near term: practical demo
  - Advanced: 15%
- Completed March, 2007
  - Possible follow-on 2009
  - Partners may pursue commercialization

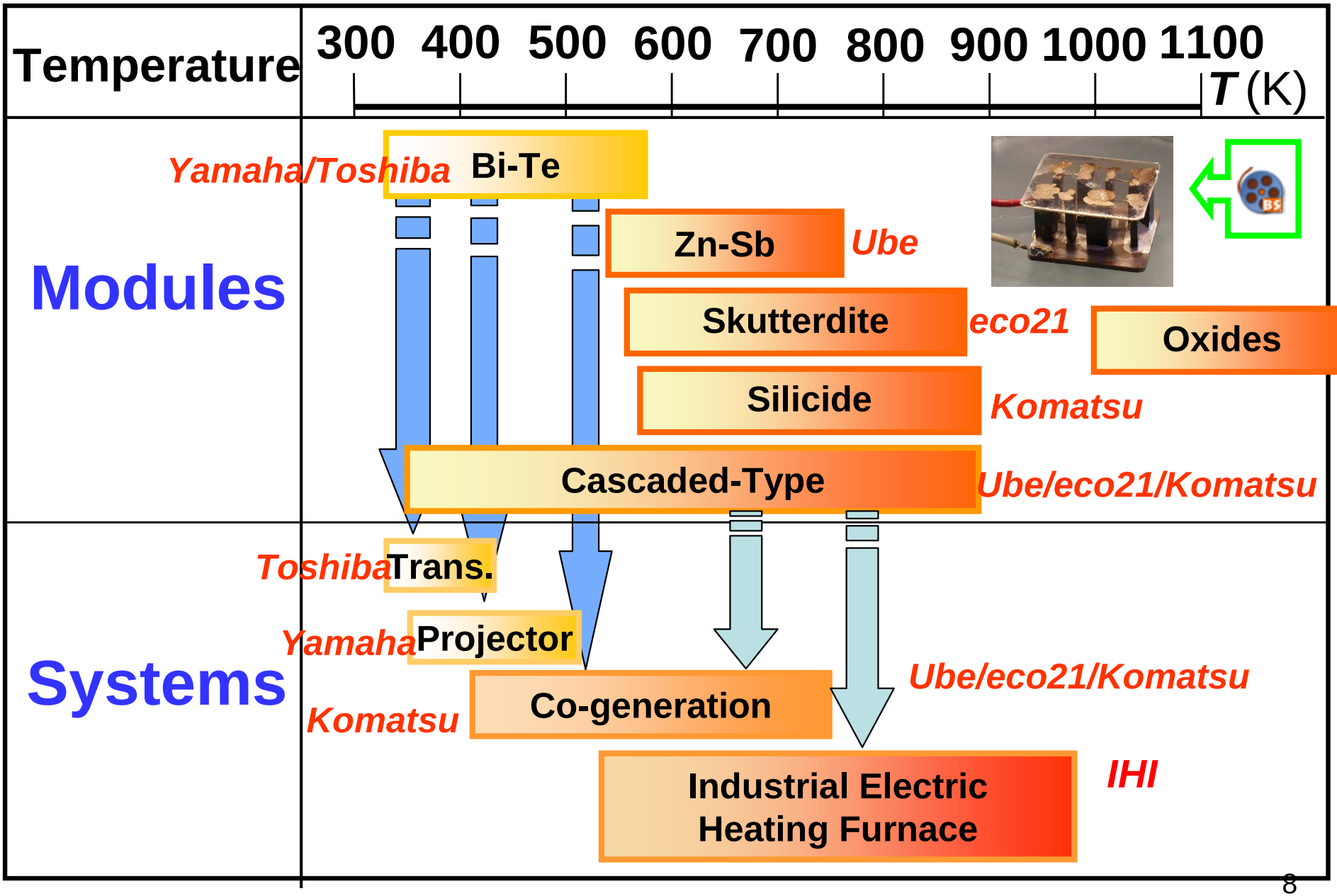


[Kajikawa, Shonan Inst. Tech., Japan]

OTEC – Ocean Thermal Energy Conversion (1980-2)
Test Plant – 500 TEG modules [Uemura, ITTJ]

Temperature Range of Modules & Application Systems

•Thermoelectric Programs in Japan:
•NEDO Prof. Kajikawa, Shonan University

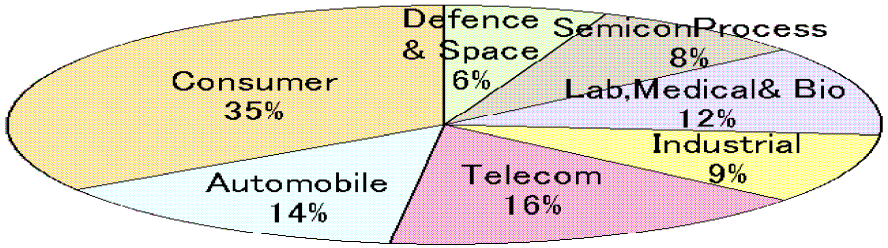


Financial considerations

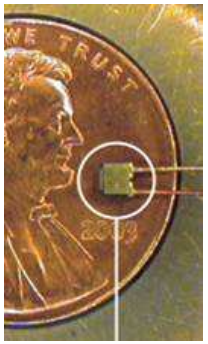
- Tiny world market for TE power generation
  - US $ 25-50M/yr (full systems)
  - [Global Thermoelectric]
- World market for cooling modules
  - US $ 200-250M/yr (modules)
- New engineering beginning to appear in marketplace
  - Amerigon (car seat cooler/heater)
  - Micropelt (miniature devices)
- Recent materials R&D (ZT) has yet to reach the marketplace
  - A few are close, for cooling
  - Nextreme (thin film, based on high ZT)
  - GMZ Energy (2008, nano/bulk materials)

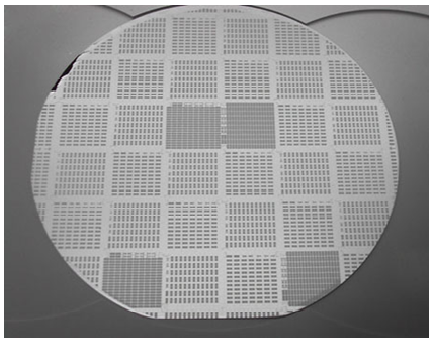
TE business today is mainly cooling

500 W TEG, natural gas pipeline, Peru
[LeSage, Global Thermoelectric]



Market Distribution for TE Cooling Modules.
[Komatsu-2007]





Nextreme (left) thin-film TE cooler and MicroPelt (right)
4” Bi_2Te_3 thin-film TE wafer.

