Research and Development Strategy for Green Innovation

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Principal Fellow
Center for Research and Development Strategy
Japan Science and Technology Agency
- CRDS and National STI Policy
- Principles of Strategic Proposal Making
- Current CRDS Movement
- Filling Gaps in Innovation Ecosystem
Organization of CRDS

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(44 full-time and 19 part-time staffs)
CRDS Strategic Proposal

Council for Science and Technology Policy (CSTP), Cabinet Office

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Ministry of Economy, Trade and Industry (METI); other ministries

Strategic Proposals
R&D investment, Priority setting, Reform of R&D system etc.

Human network
Academia, Industry, Government

Encounter of Social Wish and Science/Technology

Science fields
Birds-eye view mapping
R&D themes

International Comparative Study

Social Wish
Birds-eye view mapping
Social issues
Convergence of Knowledge for “Science for Society”
(ICSU, Budapest, 1999)

- Basic and applied research designed by knowing social wishes

  Cf. Curiosity-driven basic scientific research independent of social wishes

- Social wish as design specification for research, and need to identify currently latent social wishes

- Issue-driven research for offering solution and measures to society through Collection, Connection and Convergence (3C) of knowledge
Sustainable growth and development toward the future

Japan aims for realization of restoration and reconstruction from the disaster and promotion of STI toward sustainable growth and development of society in the future.

**Restoration and reconstruction**

To stabilize living of the people in the devastated area and reconstruct business and industries:
1) Restore and reconstruct the industries of the disaster-stricken region.
2) Restore and reconstruct the social infrastructure.
3) Realize safety living of the disaster-stricken region

**Green Innovation**

Toward low-carbon, circulating and sustainable society co-existing with nature and of good living standards for citizens:
1) Realize stable and low-carbon energy supply
2) Highly efficient and smart use of energy
3) Green the social infrastructure

**Life Innovation**

Toward health-oriented nation, where the people are vigorous in body and in mind and can feel the affluence and achieve a sense of fulfillment of being alive.
1) Develop innovative preventive care
2) Develop new early diagnostic method
3) Realize safe and highly effective treatment
4) Improve quality of life (QOL) for elderly, people with disabilities and patients

**System reforms to promote STI**

- Set up the “Science, Technology and Innovation Strategy Council” (tentative name) for the better collaboration among the industry, academia and government
- Create “a network of knowledge” among government, industry and academia
- Establish “an open-innovation platform”
- Promote intellectual property strategy and international standardization strategy
2013 Action Plan for Green Innovation
(currently under discussion by Science, Technology and Innovation Strategy Council)

Vision: Sustainable society of advanced energy utilization co-existing with nature

A) Securement of steady clean energy supply
   • Massive introduction of renewable energy by technological renovation

B) Active promotion of distributed energy systems
   • R&D on innovative energy production/storage technology
   • Smarter energy management

C) Renovation of energy utilization systems
   • Drastic reduction energy consumption by technology innovation

D) Green social infrastructure
   • Local green community co-existing with nature
CRDS and National STI Policy
Principles of Strategic Proposal Making
Current CRDS Movement
Filling Gaps in Innovation Ecosystem
General Strategy of CRDS

1. Focus on 3E+
2. Short-, mid- and long-term R&D goals
3. Basic scientific rules and principles of energy utilization under the constraints of environment and resources
4. Cross discipline collaboration based on a shared perspective view
5. Network of excellence (cf. COE) and collaboration between industry, academia and government with participation of younger researchers
1. Relevance of Energy Technologies

- Linking science to innovation, economic growth and social welfare
- Common wish to fulfill requirement of “stable, safe and sustainable energy supply with least cost”
- Contexts of national security and industrial/economic competitiveness at the nation’s level
- Assessment of energy technology options from three viewpoints of 3E+
Sustainable Society
Fulfillment of 3E+

Affluent Life
\(\text{GDP}/N\)

Life Enrichment, Equity, Ethics

National Security, Energy Saving, Efficient Improvement, Economy,

Energy and Materials Saving
\(\dot{E}/\text{GDP}\)

Decarbonation
\(C/\dot{E}\)

