3

# Research Trends of Sustainability Science on the Global Warming Problems
## – Issues on the Japan Contribution in the IPCC 4th Assessment Report –

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## 1 Introduction

Global Warming effects, the frequent abnormal weather phenomenons which cause torrential rain and hurricanes in various parts of the world, and also Arctic Ocean ice decrease, are being exposed faster than the anticipated. Therefore we, are facing a pressing situation in terms of greenhouse gas reduction

In the past, the scientists gave warning cautiously, and the process of scientifically testing Global Warming requires the accumulation of a variety of knowledge and opinions. However, the Intergovernmental Panel on Climate Change (IPCC) publicly announced the 4th Assessment Report from February 2007 to May 2007, which states that it is appropriate to define Global Warning, which was observed after the middle of 20th century, was caused by the greenhouse gases made by human activities.[1-4] It also strongly warned of the necessity for swiftly implementing greenhouse gas reduction measures in order to prevent it from exceeding risk levels, as the negative effects are increasing, accelerating, and spreading globally. Thus, the main proposition (thesis) in terms of the Global Warming problem, is to step into a new phase of "how to respond to" the problems of climate change, from the phase of only "defining" the phenomenon of climate change.[5]

Conventional environmental issues were tackled individually in the past. However, in the case of Global Warming issues, it is difficult to respond and solve the problems of phenomena and region by technical optimization in one piece, or by knowledge of single academic field, Problem-solving based approaches become more important, because Global Warming are global social issues that have more complicated and confused factors. Then we essentially need to ask ourselves how society should be in the future from the wider viewpoint.

The concept of "Sustainability" is presented as an ideal state of social development for harmonizing the global environment and human society. The science, technology and economic systems in the 21st century is called the "environmental era", and this concept is the keyword for developing discussions during various opportunities in government and business sectors or in cross-border situations. Especially in the western academe, implementation is becoming more active for establishing "Sustainability Science", which is the new interdisciplinary and integrated field for the various pressing global issues in recent years. It is not only made up by a single academic field fractionalized as in the past, but also by problem solving based approaches.

This document outlines the circumstances in which Sustainability Science is rapidly developing, as well as the background of Global Warming problem trends, and the measures for climate change in the recent years.By summarizing the research trends of Sustainability Science in various major countries, and comparing the contributions of countries in the 4th Assessment Report of IPCC, Japan's position and the international presence of Japanese researchers can be analyzed quantitatively. In considering this, the proposals will be summarized on the Sustainability Science research in Japan in the future.

## 2 The background of sustainability science

### *2-1 Characteristic of global warming problems and roles of science*

An outstanding characteristic of Global Warming problems, comparing with other various social issues, is that the knowledge and opinions of Natural Science should play a critical role when policy makers prepare and implement measures. In order to provide a variety of information and data for the decision-making processes of political measures for Global Warming risks, such as the required reduction volume of greenhouse gas and other concrete measures and processes, a great deal of research resources have been invested in and the scientific knowledge and opinions have already been accumulated.

Aiming to show that the big picture of such scientific knowledge and opinions are reviewed and streamlined, the IPCC was established upon the consensus of various national governments in 1988. This process has been established in order to reflect the measures for climate change, as well as scientific knowledge and opinions.(Figure 1) The effects and prospects of climate change intend to be for long periods of 100 years and the large uncertainty needs to be considered. Therefore, the IPCC has published the Assessment Report every couple of years, and in order to realize the timely improvement of political measures, it includes the latest knowledge and opinions. Three groups are formed; The Working Group 1 (WG1 for the Physical Science Basis), the Workng Group 2 (WG2 for Impacts, Adoptions and Vulnerability) and the Working Group 3 (WG3 for Mitigation of Climate Change), and they have each published individual Working Group Reports.[1-4]

Response to the latest 4th Assessment Report (AR4) has confirmed the effects of human activities is the cause of Global Warming, the main object of scientific activities is extremely necessary to shift from "clarifying" natural phenomenon to "mitigation" and "adaptation".[1] And the scientific rolls for the Global Warming problems

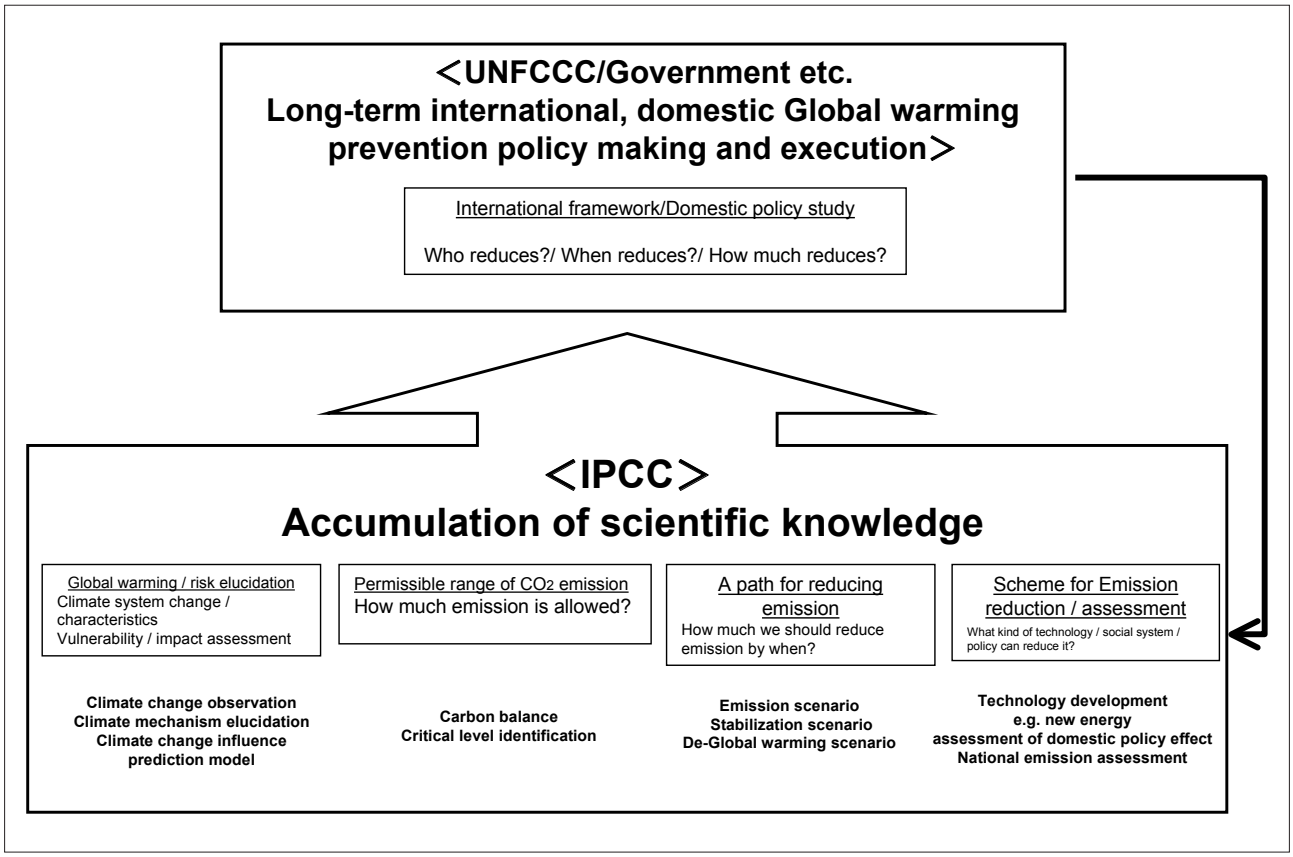


**Figure 1** : Reflection process of scientific findings concerning global warming issue to the policy

Prepared by the STFC based on Reference[6]