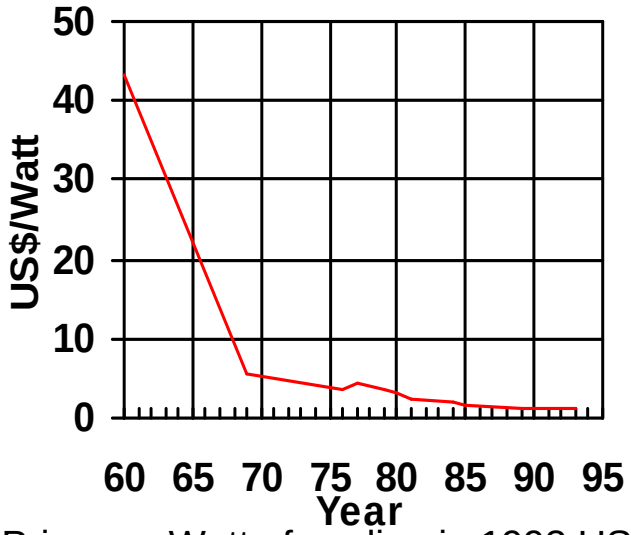
Market development -cooling

Investments In Thermoelectric Companies

Year	Company	Investor	Investment
2008	GMZ Energy	Kleiner-Perkins	N/A
2006	Micropelt	Fraunhofer/Infinion	N/A
2005	Nord	FerroTec	N/A
2005	Melcor	Laird	$20M
2005	Nextreme	RTI/Startup	$8M
2004	Marlow	II-VI Inc.	$31M
2003	Nanocoolers	Startup (folded 2008)	$8.5M
2003	Teledyne (Telan)	FerroTec	N/A
1998	Amerigon	Internal	N/A
1992	Melcor	Fedders	$14.9M

*N/A = Not Available, Blue = New, higher ZT technologies

High(er) ZT materials not yet commercial

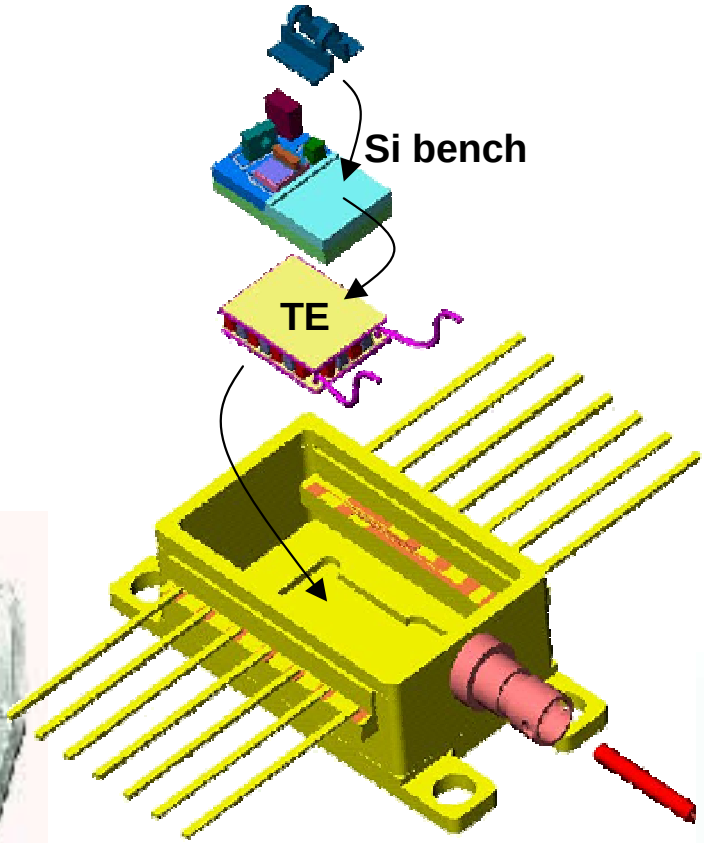


Price per Watt of cooling in 1993 US$
[Buist-1993]

- Manufacturers in China and Former Soviet Union have emerged as low cost suppliers
  - China: Fuxin Electronics, Hui Mao, HiCool, Hangzhou Jianhua Semiconductor Cooler, Hebei IT Shanghai, Taicang TE Cooler, and Taihuaxing Trading/Thermonamic Electronics.
  - Fuxin reported sales US$50M.
  - Former Soviet Union: Thermion, Altec, Kryotherm, Nord, Osterm, RIF Corp., RMT, Thermix, and ADV-Engineering.