GHG Emission Reduction, Ecological Conservation

Energy Technology

Materials Circulation Technology

Ecological Conservation Technology

STI for Society and the Environment
## Assessment Indices for Technology Options

<table>
<thead>
<tr>
<th>Energy Security</th>
<th>Environment (Safety)</th>
<th>Economy (Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resource reserve (geophysical/geopolitical distribution), Reserve-production ratio (fossil and nuclear fuels)</td>
<td>• Climate change (GHG)</td>
<td>• LCA, energy profit ratio, energy payback time</td>
</tr>
<tr>
<td>• Security and stability of resource feedstock (import dependence, independent development)</td>
<td>• Radioactive wastes, radioactive contamination (nuclear power)</td>
<td>• Fuel costs (mining, transformation, transportation, storage), material cost, energy price, electric power price</td>
</tr>
<tr>
<td>• Stability of international market fuel price</td>
<td>• Atmospheric contamination (NOx, SOx, soot, particulates), Ozone layer destruction (CFC), thermal discharge</td>
<td>• Business continuity stability against fuel price fluctuation</td>
</tr>
<tr>
<td>• Time-dependent fluctuation, rates of availability and operation (natural energy resources)</td>
<td>• Compatibility to food production, Condensation of specific molecules (N, P) (biomass, biofuels)</td>
<td>• Costs for R&amp;D, equipment, plant construction, land, installation, environmental countermeasures</td>
</tr>
<tr>
<td>• Rate of plant operation (periods of inspection and repair)</td>
<td>• Impacts on ecology and biodiversity</td>
<td>• Length of periods for environmental assessment and construction</td>
</tr>
<tr>
<td>• Response to load fluctuations</td>
<td></td>
<td>• Costs for maintenance, waste processing, decommissioning</td>
</tr>
<tr>
<td>• Disaster countermeasures and energy supply to isolated areas</td>
<td></td>
<td>• Costs for countermeasures to terrorism and disaster, recovery cost and time, compensation</td>
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<tr>
<td></td>
<td></td>
<td>• Economical impact as energy industry (energy equipment, electric power market, fuel businesses), employment</td>
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</tbody>
</table>
## Social Wish in Different Regional Contexts

<table>
<thead>
<tr>
<th>Stable and sustainable supply</th>
<th>Japan</th>
<th>East Asia</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>National security</td>
<td></td>
<td>Harmonization</td>
<td>Sustainability</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environment¹ (Generalized safety)</th>
<th>Japan</th>
<th>East Asia</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eagerness to safety and security</td>
<td></td>
<td>Technology transfer and environmental conservation</td>
<td>Consensus formation (Climate change prevention)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Growth and prosperity² (Competitive economy, better life)</th>
<th>Japan</th>
<th>East Asia</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable prosperity</td>
<td></td>
<td>Economic cooperation</td>
<td>Equity</td>
</tr>
</tbody>
</table>

1. Difference between time scales of climate change and disaster
2. Economic growth (quantitative expansion) vs. social prosperity (qualitative development)
2. Structuring Focal Areas and Research Themes
2. Structuring Focal Areas and Research Themes

- Hierarchical structures with different layers of societal needs, target technologies, scientific research and scientific disciplines
- Upper layer R&D more relevant to societal issues (Needs-pull)
- Lower layer R&D driven by technology breakthrough and basic science (Seeds-push)
- Scientific breakthroughs connected to innovative technologies and social needs in many possible ways
3. **Time Axes**

- Time scale of R&D dependent on assessment indices
- Timely technology identification, optimal target time setting, R&D policy consistent over 10 to 20 years

**Diagram:**
- Numerical targets of 3Es in 2030 defined by “Basic Energy Plan”
- “Short-term goal”
- “Long term goals” in 2020 and 2050 back cast from prediction in 2100
## Prioritization of R&D Themes in 2012

1. **Does it meet social wish (national policy)?**
   - Contribution to innovation, recovery and restoration, industry competitiveness advocated in the government policy such as 4th Basic Sci. Tech Act and the New Growth Strategy

2. **Does it make remarkable quantitative impact to energy issues?**

3. **Does it challenge to core scientific principle and make disruptive change?** (game changing?)

