The Use of Technology Roadmaps to Guide Science and Technology Policy in Japan

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Our Humankind can not survive without Good Estimation of the Future. Accurate Estimation of Future Improvement of Technology and Society would be able to be considered only by Our Engineering Societies. The estimation of future improvement of energy efficiencies and the financial payback period for accelerating the prevention effect for global warming.
JSME Technology Roadmap

(Established from 2006 as 110th Memorial Event of JSME)

Fundamental Principle: The Long Term Improvement Process of Key Physical Parameter would able to Indicate the Future of the Technology Accurately.

One Successful Example would be the Line Width of Semiconductor Memory, which would be shortened to the half at every 1.5 years. (Moore’s Principle)

Important Task is to select the Key Physical Parameters, which would control the Future Improvement of the Technology.

Purpose: To estimate the Improvement of the Technology and Future Figures of Society, and to give the Future, Clear and Quantitative Targets of Engineering and Academic Researches.
Trend of Academic Research:
To Realize the **Compact and Low Cost Heat Exchangers**=
Research and Development of Heat Transfer Enhancement

- Heat Transfer Enhancement of Boiling
  - High Performance Boiling Surface (To Decrease the Wall Superheat)
  - or
  - Enhancement of Critical Heat Flux (To remove the Higher Heat Flux)
Removal of High Heat Flux:

Plotted in Chronological Order

Possible Heat Flux For Removal

$[W/\text{cm}^2]$ 

Like one Line in Semi-Logarithm

Electric Equipment Cooling
Cooling of Large Scale Computer
Cooling of Semiconductor Lasers
Thermo-electric Cooling

$y = 3.5548 \times 10^{-94} \times e^{0.10986x}$

$R = 0.98824$
JSME Technology Roadmap:

3 Contents:

Available Removal Amount of Heat Flux

Chronological Trend of Widely Applicable Key Parameter (Heat Flux)

Discussion on Mechanism and Limit of Key Parameter in the Future

Prospects of Future Society Including the Improvement of Technology

Electrical Equipment Cooling

Cooling of Large Scale Computers

$y = 3.5548 \times 10^{-94} \times e^{0.10986x}$

$R = 0.98824$
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<th>Roadmap of high-temperature heat flux heat reduction technology</th>
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<td>Roadmap of heat pump hot water supply technology</td>
<td>Environmental Engineering div.</td>
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<td>Roadmap of automobile fuel efficiency technology</td>
<td>Transportation &amp; Logistics div.</td>
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<td>Roadmap of industrial robot technology</td>
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Technology Roadmaps For Realizing the Sustainable Society

1) For evaluating the technological innovation correctly, JSME Technology Roadmaps for Sustainable Society would be used.

2) Quantitative estimations, such as economical payback period of energy technologies, necessary total budget of energy policy would be possible by organizing the JSME Technology Roadmaps of Various Technical Divisions for Sustainable Society
**NEW FINDINGS**

The systematic organization of JSME Technology Roadmaps for Sustainable Society by various engineering divisions of JSME has been produced over several years.

Two good results have been obtained in the discussions by combining the several technological roadmaps as the new findings.

1) **Energy Usage and CO2 Emission Reduction for the Automobiles**

2) **Energy Saving for Air-conditioning and Hot Water Supply by Utilizing High Efficiency Heat Pump Systems**
1) **Energy Usage and CO2 Emission Reduction for the Automobiles**

The specific strength of materials and new materials such as Aramic fiber would be useful for reducing the weight of automobiles.

The thermal efficiency of engines has been increased gradually by many kinds of breakthrough.

The average traveling speed has been increased by the improvement of traffic control technology.

The total amount of CO2 reduction potential would be 100MT/year and the most effective method would be the increase of the traveling speed.
Fig. 1 JSME Technological Roadmap for Specific Strength of Materials
CO2 emission data of passenger cars according to weight. The graph shows the emission data in grams of CO2 per kilometer (g-CO2/km) plotted against vehicle weight in kilograms (kg). Different types of engines, such as conventional gasoline engine, gasoline engine hybrid car, lean burn gasoline engine, direct injection gasoline engine, antechamber diesel engine, and direct injection diesel engine, are represented with distinct symbols. The data points are spread across the graph, indicating a correlation between the type of engine and the emission data.
JSME Technology Roadmap of Thermal Efficiency of Engines
JSME Roadmap of the Increase of Average Traffic Speed By Traffic Flow Control and the Reduction of CO2 Emission
Fuel Consumption

Average Traveling Speed and Fuel Consumption
### Appendix B: Data sheet for the climate plans