**Table 1** : Comparison of various system design approach

| Proposal | System approach | Description | Main issue |
|---|---|---|---|
| Proposal how to determine the emission target | Multi-stage approach | Additionally increase countries committed for the Kyoto Protocol emission standard. Developing countries are imposed to commit the carbon consolidating level improvement target, depending on the income level and will be included to the committed countries when a certain economic development standard is achieved. | Less incentive for U.S.A. / developing countries in participation. |
| | Emission standard / fuel cost standards proposal (Sectoral Approach) | Set emission / energy efficiency standards for individual technologies and products, and aim at less emission per sector. | Less incentive for consumers Availability for global warming countermeasures. |
| | Brazilian proposal | Allocate emission commitment based on the total past emission estimate of each country. | Availability of past data/ reliability of the data. |
| | Triptique Approach | Classify into 3 kinds of emission groups: public welfare, industry and power generation. Bear the emission target by multinational negotiation by taking into consideration of the difference of economic structure. | Consistency / reliability of data acquisition. Equitable agreement. |
| | Reduction/ convergence proposal | Divide emission tolerance to each country to make the uniform ratio of greenhouse gas per person in a mid and long term. | Incentive for population growth. Lack of care to regional conditions. |
| | Carbon dioxide intensity target proposal | In consideration of the economic development situation of each country, impose an emission target per GDP (carbon dioxide intensity). | Availability for prevention of global warming. Link with the international emission system. Equality of system design. |
| Proposal for less emission measures | Safety valve proposal | Cap the emission trading prices (safety valve) to reduce uncertainty of expense burden of countries to commit to reduce emissions. | Equality considering the population shift. |
| | International carbon tax proposal | Agree on the globally common carbon tax to charge annually, to maintain equality to reduce uncertainty of the expense burden. | Difficulty to achieve international agreement between the resources production / consumption countries. |
| | Regional measures proposal | Agree on various proposals of different regions to supplement and replace the multination agreement. | Equality of the process. Availability for prevention of Global warming. |
| | Two track approach | Provide two types of commissions for each system (emission target or political measures) for participating nations to choose. | Feasibility of emission reduction target for the developing countries. Secure human and financial resources of developing countries. Increase administrative costs due to complexity of the system. |
| Other proposal | Sector-based CDM | Specify the commitment of Clean Development Mechanism (CDM) for the specific amount determined for sectors of the developing countries, by using the Kyoto Protocol. | Secure human and financial capability of the developing countries. |
| | Sustainable Development Political Measures (SD-PAM) | Specify the commitment to the developing countries to make greenhouse gas emission control policies in the national economic plan. | Depend on the self-decision of the developing countries. Link with the international emission trade system. |
| | Proposal for technical fund | Found an international fund for financial support to research and development of Global warming countermeasures technology. | Burden of each country. Availability for prevention of Global warming. |

Prepared by the STFC based on Reference[7]

will be continuously important in the future. And also in Japan, the discussion on strategy implementation of adaptation measures was started by the "Ministerial Meeting of the Gleneagles Dialogue on Climate Change, Clean Energy and Sustainable Development" in the Ministry of the Environment. [5]

### *2-2 Trends and subject of climate change political measures*

The UN Framework Agreement on Climate Change, the most fundamental framework of global climate change policy, was adopted in 1992, and put into force in 1994. It is presently a universal pact which most countries in the world have signed, including 188 countries and European

Communities. Under this pact, and based on the Kyoto Protocol that was adopted a resolution in 1997, an obligation of reducing the greenhouse gas is imposed during the First Commitment Period from 2008 through 2012, on the countries which fall under the "Appendix I countries" including Japan. The Kyoto Protocol had an immense effect in terms of the fact that the international society marked the first step of the full-scale measures for Global Warning.

On the other hand, as ten years passed after adoption, various issues are currently pointed out on the Kyoto Protocol. Its revision is scheduled for after 2013, when the First Commitment Period ends. Corresponding to this, the associated countries have proposed various approaches of system planning and new frameworks.(Table 1)

At the COP 13 and the COP/MOP3 in December 2007, the Bali Action Plan was presented in order to start discussion on reviewing international framework, and a new opportunity was started for examining a framework which includes the US and developing countries which was a large concern in the past. For the future, it has been agreed upon that the comprehensive process to deregulate measures and framework establishment works will be scheduled to be finished before the COP 15 held in 2009.

The political situations and economic conditions of each country that participates in the new framework examination vary, and the national interests of greenhouse gas reduction strongly conflict with each other.(Table 2) The process for forming new international systems and framework plans, and reaching an agreement on them, are expected to be harder than ever before. Researchers and scientists will be required to appropriately provide adequate scientific knowledge and opinions, as more complicated problems will be assigned as well. Based on the understanding of associated social systems, the effectiveness of technological means for solving problems and the scenarios of greenhouse gas reduction should be evaluated. It is also expected to contribute to the improvement of measurements and systems. Also, the results of consensus building are chiefly influenced by the approaches of system-plans for measures among multinational negotiations, and they can greatly influence the obligations (costs) of greenhouse gas reduction for each country. Therefore, scientists are required to play much more important "social roles" than they were in the past. As the process which reflects the scientific knowledge and opinions for political measures is being developed, the need is increasing for establishing a new knowledge system with problems solving based approaches which unify and integrate the associated academic fields.

### *2-3 Definition of Sustainability Science*

The Sustainability Science, rapidly developed especially in Europe and the USA, aims to solve various problems concerning human existence from the view of "Sustainability", such as the Global Warming problem.

The trigger for discussion on the concept of so-called Sustainability can be said to be the World Commission on Environment and Development, which was established by Japanese proposal in 1987.[12] This commission, of which the chairperson was Ms. Gro Harlem Brundtland the Prime Minister of the Kingdom of Norway, describes in its reports that the concept of the "Sustainable Development is the development which meets the needs of the present without compromising the ability of future generations to meet their own needs".

