# Materials
# Government support

| Date | Instance | Name project | Partners | Projectleader | Goal | Budget (Million Yen) | Note |
|---|---|---|---|---|---|---|---|
| 2012 – 2017 | JST | Development of High Efficient Silicon Thermoelectric Materials using Nanostructure Control | Osaka Univ., AIST | S.Yamanaka, Osaka Univ. | ZT ≥1 between RT and 600K for Nanostructured Si | 150* | Bulk nano Si TE for 300°C, with a view for application in automobile heat recovery systems. |
| 8.2011 – 2017 | JST | Fabrication of Solar-Heat Thermoelectric Materials by Controlling Ordered Structures and Phase Interfaces | Tokyo Institute of Technology | Y. Kimura, Tokyo Tech. | Solar-heat TE power generation system | 150* | 1. Controlling Ordered Structures based on Half-Heusler system. 2. Controlling Phase Interfaces. For 650~1000 K using environmentally friendly TE materials. |
| 1.2012 – 2015 | NEDO | Development of Thermoelectric Generation Technology for Steel Plant Waste Heat Recovery | JFE Steel, KELK, Hokkaido Univ. | Hidetoshi Matsuno (JFE) | Create a 10 kW test system. Optimize power efficiency without impairing steel production | 140 | Press release KELK: http://www.komatsu.com/CompanyInfo/press/201204191251262513 2.html |
| 6.2009 – 3.2012 | NEDO | Research and Development of High-performance Nano-structured Thermoelectric Materials Using Caged Compounds | Yamaguchi Univ., Hiroshima Univ., AIST, KELK, DENSO | T. Takabatake, Hiroshima Univ. | 1. ZT=1.3 at delta T=300 ºC 2. Development of High-performance TEG Systems for Practical Use | 810 | Nano-scale caged material $Ba_8Ga_{16}Sn_{30}$ (BGS and BGCS) |
| 10.2008 – 4.2014 | JST | Development of High-Efficiency Thermoelectric Materials and Systems | Nagoya Univ., AIST, Hokkaido Univ., Tokyo Univ. of Science at Yamaguchi | K. Koumoto, Nagoya Univ. | ZT>1.5, η~10% . Non-toxic, Non-rare, Cheap, and Usable in Air for wide temperature range | 227 | - |
| 4.2009 – 3.2012 | MEXT | Development of Novel Thermoelectric Modules by Ink-jet Technique | JAIST, KELK | Mikio Koyano (JAIST) | Printable TEG | 26 | - |
| 4.2011 – 3.2016 | MEXT | Development for High Temperature Thermoelectric Materials to recover unused waste heat sources | NIMS | Yoshikazu Shinohara | - | 23 | Complex structured materials such as $RB_{17}CN$ and $RB_{22}C_2N$ and Higher Borides |