Thermoelectric cooling

Water/Beer Cooler



Laser/OE Cooling

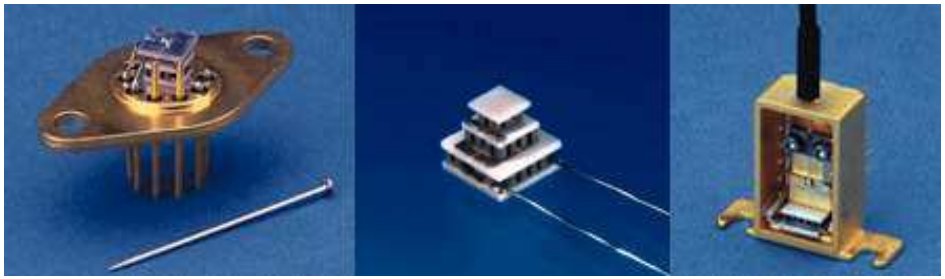
Cryogenic IR Night Vision

Cooled
Car Seat

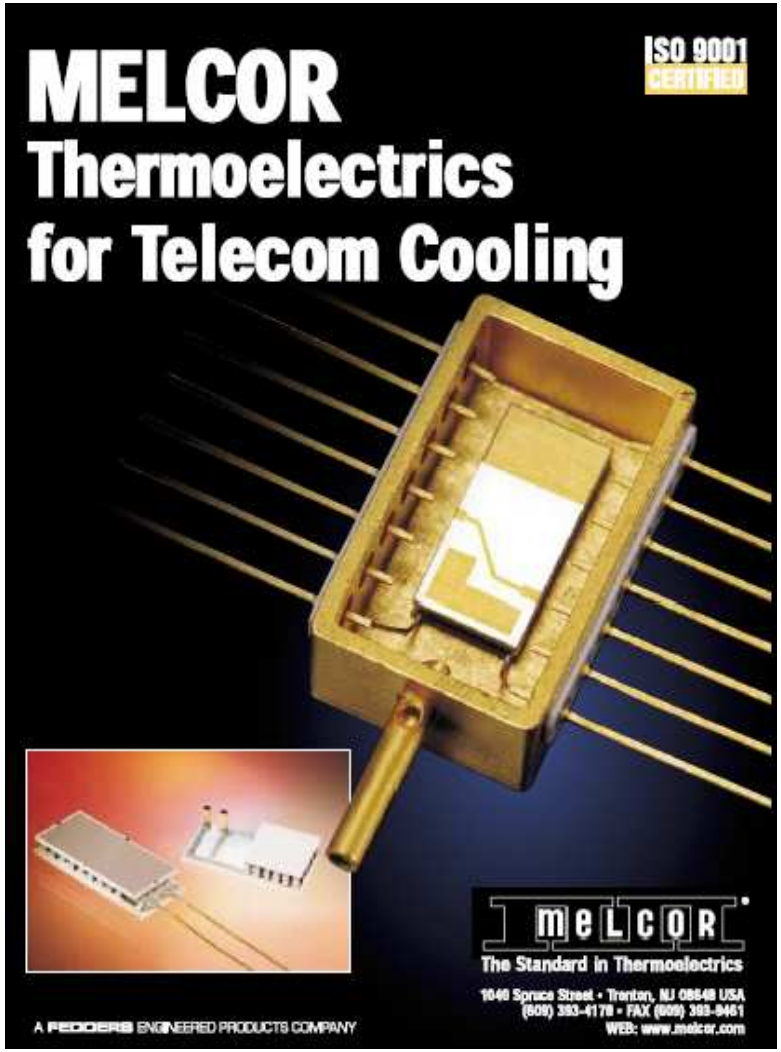
Electronic Cooling

Thermoelectric cooling for Telecom

- Melcor, Marlow and many other TE manufacturers provide coolers specifically designed for Telecom laser-cooling applications