Afterwards, response to the various discussions on how to realize the sustainable development became active at the "UN Conference on Environment and Development (Earth Summit)", which was held in Rio de Janeiro in 1992. At the "World Business Council for Sustainable Development", the necessity of an interdisciplinary research system which aims at crossing the boundaries of the traditional and existing academic fields was recognized,

With this background, the concept of Sustainability Science was proposed in the USA by R.W.Kates of Harvard University and others at the beginning of the 2000s.[13] The Sustainability Science aims to research the various global-scale issues which have come up, including the foundation of human survival as a whole. It aims to solve wide range issues, such as not only the Global Warming problem, but also finding measures for poverty, welfare, health maintenance, peace and security. As a result, this will integrate

**Table 2** : Positioning of climate change policy of each country and trends of greenhouse gas emission

| | Positioning / Policy trend | Situation of greenhouse gas emission | | |
|---|---|---|---|---|
| | | Compared to the standard year/ Protocol target | Conversion per person | To GDP (2000) |
| U.S.A. | Although the United States separated from the Kyoto Protocol in 2001, there are still discussion on emission rights by the state governments and private enterprises.<br>Discussion is still active at Federal Government level after the interim election in 2007.<br>Participated in COP13 Bali Action Plan to announce involvement of the framework discussion to expand the international measures for mitigation (=commitment or action by all the developed nations).<br>・Greenhouse gas initiative (RIGGI) by 9 states of East Coast ⇒ Aiming 10% reduction compared to the current status by 2018, with the emission rights control starts in 2009.<br>・Federal Government submitted many drafts for emission rights related legislations (for all the 6 greenhouse gases, for a significant reduction of 50% by 2050). | 13.8% (2000) / (▲ 7%) | A 5.5t-C/ person | 151t-C/ USM$ |
| Europe | Taking a lead of the climate change international negotiations throughout. Reallocate the emission reduction target of the entire EU by the burden sharing.<br>Aiming to frame the Kyoto Protocol type system to set the global target of emission reduction based on the achievement of E-ETS for the post-Kyoto framework.<br>・Start EU emission quote trading system (EU - ETS) ahead of the world in January, 2005.<br>・The policy framework common to EU nations to be presented to achieve the target of Kyoto Protocol by European Climate Change Plan (2006). | ▲ 2.9% (2002) / ▲ 8% | A 2.1t-C/ person | 124t-C/ USM$ |
| Russia | The largest emission framework in the current emission system, due to economic slump after the disintegration of Soviet Union.<br>Although Russia's ratification played a key role for Kyoto Protocol, Russia is interested in and places more importance on economy and social issues, than climate change. | ▲ 33.8% (2000) /0% | A 2.7t-C/ person | 1423t-C/ USM$ |
| Developing countries | Maintains the negotiation power to the developed countries as one group (G77 + China)<br>There are many different stakeholders.<br>Announced the involvement in the framework discussion for expansion of the global mitigation measures in COP 13 Bali Action Plan (=Actions to reduce emission with a measurement/report and review method as long as possible for the developing countries.<br>・Superpower of emission (China, India and South America): taking a lead in discussion of the developing countries. Requests supports and commitment to the developed countries.<br>・Oil-producing countries (middle east): concerned about decrease of oil money.<br>・Association of small island countries: requested a severe emission reduction to all countries, including developed and developing countries.<br>・Least developed among developing countries: emphasized on the position of a victim, same as island countries. | ※ China 33.3% (2000) /none | A 0.6t-C/ person | ※ China 820t-C/ USM$ |
| Japan | Emission increased, though Japan has a commitment of emission reduction.<br>If purchasing the excess from overseas, public funds burden of 1-2 trillion yen is expected per year.<br>On the other hand, while concentrating on the equality of Kyoto Protocol, no discussion/introduction of economic sanctions such as ecotax / emission rights trading system has advanced. | +6.4% (2006) ▲ 6% | A 2.5t-C/ person | 68.9t-C/ USM$ |

Prepared by the STFC based on Reference[7-11]

the segmented academic fields for solving issues, and seek for integrated approaches crossing the boundaries of the traditional academic fields of Natural Science, Social Science and Humanities. It has been developing rapidly and variously in recent years, centering on Europe and the USA. However, the situation until now cannot be said to have established an effective methodology.

At first, the Global Warming problem was one of the Sustainability Science subjects along with the North-South poles and poverty issue. Later, as the negative effects of the Global Warming problem are increasing and deepening, it has become accordingly, the current central issue. (Figure 2)

## 3 Trends of sustainability science rsearch for the global warming problems

### *3-1 Fundamental proposition and research topic*

The final goal of Sustainability Science in terms

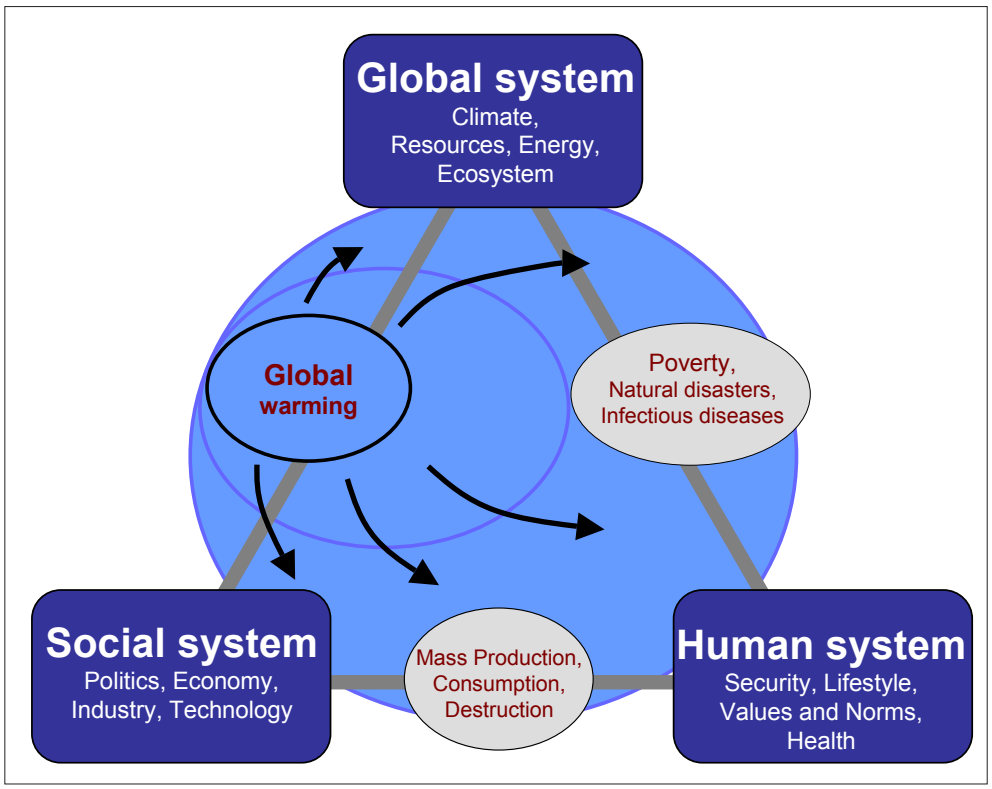


**Figure 2** : Sustainability science topics and change of global warming issue status

Prepared by the STFC based on Reference[14]

of the Global Warming problem is to stabilize the level of greenhouse gas in the atmosphere, and to make the foundations of human survival be sustainable. The process cycle for reaching that final goal is thought to be divided into seven steps, as shown in Figure 3 in the items (1) – (7). Various research topics are set up corresponding to the Fundamental Proposition of each stage; however, they are all research topics which require the interdisciplinary academic fields to cross the boundaries of natural science, social science and humanities. The environmental field relatively has practiced the integrated implementation in the past, however, the research topics which the Sustainability Science covers, include a wider range of subjects than before. This complicates relations of mutual interests, and this characteristic calls for much more comprehensive knowledge, as well as the integration and systemization of multiple academic approaches.