4. **Does it cultivate research incentive of young researchers, train them, and contribute to human resource development?**

- Distinguish short-term and mid- to long-term R&D themes
- Watch negative impact of new science and technology
- Be aware that energy issues have deep relationship to social and economical aspects, and a new scientific methodology is necessary to quantitatively predict R&D outcomes’ influence
- CRDS and National STI Policy
- Principles of Strategic Proposal Making
- Current CRDS Movement
- Filling Gaps in Innovation Ecosystem
Strategic R&D Themes Focused by CRDS

1. **Science for energy policy**: Modeling energy technology and economy
2. **Phase interface science** for efficient energy utilization
3. **Energy carriers** for transportation, storage and utilization of renewable energy
4. Analysis and control of ions and electrons in *buttery electrodes*
5. Advanced technology development for medium to low temperature *thermal energy*
6. Technology and system development for utilization of off-shore natural energy resources
7. **Sustainable nitrogen circulation**
Basic Energy Plan: Primary Energy Breakdown in 2030

- **Total 592**
  - Renewable etc.: 35 (6%)
  - Nuclear: 60 (10%)
  - Coal: 130 (23%)
  - Natural Gas: 105 (19%)
  - LPG: 18 (3%)
  - Oil: 244 (39%)

- **Total 517**
  - Renewable etc.: 67 (13%)
  - Nuclear: 122 (24%)
  - Coal: 88 (17%)
  - Natural Gas: 81 (16%)
  - LPG: 18 (3%)
  - Oil: 141 (27%)

**Great East Japan Earthquake**

New energy plan options for 2030 with nuclear power fractions of:

- a. 0%
- b. 5%
- c. 20~25%

and renewables of 25~35%
Science for Energy Policy: R&D on Engineering and Economy Models

Affluent Sustainable Society Fulfillment of 3E

Countermeasures & Assessment

Analysis & Modeling

Observation & Measurement

Predictive measures

Energy and resource saving
High efficiency energy use, energy economy, energy security

Natural energy
GHG emission reduction, environment and biodiversity

Understanding of current structure of energy consumption and economy

Predicting future energy flows and economy dynamics

Advancing and integration of engineering and economy models
Public funding to collaborative work of engineering and economics
Human resource development

Individual welfare
QOL, Equity, ethics

CRDS-FY2011-SP-07 (March 2012)
Emerging S&T Issues

(1) **Securement of resources** -- including **risk-hedge**
   - Middle east, Australia, Indonesia, Canada and Russia are important countries for Japan’s energy security

(2) **Improvement of energy efficiency in power generation sector**
   - **Fuel consumption:** Electricity of only 3.6 EJ/year from fuels of 9.8 EJ/year (6.2 EJ/year is missing)
     - IGCC, Ultra Super Critical Steam Turbine, 1700°C Gas Turbine, SOFC etc.
     - How to produce and distribute the electricity?

(3) **Increase of energy efficiency in petrochemical division**
   - More than 10% of loss as wasted heat
     - Recovery of the wasted heat for high energy efficiency distillation

(4) **Reduction of energy loss on board**
   - High efficiency engine, fuel cell, butteries, other technologies including liquid fuel

(5) **Efficient heat supply at low temperature**
   - Heat pumps with high energy efficiency (COP>6), solar heat, thermal energy storage

(6) **Increase the use of renewable resources**
Phase Interface Science for Energy Efficient Society

Energy equipment and systems (transform, transport, storage, utilization)

Energy input

Energy output

Suppression of interfacial irreversibility

Utilization of new interfacial phenomena

H₂ production by photocatalyst

• High efficiency solar cell
• Permeable membrane

Control and reduction

Irreversible loss

Approach to theoretical limit

Efficiency increase, cost reduction

Improvement of FC electrodes with new materials

Multi-scale modeling and simulation

Control / optimization

By mathematics

Achievement of theoretical limiting performance

Renovation of technology base

Possible Contributions

• Highly efficient power plant
• Highly efficient fuel cell system
• Highly efficient air-conditioning and water supply system
• Highly efficient transport vehicles (automobile, aircraft)
• Highly efficient ultrapure water production system
• Highly efficient solar power systems