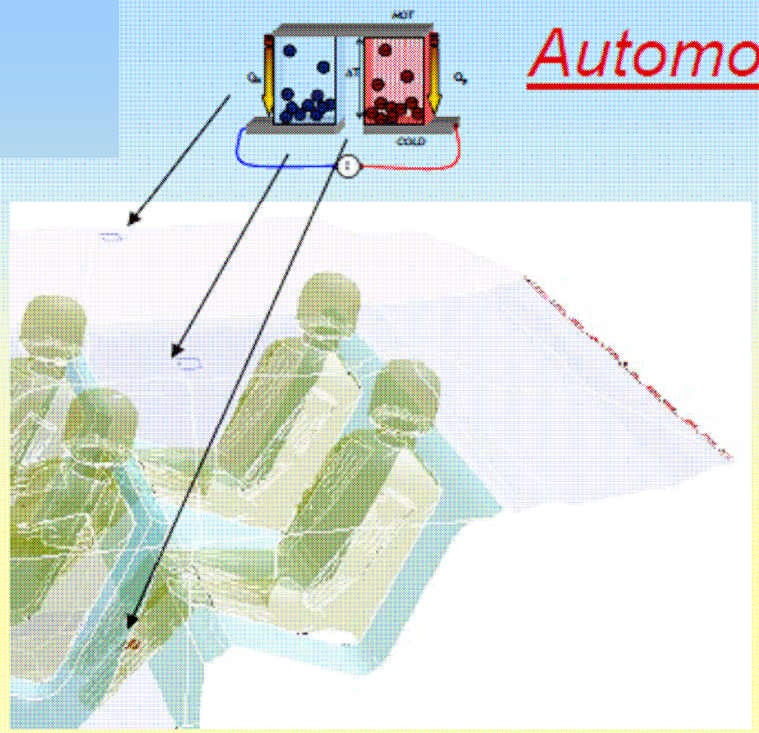
From Melcor, http://www.melcor.com



Higher ZT = better, cheaper

Thermoelectric cooling for automotive applications- air condition,…

Automotive thermoelectric HVAC

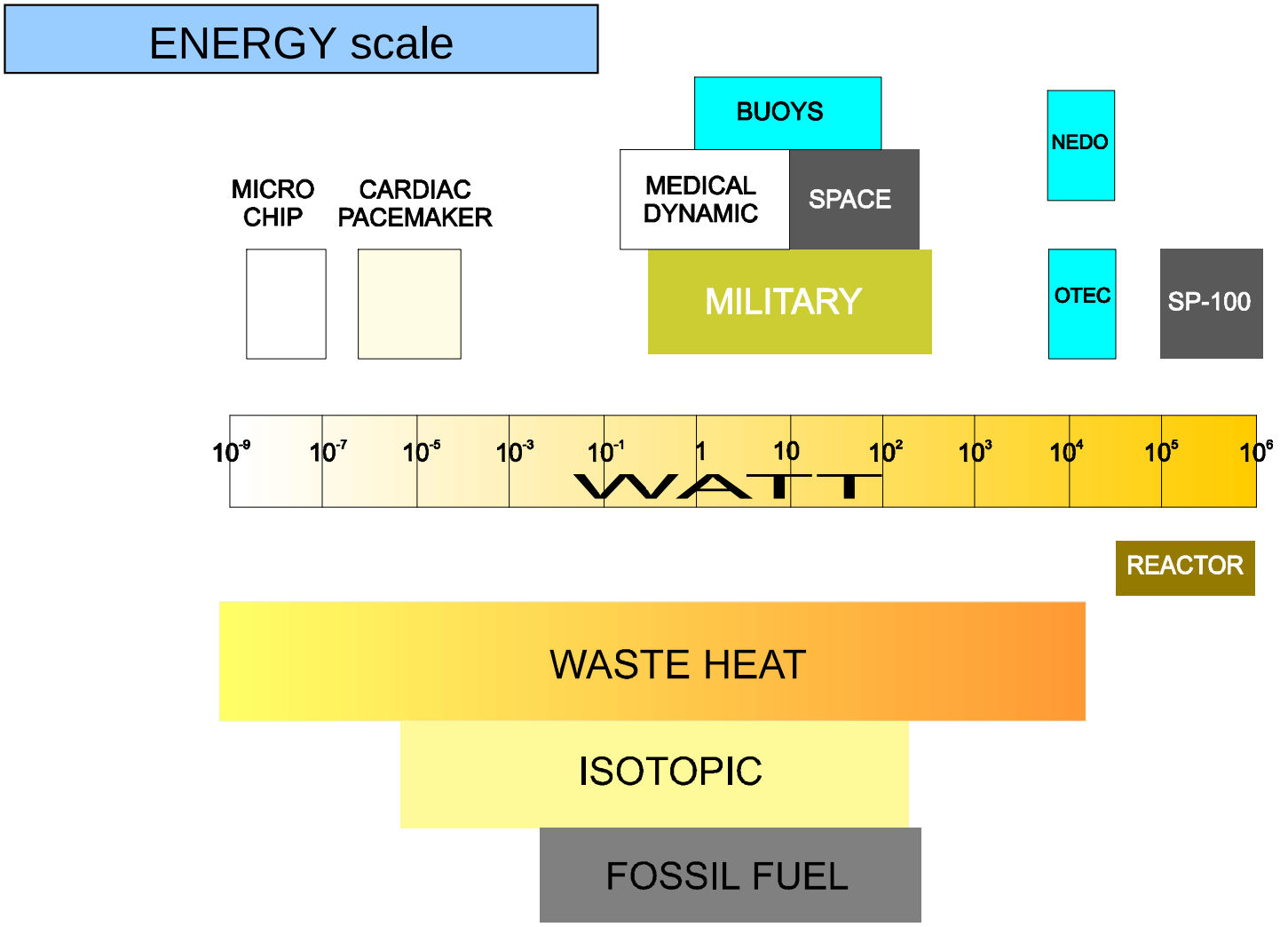


- Environmentally friendly
- Reversible defrosting/heating/cooling
  - Issue in small North-European diesels
- Reliable
- Heating/cooling power proportional to current: easy to control

- Very compact: **distributed cooling** power across vehicle
  - Multizone HVAC without mixing valves
  - Higher personal comfort
- Improved performance during transients: fast cooldown
- **Possibly enhanced personal comfort with reduced energy consumption**

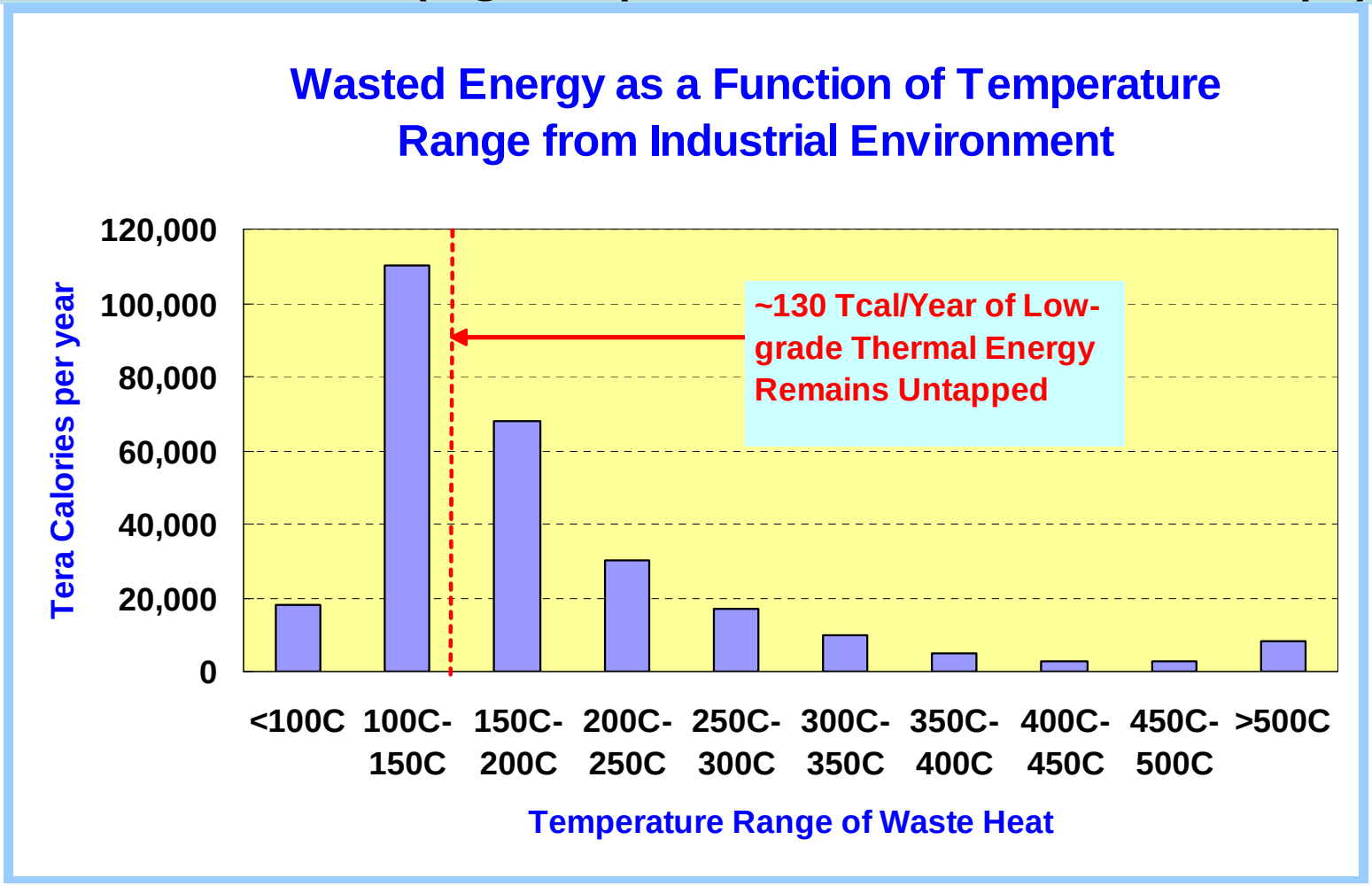
Amerigon cooled seat:
~ 400,000 vehicles/year