The above reflects the following features which Global Warming problems have:

First, it is estimated that the negative effects caused by the Global Warming is large and irreversible. There is a threatening possibility of permanent damage if any actions are taken before perfect and reliable evidence is provided. Secondly, complicated factors and structures exist which make the cost allocation of each global warming measure difficult. As a result, it will be difficult to clearly identify the relationship between an independent action as a cause and any negative effects. For example the substances which deplete the ozone layer pollute the atmosphere and contaminate water. Thirdly, problem resolutions concerning the differences between the developed and developing countries are especially necessary. This includes the stages of economic development, the living standard, and the contributions to factors, the degree of influence, and the responding ability. The fourth feature is that greenhouse gas emission is caused by energy use for all economic activities such as manufacturing, services, transportation, and agriculture, as well as everyday human life. Therefore, the problems cannot be solved without changing the current fundamental states of the economy and society.

### *3-2 Research trends*

**(1) Research trends in Europe and the USA**

In the USA where the concept of Sustainability Science was first proposed, the “Sustainability


**Figure 3** : Basic thesis and research topics of sustainability science concerning global warming

Prepared by the STFC based on Reference[15,28]

Science Project" was led by the Kennedy School of Harvard University from 2000 through 2003, and it was funded and started by the National Science Foundation (NSF) in the USA.[16] The forum activities, which were established through this project, have led to the Innovation on Science and Technology for Sustainability ISTS forum which has been developing with a wide variety of links,[17] and currently belongs to the American Association for the Advancement of Science AAAS. Various organizations contribute funds, such as the Federal Government, State Government and private sectors, and many research programs led by the universities are proceeding. (Table 3) In Europe, many similar research programs which are led by the United Kingdom, the Kingdom of Sweden and the Kingdom of the Netherlands are also in progress.(Table 4)

The topics taken up for the research vary from modeling the "resilience (adaptation ability)", and focusing on integration approaches of technology, ecosystems, and social systems, to focusing on human resource training for policy makers who are in charge of planning related policies in government organizations, as well as the leaders who will solve the issues at international organizations and private sectors through integrating (unifying) the analyzing skills in the science field and the skills of establishing political plans and measures. ( Table 5(a)) The subject social system scale varies as well, from the community of a regional society to the national level and the international society. (Table 3 and Table 4)

The researchers who grapple with the Sustainability Science are mainly in the fields of engineering, business administration, policy science, and biology. In addition, there is participation from various academic fields crossing the academic borders of Humanities, Social Science and Natural Science with problem solving approach. (Table 5(b))

The methodology is not necessarily adequately

**Table 3** : Research trends of sustainability science in universities of western countries

| University Base / program name | Main purpose / Research Topics | Department (Host underlined) | Classification |
|---|---|---|---|
| Columbia University earth science information network Kokusai center (CIESIN / US) http://www.ciesin.columbia.edu | Fusion of society / nature / information science. Coaction of human / environment. Sustainable environment, happiness, poor eradication. Suggest space mapping data and ESI (an Environmental Sustainability index) by United Nations millennium project. | CIESIN | Study |
| Ohio State University resilience center (US) http://www.resilience.osu.edu | Resilience (adaptability) modeling of an industrial system such as the manufacturing, transportation, energy, architecture, agribusiness, retail trade. Short-term risk management and long-term sustainability acquisition. | Unification systems engineering Architecture, public policy, business (environment / resources) | Study /GP |
| Wisconsin Matheson University Sustainability・global environment center (SAGE /US) http://sage.wisc.edu | Coaction of natural resources / health / security / global environment. Ph.D. program and post-doctoral researcher training. | SAGE | Study /GP |
| University of Texas Austin school Sustainable development center (US) http://utcs.org | Sustainable design / plan / development. Complementary program of study / education / community participation. | Architecture, architectural engineering, public, business | Study, education, service fusion /GP |
| Michigan State University system fusion / Sustainability Center (CSIS / US) http://csis.msu.edu | Creative system / field fusion (environmentology / social economics / population statistics) beyond a limit of arts, social science and natural science. COE establishment and researcher training concerning sustainability for region, nation and world | CSIS, environmental science, policy, plant ecology, pedagogical psychology, forest | Study /PG |
| Kansas State University environmental management / Sustainability Consortium (US) http://engg.ksu.edu/CHSR | Sustainability Science, sustainable development. Community participation. | Chemical engineering, agriculture | Study, education, service fusion /GP |
| Delaware university energy / environmental policy center (CEEP / US) Energy Environmental Policy Program http://ceep.udel.edu. academics/phd/enep.htp | Coaction between politics / economy / environment, and policy study. Educational program (environmental Dr. energy policy master /, Dr. technology / environment / social master /) of four subjects. | CEEP, agriculture natural resources, the humanities, engineering, the ocean, pedagogics, a public policy | Study, education, service fusion /GP |
| Clark University Environmental Science Program (US) http://www.clarku.edu/ departments/ES | Fusion of social science / physics / biological science. Department educational program comprising earth system science / environmental protection biology / environmental science policy courses. | Environmental science, economics, political science, chemistry, philosophy, physics, control | Education /UP |
| Environmental Science Policy Program (US) http://www.clarku. edu/departments/idce/ academicsGradESP.cfm | Integration of environment / technology / society / development. Understanding on environmental issues, creative solution skill, literacy, multiple cooperative skillEnvironment and health, sustainability of climate and energy, environmental management policy. Master educational program. | Environmental science / policy, earth science, biology, mathematics, calculation science | Study, education, service fusion /GP |
| The University of California Environmental science program (US) http://oie.ucla.edu/major.htm | Sustainable development. Coaction of human and environment. Influence of rapid increase of population and economic development to global environment | Environment, atmosphere / oceanography, engineering works / environmental engineering, earth science, biology, evolution biology, environmental health, | Education /UP |
| Michigan State University Environmental science policy program (US) http://www.environment.msu. edu | A fusion program about an environmental science policy. Ability for Model T and various research and management skill in various fusion areas for problem solving of complicated environmental issues Ph.D. program auxiliary specialty and a master's course program. | Environmental science / a policy, agnoromy, animal science, biochemistry, material chemistry, the other majority | Study, education, service fusion /GP |
| Arizona State University International Sustainability Institute (GIOS / US) http://sustainable.asu.edu | Cooperation by different fields / unification. Next generation leader training, corresponding to various problems (urbanization, sustainable energy / resources, aquatic resources / food shortage, biodiversity depletion, economic development and reformation of society, socioeconomic adaptability). | GIOS, architecture, landscaping, engineering works / environmental engineering, economy, ground physical science, a law, public policy | Study, education, service fusion |