Solution to Energy Issues

Energy security, Economical competitiveness, Emission reduction

New energy and Energy-saving technologies

Cooling technology

• Adiabatic materials

Drag reduction of vehicles

Drag reduction of heat transfer

CRDS-FY2010-SP-05 (March 2011)
Renewable Energy Carriers for Transportations, Storages, and Utilizations

1. For international and intercontinental transportations
2. For leveling of natural energy in local regions
3. For house energy systems

Electricity from Natural Resources

- Solar-thermal
- Photovoltaic
- Wind-power
- Hydraulic
- Geothermal
- Wave and tidal

Solar Energy

Solar-thermal
Solar-light

Combustion Engines

- H$_2$ Engines, H$_2$ Turbines
- Ammonia Engines
- Direct Methanol FC
- Direct Hydride FC
- Direct Ammonia FC

Fuel Cells

- PEFC SOFC

Organic Hydrides

- Methanol
- Ammonia

Cryogenic

Ammonia Synthesis

Electrochemical synthesis of NH$_3$

Electrochemical reduction of CO$_2$

Water Electrolysis High Press./Temp.

H$_2$

Methanol Synthesis

Hydrogenation

Metal Magnesium

Thermochemical

Photocatalysis

Thermal Reduction

Hydrogen Production

1. For international and intercontinental transportations
2. For leveling of natural energy in local regions
3. For house energy systems
Thermal Energy Utilization

Present

- Fossil fuels
  - High temperature
  - Stability
  - Low emission
  - Combustion
- Internal combustion heat engine
  - Heat resistance
  - High compression ratio
  - Humidified cycle
- Heat exchange
- Chemical process
  - Catalyst
  - Co-production
- Material/Fuel
- Mid & low temperature heat demand
- Work
  - Electric power
Combustion

- High temperature
- Stability
- Low emission

Internal combustion heat engine

- Heat resistance
- High compression ratio
- Humidified cycle

External combustion heat engine

- Gas cycle
- Steam cycle (Kalina, Organic, Trilateral)

Thermoelectric

- High ZT

Refrigeration cycle

- Low ODP, GWP refrigerant/system
- Desiccant
- Thermally driven

Energy Management

- Heat sensor
- Database
- PCM
- Chemical storage

Transport

- Less pumping power
- Enhancement
- Low temp. diff.

Storage

- PCM
- Chemical storage
- Catalyst
- Co-production

Material • Fuel

Mid & low temp. heat demand

Heating

Gasification

Renewable heat

Unused heat

Fossil fuels

Gasification

Combustion

- High temperature
- Stability
- Low emission

Internal combustion heat engine

- Heat resistance
- High compression ratio
- Humidified cycle

External combustion heat engine

- Gas cycle
- Steam cycle (Kalina, Organic, Trilateral)

Thermoelectric

- High ZT

Refrigeration cycle

- Low ODP, GWP refrigerant/system
- Desiccant
- Thermally driven

Material • Fuel

Mid & low temp. heat demand

Fossil fuels → Gasification → Renewable heat → Unused heat

Internal combustion heat engine → Heat exchange → External combustion heat engine

Thermoelectric → Refrigeration cycle

Heat exchange → Material • Fuel

Future

Heating

Non heating

- Insulation
- Recuperation

Heat demand

Work Electric power

Future
- CRDS and National STI Policy
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- Filling Gaps in Innovation Ecosystem
Gaps to be Filled

Between:

- Basic and applied research
- Scientific disciplines
- Industry/business, research laboratories and universities
- Government ministries and funding agencies
- Scientists/engineers/administrators and society
Consolidated Funding Schemes

Network of Excellence

Scientists + Engineers + Administrators

Universities
Res. Labs
Industry

Cabinet office
CSTP
SCJ

MIC
NICT
FDMA

MEXT
JSPS
JST

Min. Health, Labor & Welfare
NIBIO

MAFF
NARO

METI
NEDO

Min. Land Infra. & Trans.
JOGMEC

Ministry of the Environment
JRTT
International Institute for Carbon-neutral Energy Research

Kyushu University
Best-equipped and best-funded laboratory on hydrogen research

University of Illinois
Prominent research record on hydrogen/materials compatibility

President of Kyushu University

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Vice Director: Prof. Y. Murakami

Science Steering Committee
(Thematic area leaders)

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Prof. T. Ishihara

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Research Teams

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