TE Power Generation



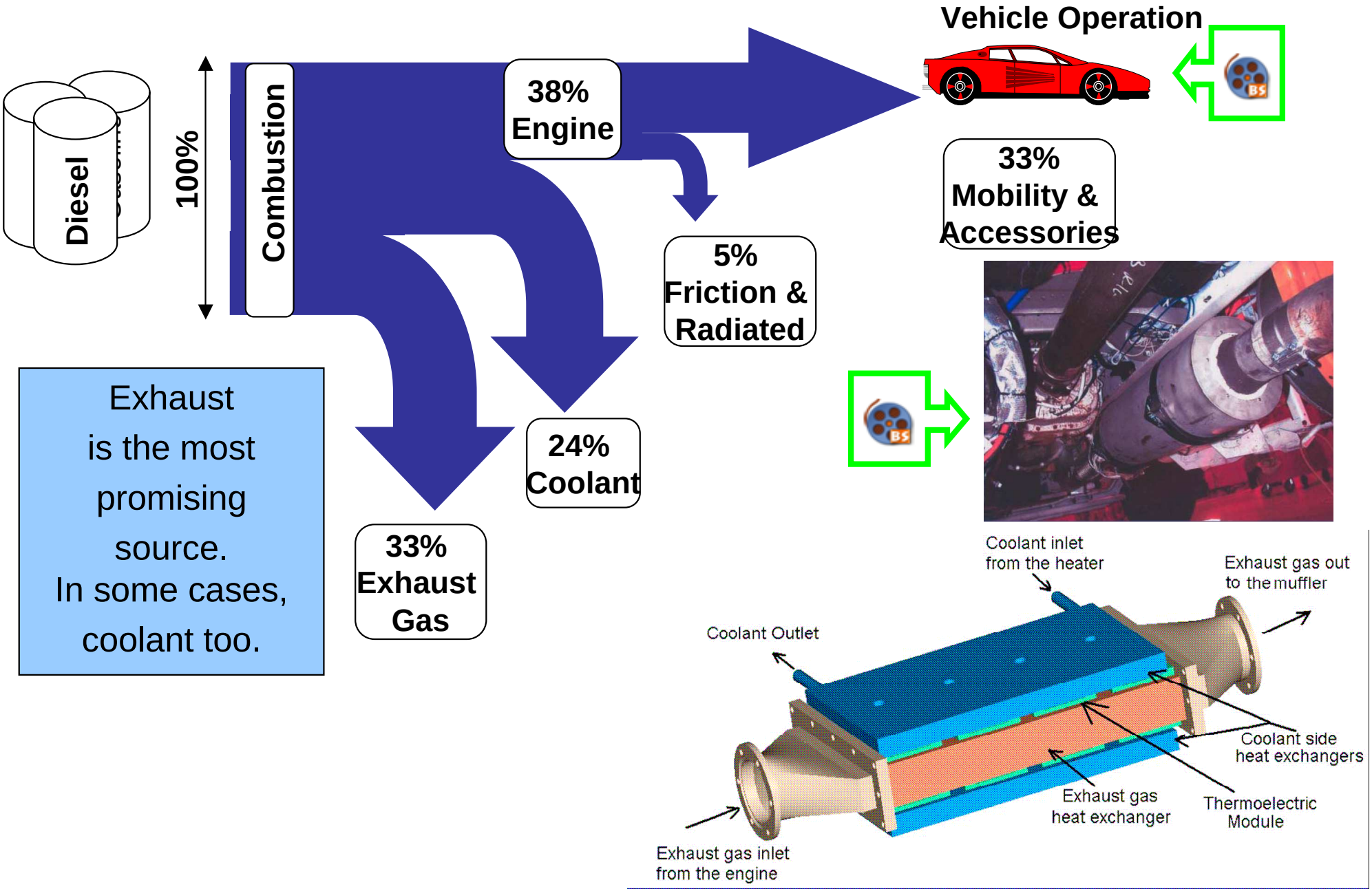
TE power generation (actual + studies)
cover > 12 orders of magnitude

Abundance of Thermal Energy in Industrial **Waste Heat** (eg: Japan; Ref: Toshiba Corp.)