# Applications Overview

**Waste heat recovery**

- Furnaces
- Automotive
- Co-generation

**Renewable energy sources**

- Sun
- Geothermic
- Biomass

**Micro-TEGs**

- Autonomous sensors
- Wearable electronics

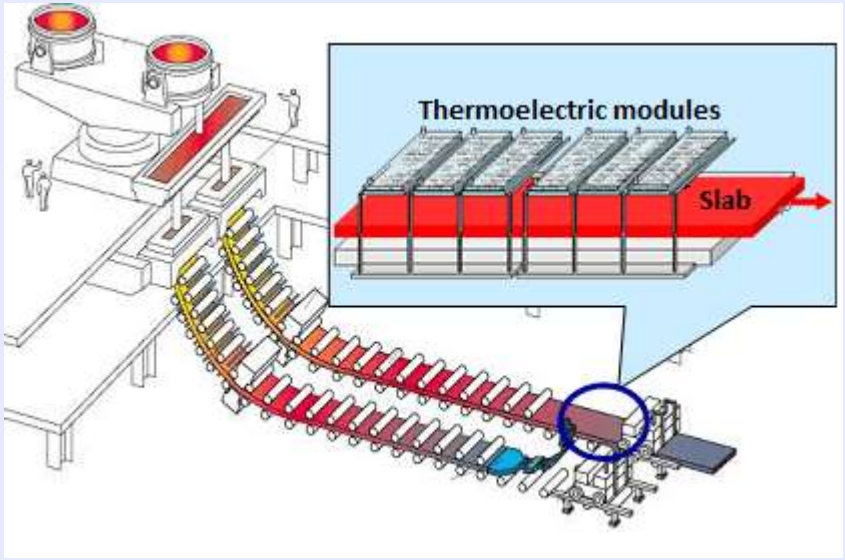
# Applications

## Steel Furnace

- Recover waste heat from steel production (4)
- Goal: 10kW

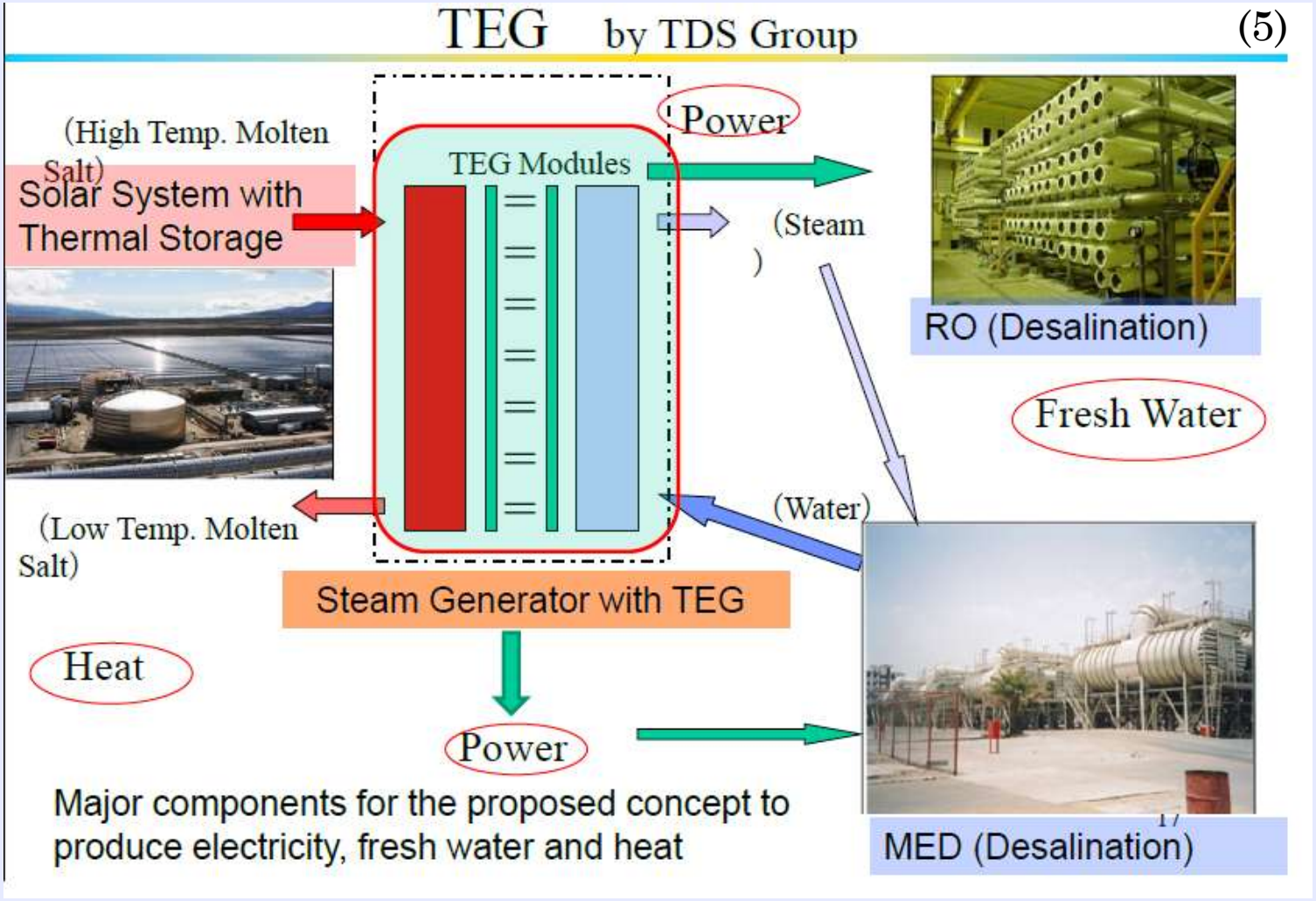
- Benefits:
  - Low maintenance and long lifetime of system
  - Improved energy efficiency

Test facility at JFE-Steel
generator modules by KELK (Komatsu)