| University Base / program name | Main purpose / Research Topics | Department (Host underlined) | Classification |
|---|---|---|---|
| University of Notre Dame Biology / environment / society international coupling program (GLOBES / US) http://globes.nd.edu | International coupling of biology / environment / society. Field fusion of natural science / humanities / laws Problem solving type leader training A Ph.D. program (NSF fund). | Biological science, mathematics, physics, chemistry, biochemistry, economy, dosage economy, philosophy, history | Study, education, service fusion /GP |
| Iowa State University Sustainable agriculture program (GPSA / US) http://www.sust.ag..iastate.edu/gpsa | Next generation agriculture sustainable in the society, economy and environmentNatural resources multi-purpose control. Systematic thinking, structure of problemsCooperation with different fields and leadership skill | Agriculture / creature systems engineering, agriculture education, animal science, anthropology, biology, economy, food science, others | Study /GP |
| Yoke University Sustainability・Innovation Institute (IRIS / Canada) http://www.iris.yorku.ca | Multi-field research group with 11 professors concerning sustainability from a school A community-based study service offer (sustainable Toronto) to Canadian Government Sustainable supply of water use of Mongolia etc. | IRIS | Study, education, service /UP / GP |
| Florida international university Latin America Caribbean center Sustainability Science Institute (ISSLAC / US) http://lacc.fiu.edu/centers_institutes | Problem solving type research concerning coaction of environment, society of Latin AmericaFusion of natural science and social science. Sustainable development promotion, integrated system for adaptation control, social education program. Forest community control in Mexico Integrated type community oriented research | Environment | Study /GP |
| University of California LA school Sustainability・Leader Program (US) http://www.anderson.ucla.edu/leadersinsustainability.xml | Multi-field type leader training concerning sustainability. | Management, laws, public policy, public health, application science, engineering, geological feature, economy, environment | Study, education, service /GP |
| Pittsburgh university Mascaro Sustainability Initiative (MSI / US) http://www.engr.pitt.edu/msi | Training of students in engineering through multi-field researches in order to establish a sustainable community infrastructure (NSF / Education Ministry fund) | Chemical engineering, the other university (Pennsylvania state establishment size, Carnegie Mellon Univ.) | Study, education, service /GP |
| Alaska Fairbanks University Resilience program (US) http://www.rap.uaf.edu | Integrate the approaches of biology / economics / policy science / community / community development, understand a local system function and aim at acquisition of sustainability of environment / economy / culture. Training of problem-solving skills concerning sustainability of a region , for scholars / policy makers / corporate management | North Pole biology, anthropology, biology, economy, geological feature, geography, natural resources control, policy | Study, education, service /GP |
| Loma Linda University Social policy / society study program (US) http://www.llu.edu/llu/grad/socialwork/phdmain.html | Acquisition of the integrated procedure that is necessary for the field of sustainable development policy. Agenda is: health / knowledge management / agriculture / natural resources, poverty control An fusion curriculum for Ph.D. programs of the fields of social science / social ethics / study procedure / statistics / information technology. | Social circumstances, the earth / biological science, public health, information geological feature | Study, education, service /GP |
| Harvard University international Development Center Sustainability Science Program (US) http://www.cid.harvard.edu/sustsci | Understanding of coaction of human / ecosystem. Research and development, improvement of community management Globalization and sustainable development. Ability development by international cooperation networking Sustainability of agriculture, biodiversity, city, energy / resources, health, waterFellows from post-doctoral researchers from graduate schools and industry-academia programs to participate in a project for 5 years at the shortest | International development center, Kennedy school, public health, medical treatment, education, laws, business | Study, education, service /PP |
| Pennsylvania Clarion University Sustainability / policy science program (US) http://www.clarionedu/departments/phys/sustainability | Foster problem solving skills by integrating analysis skill and policy making skillA wide range of human development for green business, state governments and NPO | Physics, a creature, chemistry, mathematics, communication, the human, geological feature, earth science, economy, philosophy | Study, education, service /UP |
| University of California San Diego school Environment / sustainability initiative (US) http://esi.ucsd.edu | Education and ability development for sustainable problem solvingInnovative cooperation home and abroad, or industry and academia Problem solving of region, nation and world | Oceanography | Study, education, service |

Note: Abbreviation: UP (Undergraduate Program), GP (Graduate Program), PP (Post-graduate Program)

Prepared by the STFC based on Reference [18]

established, but the discussions for the next phase of development, such as curriculum designs, career paths of researchers who participate, and the necessary partnerships, have been made rapid progress. This is possible through establishing a network among government, industry and academia centering on the universities as a base, and implementing various research projects in an integrated manner. (Table 6)

**(2) Status of Japan**

Based on the 2nd Science and Technology Basic Plan (FY2001 - FY2005), the Council for Science and Technology Policy (CSTP) established a Project Team, collaborating with ministries and government offices, for Technology to Prevent Global Warming, which was called the "Global Warming Research Initiative" (FY2002 - FY2006). This is aimed for the integrated promotion of climate change related research in Japan.[19] The initiative had three intentions; (1) to realize technology for reducing 6% of the greenhouse gas in Japan compared to 1990, which was in the First Commitment Period, (2) to propose and submit the scenario of greenhouse gas reduction, and (3) to establish the foundation to provide scientific knowledge and opinions for contribution to the decision making of climate change treaty framework, based on the purpose of international cooperation. This has established four programs in the field of climate change, which are the "synthetically monitoring of Global Warming," the "future forecast and climate change research," the "effects and risk evaluation" and the "responding policy research," and this has launched and promoted various researches in an integrated manner.

Under the 3rd Science and Technology Basic Plan (FY2006-FY2010), environmental sciences have been selected for one of four priority fields to be promoted, and they have specified the most important research topic as the "Global Warming and Energy Problem Resolution" in the implementation strategies by field. A new activity, however, which corresponds to the initiative operated under the 2nd S&T Basic Plan, has not been started as of today.

In this period, centered on five local universities led by the University of Tokyo, the Integrated Research System for Sustainability Science IR3S was started. The IR3S consists of the Planning headquarters, the research Headquarters of the five participating universities, and six cooperation organizations.(Figure 4) They all promote the integrated flagship project associated with the Sustainability Science focusing on the academic field each participant specializes in.

The IR3S' aim is to ultimately provide the measures, visions, standards and indicators in order to re-establish the systems underlying human existence, by defining and solving the occurrence mechanism of global problems from the view of "Sustainability." It also aims to establish the methodology of Sustainability Science, promote outreaching activities for societies, provide personnel training for research, periodically issue international academic papers, cooperate internationally, and practice wide-range activities in an integrated manner in order to build a world-class foundation and network for Sustainability Science.