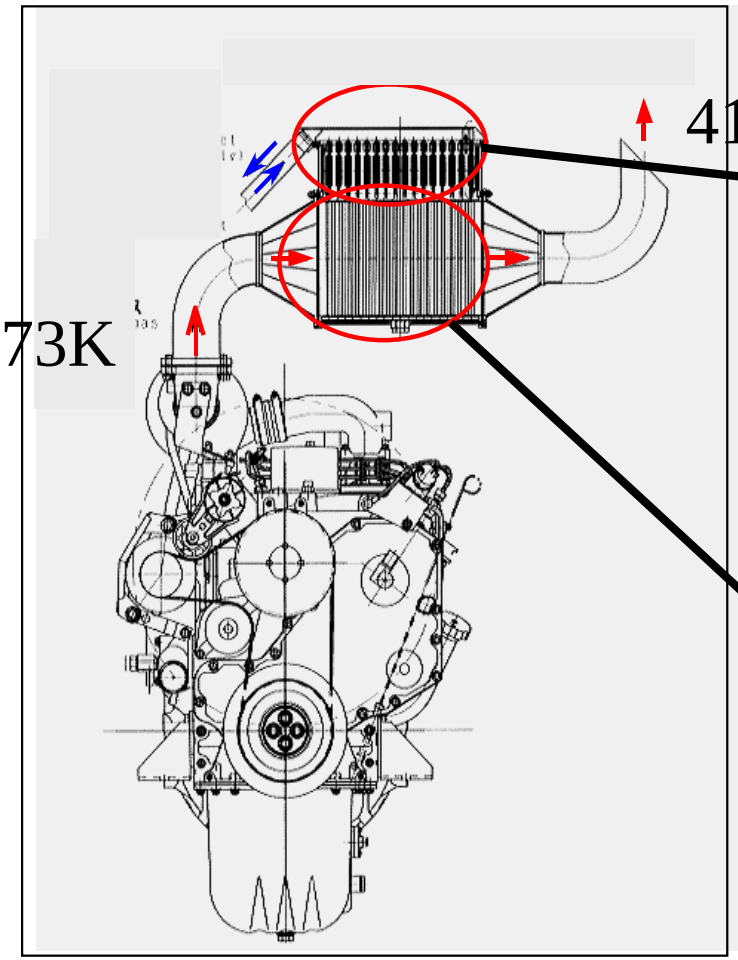


- **Low grade heat in one sector - 130 Tcal/yr – equivalent to 250 Million Pounds of CO_2**
- **Capturing low-grade waste heat into useful power is intrinsically a difficult thermodynamic problem (Carnot Efficiency ~ ($\Delta T/T_{hot}$))**

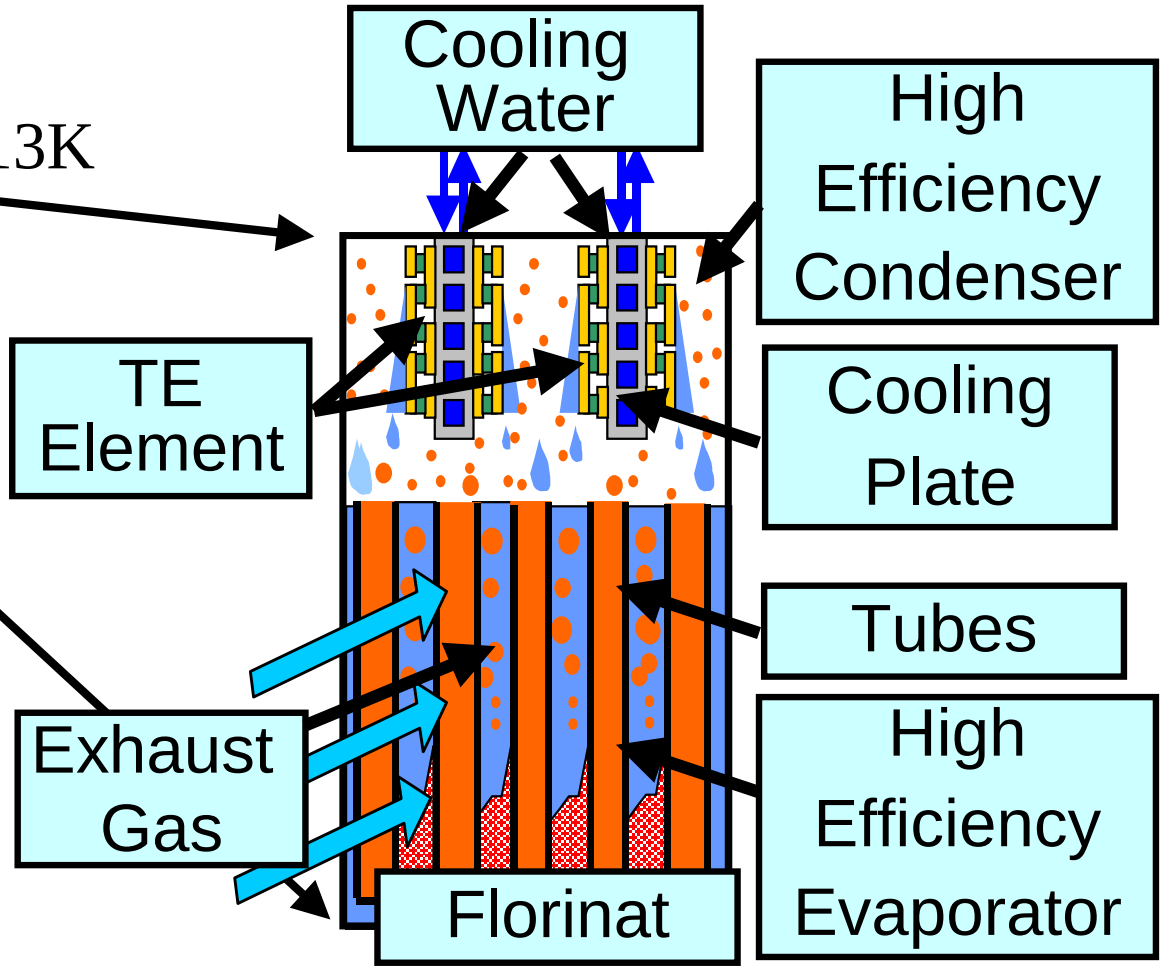
Waste heat- automotive application
Heat Distribution in Vehicles