# Applications

## Desalination plant

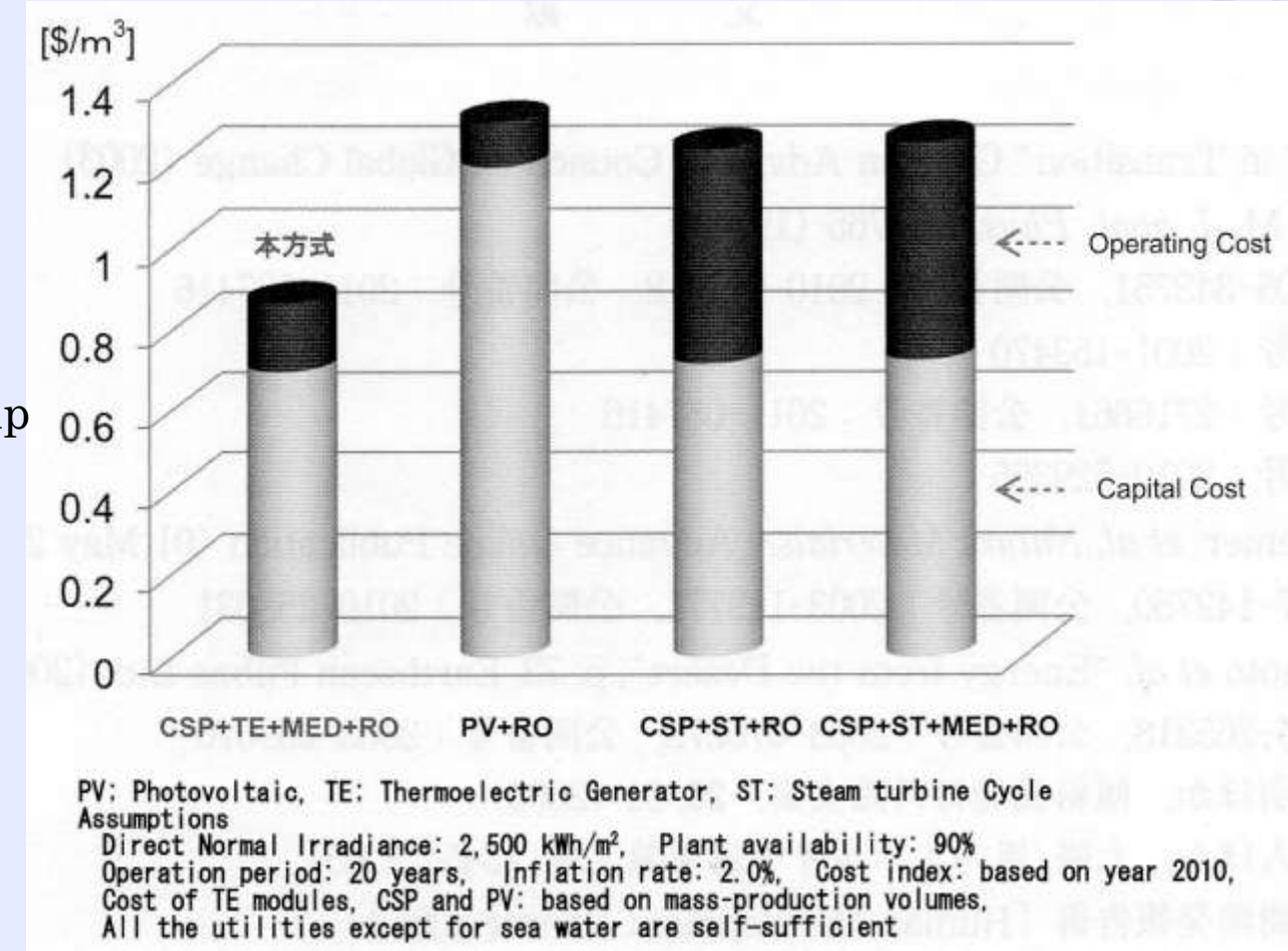


# Applications

## Desalination plant

CSP = concentrated solar power
MED = Multiple-effect distillation
RO = Reverse Osmosis

JAXA, China and TDS group
Capacity: 10.000 t/d
Site: Middle East
Plant Life: 20 year
Construction year: 2010
Efficiency of TEG: 7%




PV: Photovoltaic, TE: Thermoelectric Generator, ST: Steam turbine Cycle
Assumptions
Direct Normal Irradiance: 2,500 kWh/m², Plant availability: 90%
Operation period: 20 years, Inflation rate: 2.0%, Cost index: based on year 2010,
Cost of TE modules, CSP and PV: based on mass-production volumes,
All the utilities except for sea water are self-sufficient

# Applications
## Biomass

- TES New Energy (6):

**Hatsuden-Nabe**:
Thermoelectric cookpot.

"**Firepower 40**"