### *3-3 Bibliometric of the IPCC 4th assessment report for quantificating trends of sustainability scinese*

The Sustainability Science is a newly integrated academic field and thus it is difficult to measure the development status quantitatively. On the item of problem solving for the Global Warming problems, however, the IPCC Assessment Report can be said to be the accumulation of scientific knowledge and opinions most strictly selected at the present time. Therefore, when comparing the contribution level by country in the IPCC Assessment Report, Japan's position on Global Warming problems in the research activities of Sustainability Science is measured qualitatively.

Since the 1st Assessment Report (in 1990), the IPCC has released an Assessment Report every 5 years. The basic content of the Assessment Report is mostly consistent, and consists of three reports prepared by the 1st Theory-Oriented Research Group (Natural Science Reasons: hereinafter called "WG1"), the 2nd Theory-Oriented Research Group (effects, adaptations, vulnerability: hereinafter called "WG2"), the 3rd Theory-Oriented Research Group (climate change mitigation: hereinafter called "WG3") and the synthetic report (SYR). It

**Table 4** : Research trends of sustainability science in universities of western countries

| University Base / program name | Main purpose / Research Topics | Department (Host underlined) | Classification |
|---|---|---|---|
| arXiv University (Spain) Environmental quality and sustainable development (Spain) http://wzar.unizar.es/servicios/epropios/oferta/194.html | Sustainable development, systematic thinking, sustainability index, environmental efficiency of natural resources/energy, social economy, poverty factor / causality / solution We supplement an education gap of the fields of fusion. Invite lecturers from inhouse and outside of the school, such as International NPO (Lead) For engineers, scientists, a managers, school teachers, government officials. A graduate school program aiming personnel training to create sustainable development. | Mechanical engineering, chemical engineering, environmental engineering, applied physics, public law, environment, an environmental education | Study, education, service fusion /PP |
| Sussex university Unification sustainability center of society / technology / environment (British STEPS) http://www.steps-centre.org | The international research hub established in October, 2006. Supported by Economic Social Research Council (ESRC) of UK Government Scientists / government officials / citizens / industry to participate in the program home and abroad ESRC provides the competitive research fund for 5-10 year projectAiming an integrated approach of technology / ecological system / society to realize sustainable and resilient society (adaptability). Topics to be set such as dynamics, governance, negotiation under uncertain conditions in the areas of "food and agriculture" “health and disease” and “waster and sanitation” Fostering the next generation social scientists who are able to make full use of dosage / analysis tool effective for the actual problems Develop a new methodology and evidence-based policy study | Development | Education |
| Utrecht university Sustainable development (Netherlands) http://www.geo.uu.nl/mastersd | Acquisition of technical knowledge / skill about sustainable development. For researchers, management and policy management in industry, academia and governmentAbility building for analysis, planning, implementation, and communication concerning sustianable development issues from a multiple views of humanities and natural scienceCooperation with universities in US, Canada and EuropeThe curriculum includes "energy / resources", "land use / environment / biodiversity", and “" environmental policy / control". | Copernicus Institute | Study, education |
| Maastricht University Unification assessment / sustainable development International Center (ICIS / Netherlands) http://www.icis.unimaas.nl | Understanding of the concept of sustainable development concerning ethics, laws, social economics / political science / environmental basics Quantitative assessment of sustainable development using the integrated assessment methodPractical understanding of governance method and business approaches from various viewpointAbility building for implementation of sustainable development and governance as a group member of government and industry. | ICIS | Study, education, service fusion /GP |
| Lunds University An international master program (LUMES / Sweden) about environmentology / Sustainability Science http://www.lumes.lu.se | Ability building for problem solving from various aspects through appropriate topic settings and mutual relations systemization for sustainable developmentCommunicative competence. Ability for analysis / measures drafting of complicated problems Adaptability to multi-culture / multi-environment | Sustainability studies center (LUCSUS), policy science, economic history, environment, an energy system, architecture, design, chemical engineering, geography, sociological jurisprudence | Study, education, service fusion /GP |
| Sustainable development (Sweden) http://www.uu.nl/internationalmasters | Sustainable energy / resources / land use, biodiversity, environmental policy / control. Sustainability analysis from an academic viewpoint of humanity and natural scienceA program for Masters Degree | Innovation / environmental science, chemistry | Study /GP |

| University Base / program name | Main purpose / Research Topics | Department (Host underlined) | Classification |
|---|---|---|---|
| Blekinge Institute of Technology Strategic leader program (MSLS / Sweden) http://www.bth.se/msls to prolonged possibility | Aiming leader training and international networking for strategic skills of sustainable development. Sustainable development, innovation research initiatives (SPIRT), environmental NPO “Natural Steps", and other universities such as Kunming University, China and other international institutions for cooperation | Engineering, management | Study, education, service fusion /PP |
| East Anglia University Tyndall Climate Change Research Center (UK) http://www.tyndall.ac.uk | Scientists / economists / engineers / social scientists participate in multi-field researches and dialogues to achieve sustainable society, with industry, government officials, press and citizens, to lead the world climate change policies in England and the world for mid and long term. Aiming to accumulate knowledge concerning sustainability contributing to actual policies and actionsIntegrated assessment / energy / adaptation, in addition to international policy / international development / city planning | Tyndall Climate Change Research Center, other universities (Cambridge, Oxford, Southampton, New Castle, Sussex University) | Study /PP |

Note: Abbreviation: UP (Undergraduate Program), GP (Graduate Program), PP (Post-graduate Program)

Prepared by the STFC based on Reference [18]

covers all the research topics which Sustainability Science intends to cover.(Figure 3)

The selection of IPCC Assessment Reports authors is subject to keeping objectivity in order to completely and comprehensively evaluates the scientific facts, and is based on strict rules excluding any political pressure.[22] The authors are classified into the following four types (kinds, classes) by their role:

(1) Coordinating Lead Authors (CLA):The author in charge of all assigned chapters, the decision maker of editing plan
(2) Lead Authors (LA): The author in charge of the assigned chapter
(3) Review Editors (RE): Supervises and advises during the review process
(4) Contributing Authors (CA):The person who collaborates in writing and provides needed information (data and documents)

The CLA and LA are selected from top-level research experts in each research field, who has been recommended by a government or an international organization.[23] This selection process is considered to have deviation from origins, genders and ages, but the country distribution, (Table 7) and the number of CLA and LA selected might show a distribution of influential and core researchers in a specific research field. Also, the authors of CLA and LA write the latest scientific knowledge and opinions in their assigned research filed, in principle, quoting the refereed theses which have been publicly announced in the academic periodicals. Therefore, the share of Japanese theses,(Table 9) in terms of theses quoted in the IPCC Assessment Reports, is thought to show the number of Japan research activities. On the other hand, a CA collaborates in writing and provides the needed information for the parts the LA cannot do. In principle, the selection of the CA is made by the LA. As the CA, a researcher who publicizes the influential international theses regularly, participates in and presents at the international conferences, and shows his/her presence in the international research community is selected. Therefore, the distribution of selected CA numbers by country (Table 8) is thought to show the distribution of researchers who show their international presence in their specific research field.