Thermoelectric Power Generation System for Diesel Engine Co-Generation System

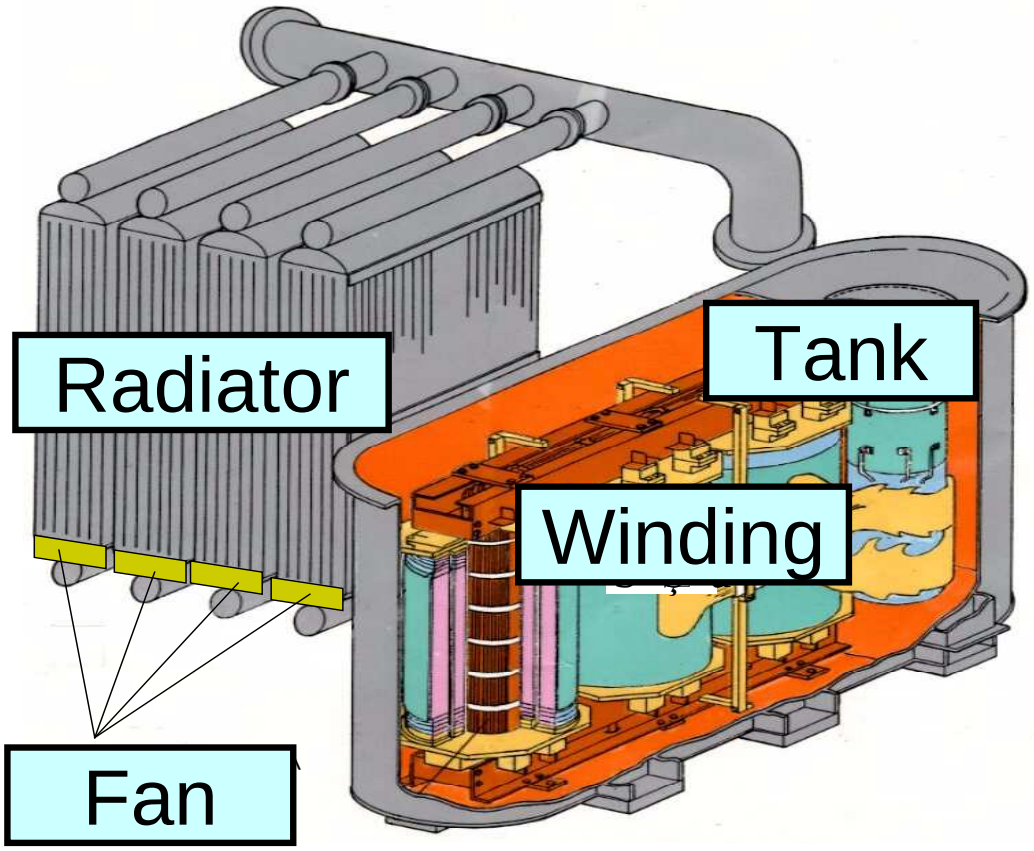


Diesel Engine

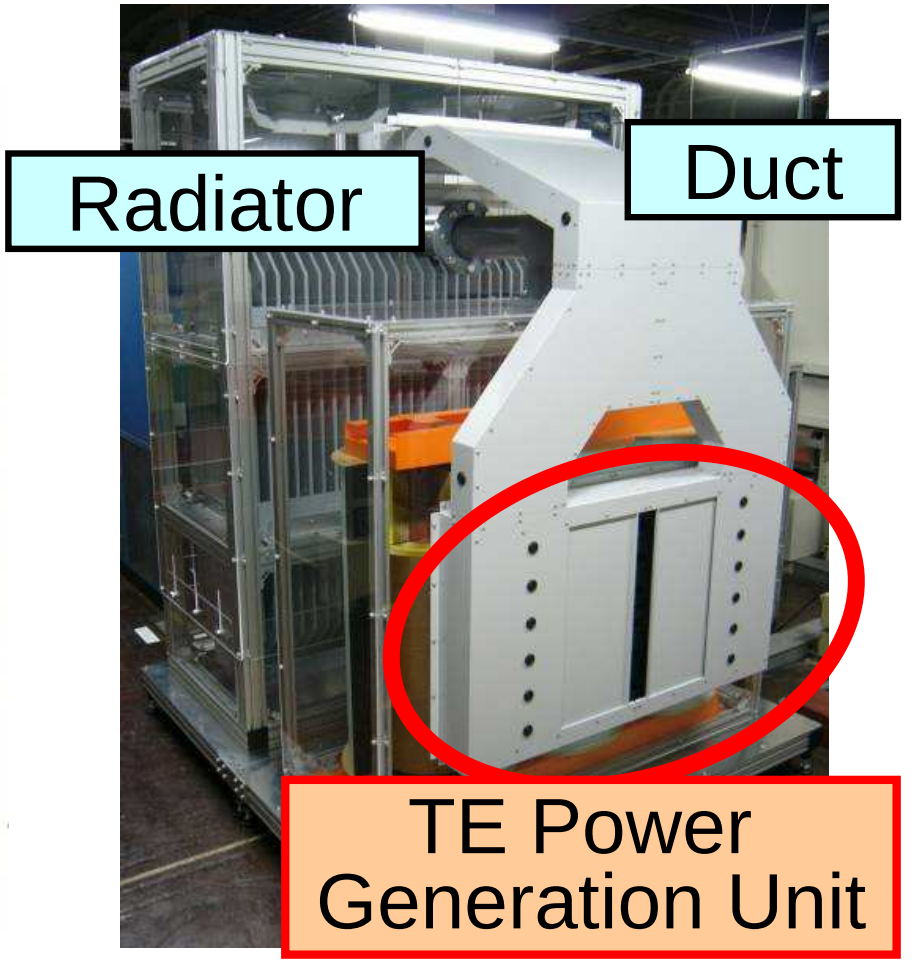


Schematic of Thermo-Siphon Type Heat Recovery TE System

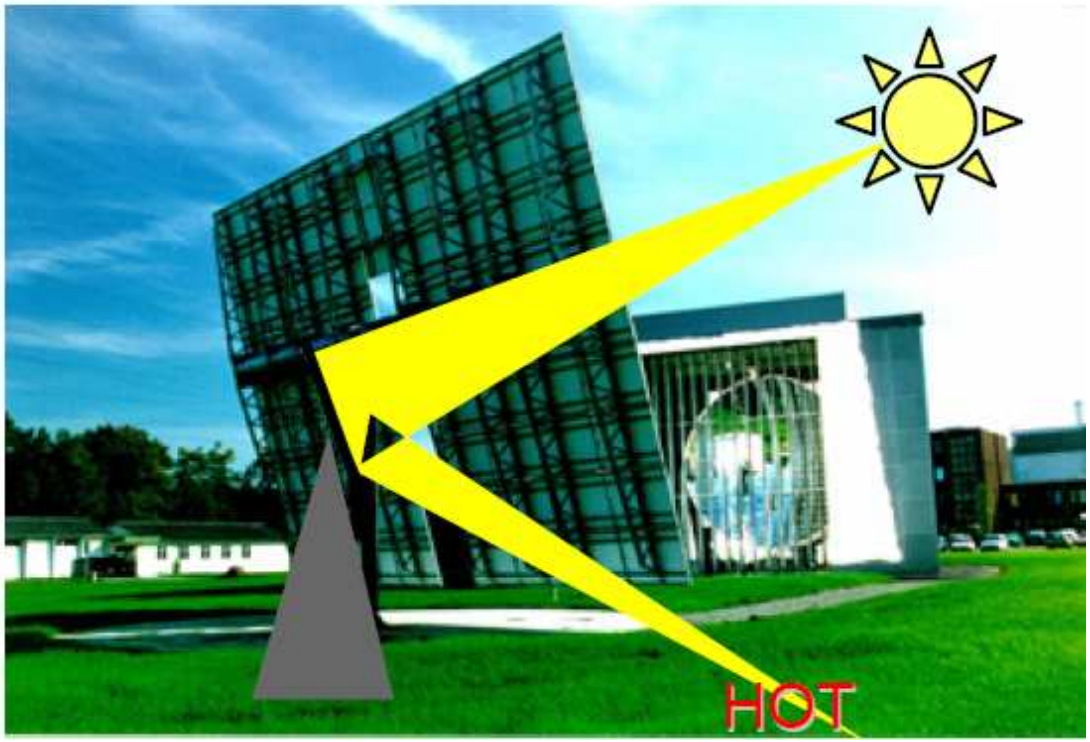
Thermoelectric Power Generation System using rejected heat from Electric Transformer



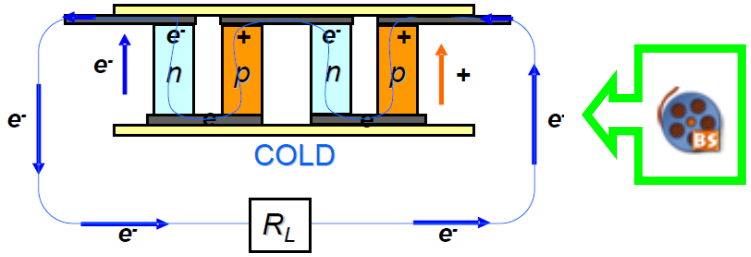
Schematic of Electric Transformer



Demonstrated system