# Applications

## Biomass

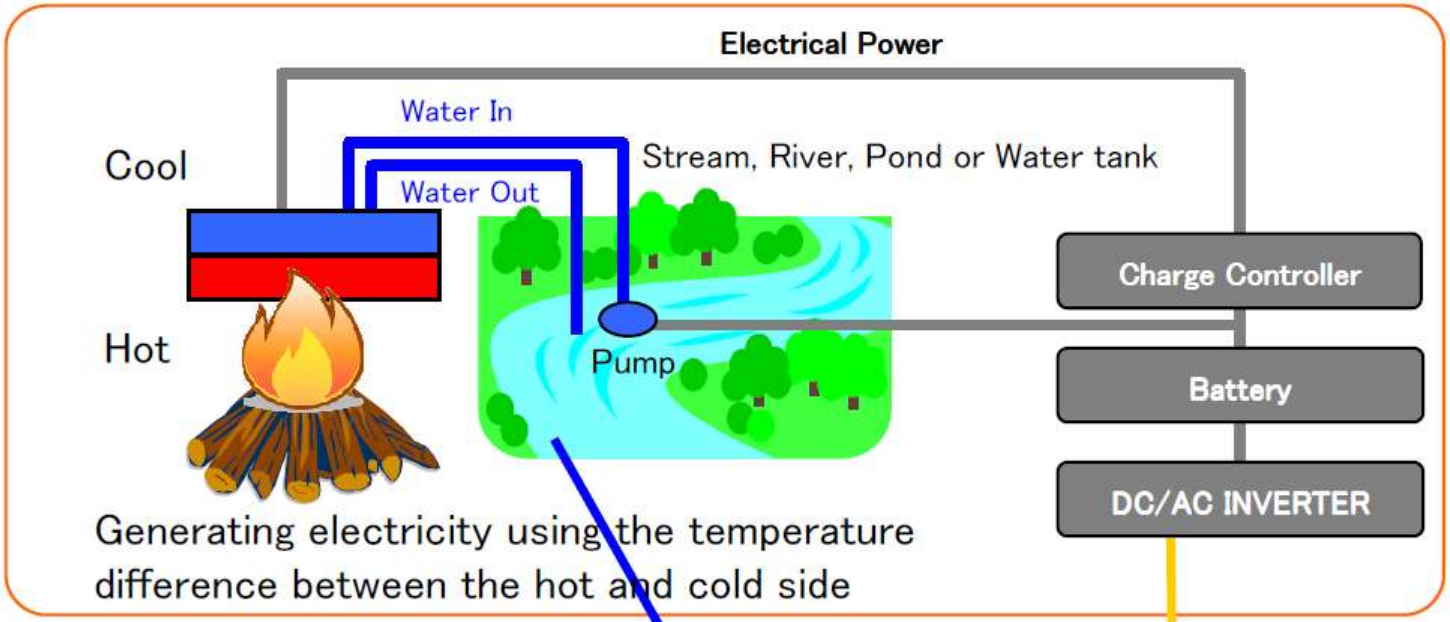
**Fire sources**


Fire Box


Bonfire

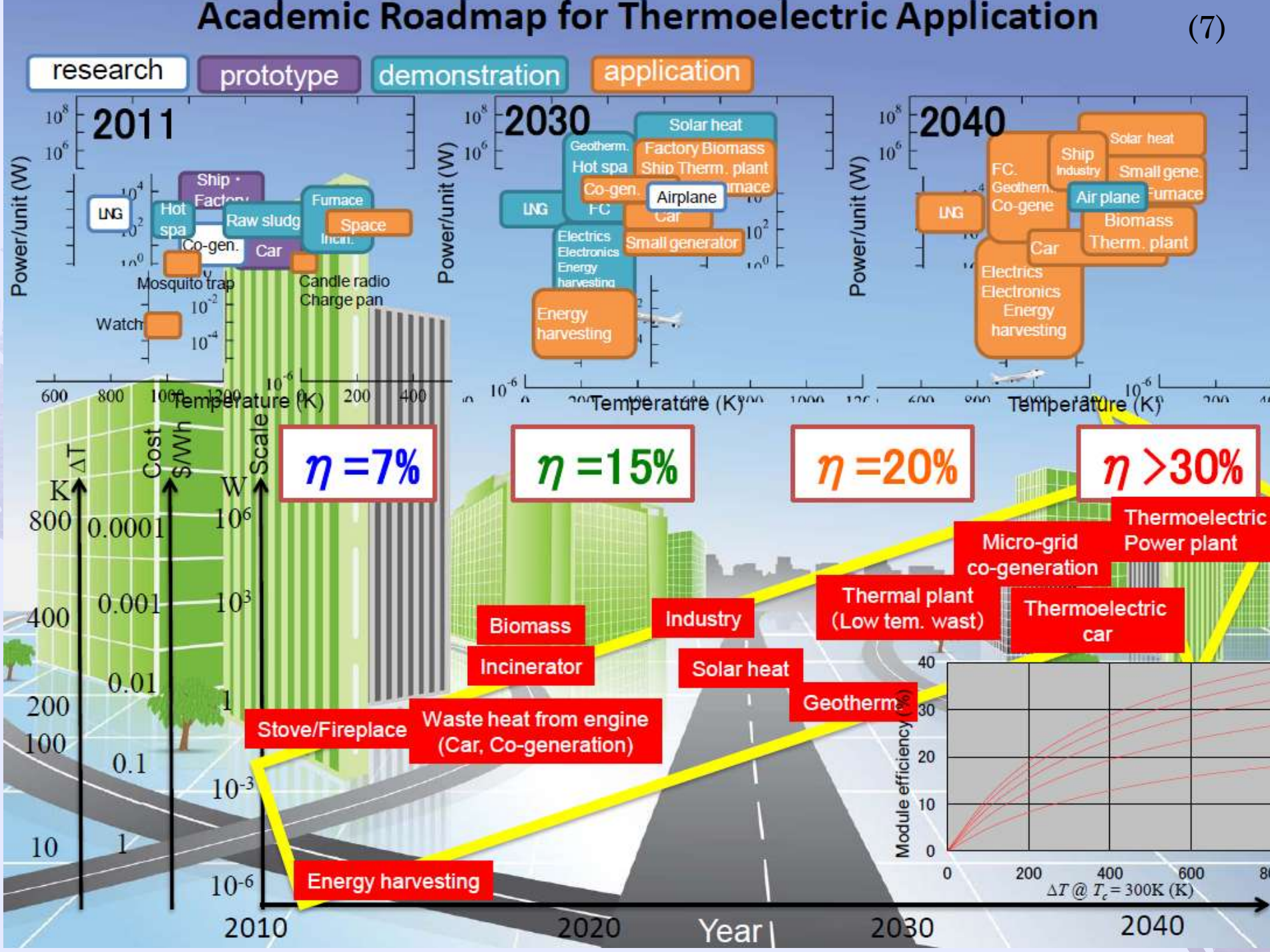

Gas

**Fire Power 40**




**Usages**

- Laptop computer
- ROM Water Filter
- Lights
- USB Connected Gadget


Academic Roadmap for Thermoelectric Application
research
prototype
demonstration
application
2011
2030
2040
Power/unit (W)
Temperature (K)
LNG
Hot spa
Ship
Factory
Raw sludg
Furnace
Space
Co-gen.
Car
Mosquito trap
Candle radio
Charge pan
Watch
Geotherm.
Hot spa
Solar heat
Factory Biomass
Ship Therm. plant
Co-gen.
Airplane
FC
Car
Electrics
Electronics
Energy harvesting
Small generator
Energy harvesting
Ship
Industry
Solar heat
Small gene.
FC
Geotherm.
Co-gene
Air plane
Furnace
Biomass
Therm. plant
Car
Electrics
Electronics
Energy harvesting
ΔT
K
800
400
200
100
10
Cost
$/Wh
0.0001
0.001
0.01
0.1
1
Scale
W
10^6
10^3
1
10^-3
10^-6
η =7%
η =15%
η =20%
η >30%
Thermoelectric Power plant
Micro-grid co-generation
Thermal plant (Low tem. wast)
Thermoelectric car
Biomass
Industry
Incinerator
Solar heat
Geotherm.
Stove/Fireplace
Waste heat from engine (Car, Co-generation)
Energy harvesting
Module efficiency (%)
40
30
20
10
0
0
200
400
600
ΔT @ T_c = 300K (K)
2010
2020
Year
2030
2040

# Conclusion

- Japan highly involved with top research on thermoelectric materials
  - Especially the use of cheap, safe and abundant materials
- Nanostructuring for better efficiency, but challenge remains making bulk while retaining nanostructure
- Thermoelectric generators might become an additional source of (renewable) energy in the near future

# References


1. Article: Complex thermoelectric materials, Jeffrey Snyder, 2008
2. Article: R&D Trends in High Efficiency Thermoelectric Conversion Materials for Waste Heat Recovery, Hiroshi Kawamoto, 2008
3. Website FDC plasma sintering
4. Press release JFE Steel (Japanese)
5. Presentation at DOE (USA) Prof. Takenobu Kajikawa, 2012
6. Website: TES New Energy
7. Made available by Professor Takenobu Kajikawa