**Country:** JAPAN  
**Population (2006):** 127.9 million  
**Area:** 377,923 km²  
**GDP:** 4 trillion $

<table>
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<tr>
<th>GHG emissions (tons CO2-eq.)</th>
<th>CO₂</th>
<th>Total</th>
<th>Baseline</th>
<th>2007</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
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<tr>
<td><strong>GHG emissions by sector (tons CO2-eq.)</strong></td>
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<td><strong>Transportation fuels</strong></td>
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<td><strong>AUTOMOBILES</strong></td>
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<tr>
<td><strong>FIG.1</strong></td>
<td>New Materials: such as Aramid Fiber (Specific Strength Relative to Steel) Weight Reduction (%)</td>
<td>0%</td>
<td>0.35%</td>
<td>1.00%</td>
<td>1.30%</td>
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<tr>
<td><strong>Fig.2</strong></td>
<td>Engine Thermal Efficiency (Gasoline Engine)</td>
<td>36%</td>
<td>37.20%</td>
<td>39.50%</td>
<td>42.50%</td>
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<tr>
<td></td>
<td>Average Traveling Speed by Traffic Flow Control Technology</td>
<td>20 km/h</td>
<td>30 km/h</td>
<td>40 km/h</td>
<td>50 km/h</td>
<td></td>
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<tr>
<td></td>
<td>(20% Red CO₂)</td>
<td>(30% Red CO₂)</td>
<td>(40% Red CO₂)</td>
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<tr>
<td></td>
<td>Estimated Total CO₂ Emission from Automobiles</td>
<td>222 MT</td>
<td>178 MT</td>
<td>151 MT</td>
<td>122 MT</td>
<td></td>
<td></td>
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<tr>
<td><strong>CO₂ Reduction Potential</strong></td>
<td>44 MT</td>
<td>71 MT</td>
<td>100 MT</td>
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| **Residential, commercial and other sources** | | | | | | | |
| **HEAT PUMP HEATING & HOT WATER SUPPLY** | CO₂ Reduction Potential | 50% Replace | 100% Replace | CDP=6 | | | |
| **Fig.3** | Heat Pump Hot Water Supply (CO₂) | 33 MT | 66 MT | 77 MT | | | |
2) **Energy Saving for Air-conditioning and Hot Water Supply by Utilizing High Efficiency Heat Pump Systems**

JSME Roadmap of Heat Pump Hot Water Supply

COP of supplying hot water: the value of 5 or higher.

Efficiency of electric power generation of about 40%, over twice of the total heat release by combustion by utilizing high efficiency heat pump.

The CO2 reduction potential by replacing the boiler, heater and absorption heat pumps would become the order of 200MT/year.

This value would be over 10% of the total CO2 emission in Japan.
Fig.3 JSME Technological Roadmap for Heat Pump Hot Water Supply System (Trends of COP & Technical Breakthrough)
<table>
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<tr>
<th>Heat Pump Heating &amp; Hot Water Supply</th>
<th>CO2 Reduction Potential</th>
<th>50% Replace</th>
<th>100% Replace</th>
<th>COP=6 100% Replace</th>
</tr>
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<tbody>
<tr>
<td>Heat Pump Hot Water Supply (COP=5) for Houses replacing Boiler and Heater</td>
<td>33MT</td>
<td>66MT</td>
<td>77MT</td>
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<tr>
<td>Heat Pump Heating (COP=5) for Houses replacing Boiler and Heater</td>
<td>25MT</td>
<td>51MT</td>
<td>69MT</td>
<td></td>
</tr>
<tr>
<td>Heat Pump Hot Water Supply (COP=5) for Buildings replacing Boiler and Heater</td>
<td>17MT</td>
<td>34MT</td>
<td>39MT</td>
<td></td>
</tr>
<tr>
<td>Heat Pump Heating &amp; Cooling (COP=5) for Buildings replacing Boiler and Heater, Absorption Heat Pump</td>
<td>20MT</td>
<td>40MT</td>
<td>47MT</td>
<td></td>
</tr>
<tr>
<td>Total CO2 Reduction Potential</td>
<td>95MT</td>
<td>190MT</td>
<td>222MT</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>270MT</strong></td>
<td><strong>175MT</strong></td>
<td><strong>80MT</strong></td>
<td><strong>56MT</strong></td>
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Amount of Energy Usage from the Viewpoints of Our Daily Life (Japanese Case)

Contents from Viewpoints of Our Daily Life (Total 5150W, LCA Analysis including Materials)

Clothes: 137W (Clothes & Bed 86W, Washing: 51W)
Eating: 296W (Green House 128W, Cooking 59W, Refrigerator 50W, Restaurant 59W)
Business & School: 869W (Building & Construction 652W, Public Transportation 122W, Hotel 95W)
Society: 918W (Carriage 324W, Store 155W, Hospital 81W, Road Construction 103W, River 92W, Movie 27W)
not cleared: 1354W
Energy Cost and Importance of Cheap Energy

Energy Cost: Japanese Case
Gasoline: Car for 10km Drive 1 litter $1
Electricity: One overnight cooling for one room in summer $1
City Gas: Bathing for one family with water usage $1
Kerosene: One overnight heating for one room in winter season $1

Gasoline $1 for 1 litter in Japan
Kerosene 70 cents for 1 litter in Japan

But in the shopping store
Natural Water & Tea $1.5 for 1 litter container in Japan
Milk $2 for 1 litter in Japan

Gasoline and Kerosene are not valuable compared with Natural water and Milk? NO! Our Society depends on the cheap energy. Energy Production Industry is not easy to survive from the Economical Viewpoints. (example: Biomass Energy Production)
Possibility of Reducing the Energy Consumption based on Daily Life Analysis

15%: Cooling, Heating & Hot Water Supply for Houses & Buildings would be reduced largely by Utilizing High Efficiency Heat Pump System (Instead of Combustion Electricity would be Useful)

10%: Automobiles for Personal Use would be Effective to be reduced by Utilizing Alternatives (Public Transportation System, Trains Bicycles)

10%: Decreasing the Amount of Building Construction would be Effective (Maintenance would be much more important than Construction)

10%: Reducing the Total Amount of Electric Equipments would be Effective (Total Amount of Electricity Consumption should be Reduced)
RECOMMENDATIONS

1) Produce the reliable technology roadmaps for estimating the future technological performance, for selecting the future energy and environmental policy and for accelerating the prevention effect for global warming.

2) By presenting the comprehensible quantitative engineering data of energy usage and CO2 emission in public, we should promote the quantitative discussion for accelerating the reduction of the CO2 emission.