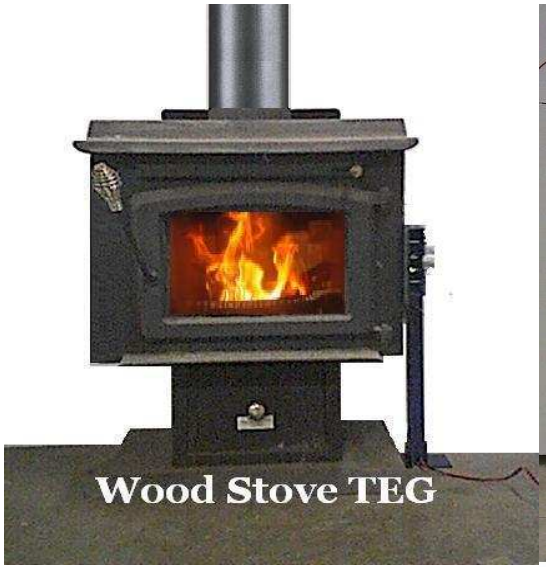
Solar energy harvesting

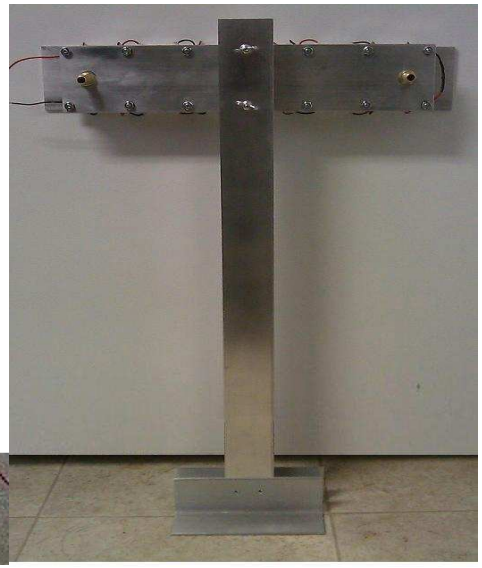


Woodstove – Third World, but …..

Philips Research – Woodstove

- Paul van der Sluis
  - Philips Research Eindhoven, The Netherlands
- 400 million stoves world wide market
- Pilot of 1000 pieces in India
- TEG powers fan
  - Recharges ignition battery
  - Powers fan – improved combustion





Power Outage or Off-Grid Power / Keep a 12 Volt Battery Fully Charged!