Accordingly, the IPCC Assessment Report is thought to make the research activities of each country and the international presence of researchers evident, by comparing the number of authors in a research field and theses quoted from a country.

Referring to the Assessment Reports by each WG[2–4] in the 4th Assessment Report of IPCC which was publicized in 2007, the number of CLA, LA and CA are summed up by the country and institutions in which they belong. The ratio of

**Table 5** : Actual sustainability science of universities of western countries

**a)** : Program focus

| Topic | The number of the programs |
|---|---|
| Human-nature Interactions | 12 |
| Policy / Decision-Making Relevance | 11 |
| Community Engagement / Communication | 10 |
| System Thinking | 8 |
| Sustainability as 3-Pronged (ecological, enviro, social) | 8 |
| Student as change agent | 5 |

**b)** : Disciplinary distinction

| Fusion | The number of the programs |
|---|---|
| Inter-disciplinary | 18 |
| Multi-disciplinary | 9 |
| Trans-disciplinary | 4 |
| Cross-disciplinary | 2 |

**c)** : Collaborating departments

| School/ Department | The number of the participation | Department | The number of the participation | Department | The number of the participation |
|---|---|---|---|---|---|
| Engineering | 14 | Environmental science | 6 | Geology | 3 |
| Economics | 12 | Humanities | 6 | Public Affairs | 3 |
| Policy science | 11 | Laws | 6 | Education | 3 |
| Biology | 10 | Anthropology | 5 | Health / Medicine | 3 |
| Business/ Management | 10 | Chemistry | 5 | International development | 2 |
| Arts & science | 8 | Geography | 4 | Mathematics | 2 |
| Architecture | 7 | Physics | 4 | Sociology | 2 |
| Agriculture | 6 | Urban planning | 4 | | |

**d)** : Funding sources

| | The number of the programs |
|---|---|
| University | 16 |
| Research Contracts | 12 |
| NSF (Federal research bodies) | 8 |
| Unspecified “private” source | 8 |
| Government (USA) | 7 |
| Private foundation grant | 5 |
| Student fees | 5 |
| Government (Europe) | 5 |
| Corporate | 4 |
| Government (non-USA/Europe) | 3 |

Source: Reference [18]

the numbers of CLA, LA and CA to the whole is shown in the Table 7 and Table 8. Also, in the case of theses quoted by each WG in the Assessment Reports, the theses of which head author has a Japanese name are counted as Japan thesis, and their shares to the total number of theses quoted are compared by WG and shown in the Table 9.

The ratio trend that Japanese occupy as authors in the three fields of WG1, WG2 and WG3, CLA/LA is sixth and for CA is seventh among the participating countries in the 1st Theory-Oriented Research Group. Their ratios totals are from 4% to 5%. In the 2nd Theory-Oriented Research Group, the Japan’s position is relatively low compared to its positions in other Theory-Oriented Research Groups. The CLA/LA ratio is tenth and the CA ratio is fourteenth among participating countries, and their ratios totals has been kept down to about 2% to 3%. The Japan’s position in the 3rd Theory-Oriented Research Group is relatively high, as theca/LA ratio is second and the CA ratio is third among the participating countries, and their ratio total is 5% to 8%. If these numbers are compared to the number share of theses not-quoted in the whole environmental field in Japan, which is 7% ,[24] it can be said that Japan more than adequately contributes in the subject fields of 1st and 3rd Theory-Oriented Research Group. On the other hand, in the subject field of 2nd Theory-Oriented Research Group, not only is the contribution low from the international-level viewpoint, but the average of the whole environmental field in Japan is also kept at a low level.

The ratio of the papers by Japan, among all the quoted papers in the IPCC Report (Table 9) shows an improvement of levels in all Theory-Oriented Research Groups, for every revision issued, when comparing it with the 1st Assessment Report. However, if comparing the ratio of Japanese CLA/LA or CA in the 4th Assessment Report and the ratio of Japan in all quoted material, it shows the ratio of Japanese papers have decreased in Theory-Oriented Research Groups as a whole. This means that a difference still exists when compared to the top level European and American researchers, from the aspect of high quality research expansion as a whole. The enrichment of the research class and their international presence has improved year by year, due to the fact that top-level Japanese researchers showed their contributions as they were selected as CA etc.,. The share of Japanese theses in the field of weather forecast and marine

**Table 6** : Topics extracted from sustainability science research program progress of universities in western countries

**a)** : Program Challenges

| Challenge | The number of the programs |
|---|---|
| Integrating natural and social science research / working across academic units | 18 |
| Funding : researcher funding & student scholarships | 15 |
| Curriculum design | 9 |
| Maintaining academic rigor (balance of applied and basic research) | 7 |
| Creating public-private partnerships/collaborations | 4 |
| Rewarding faculty for interdisciplinary work | 4 |
| Marketing / attracting students | 4 |
| Determining what methods should be taught & used | 3 |
| Institutional structure (types of degree programs / number of electives allowed) | 2 |
| Quality / Quantity of researchers | 1 |
| Career tracks in sustainability science | 1 |
| Creating practical real-life projects for students | 1 |
| Scale (global vs. local) | 1 |
| Ensuring diversity within the learning environment | 1 |
| Student Retention | 1 |

**b)** : Partners needed

| Partner classification | The number of the programs |
|---|---|
| Additional university department | 25 |
| Other university (domestic) | 19 |
| Region/State/Federal Government | 14 |
| Other university (overseas) | 12 |
| General domestic | 12 |
| General overseas | 12 |
| Industry | 6 |

Note : The number of programs among 49 investigation subject programs of References

Source : Reference [18]

meteorology has been especially improving their levels. This is thought to be a result of the large-sized projects which have been implemented, such as the Global Simulator and the Argo Plan.

On the other hand, when looking at the situations in other countries, the United States, the United Kingdom and Canada regularly show their high-ranking presence in all Theory-Oriented Research Groups. Especially, the high-level performances of United States' research, even though they seceded from the Kyoto Protocol, is outstanding and gaining a lot of attention. In these top level countries, the international research is conducted adequately for the peripheral countries and regions as well as vulnerable regions, other than the research for their own land. The Japanese research is thought to be insufficient for its contribution from the aspect of international cooperation.

In terms of the other countries, China and India, which do not have any obligations of greenhouse gas reduction by the Kyoto Protocol, it can be said that they have a presence which is almost the same level of Japan. Especially in the research field in which the 2nd Theory-Oriented Research Group covers the implementation measures, it can be said that China and India show a stronger presence than Japan, and are closer to the European and American presence. In the future, for the purpose of establishing the framework for an implementation plan to the COP15 (will be held in Copenhagen) in 2009 in accordance with the Bari Action Plan, it is necessary to observe the research trends of China and India, which have performed leading role in the discussions among developing countries.

The relationship with China as a neighbor country, in particular is needed. This can be accomplished by inviting Chinese researchers more often to the Sustainability research bases in Japan, starting international cooperation between both countries, networking the associated government officials in both countries, networking the industry sectors to conduct research for

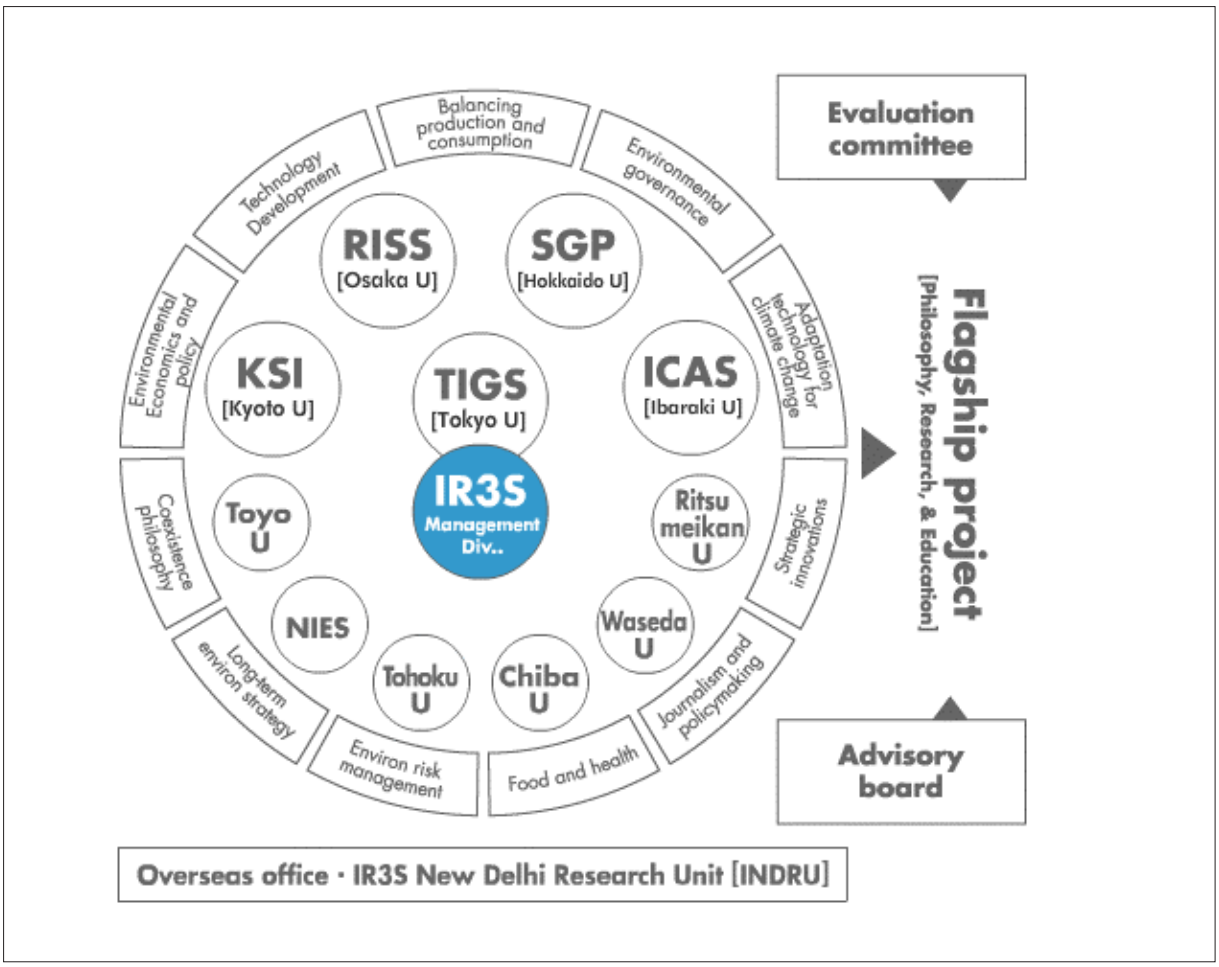


**Figure 4** : IR3S / Integrated Research System for Sustainability Science members

Source : Reference [20]

adaptation measures, and promoting flagship projects. In order to implement this, it is desirable to review the supporting system of the international cooperative research by the governments. Not only for the environmental field, but in international cooperation in terms of past scientific technology, various associated governmental organizations have practiced individually for each political purpose at each stage of research, development, practical implementation and technology transfer. In recent years, a movement has been started to review the diplomatic relations of scientific technology in whole by a process intending to solve the issues. Aiming at improving the problem solving abilities of developing countries through scientific technology cooperation, the Ministry of Education, Science and Culture and the Ministry of Foreign Affairs have discussed dispatching manpower, and this has been examined by international cooperation research, the Official Development Assistance (ODA) in cooperation with the Japan Industrial Counselors Association (JICA) and the Japan Science and Technology Agency (JST). In addition to these groups, the Ministry of Economy, Trade and Industry (METI) is implementing international cooperation projects through the International Center for environmental Technology Transfer (ICETT), Energy Conservation Center, Japan, New Energy and Industrial Technology Development Organization (NEDO), and other bodies. The Ministry of Agriculture, Forestry and Fisheries has individually implemented international cooperation projects through Japan International Research Center for Agricultural Science (JIRCAS). It is necessary to enforce cooperation between these ministries.

The following shows the status of research investments in Sustainability Science done by the government of Japan. Figure 5 shows the status of scientific research funds in recent years and the number of supported projects by each ministry as a comparison for each research topic of the Sustainability Science.[26] It is mostly occupied by the number of research topics selected in the fields

of (2) the carbon cycle and carbon concentration, (3) global warming and climate change of the 1st Theory-Oriented Research Group, and (6) the mitigation measures of the 3rd Theory-Oriented Research Group. It is clear that the number of selected research topics is extremely small in the fields of (1) the social structure and GHG emission, (4) environmental and social effects, (5) implementation measures, and (7) the social system. The degree of Japanese contribution is low in the research fields of effects, adaptations, and vulnerability, which are the subjects of 2nd Theory-Oriented Research Group in the IPCC Assessment Reports. It is considered that the government research investment funds are relatively small for these fields, or that researchers do not exist in those fields at all.

For the research areas such as effects, adoptions, and vulnerability, which are the subjects of 2nd Theory-Oriented Research Group, there is a need for problem solving approaches in Sustainability Science and they should correspond to the boundaries and integrated areas of natural science, social science and humanities.

As a factor for government research investment funds being relatively small to these fields, it is considered that there are the peculiar issues in Japan which prevent the cooperation to be promoted in the boundaries and integrated areas of natural science, social science and humanities. Table 10 shows the research topic which was given at the Council for Science and Technology Policy,[27] and the ways solving the issues are discussed at the same time. In the future, the discussion will be further enhanced for parties concerned to additionally enforce, proceed and promote specific concrete countermeasures.

As mentioned earlier, the universities in western countries were encouraged to proceed with project research and curriculums on the Sustainability Science, with the support of central and local governments. A wide range of cooperative research aiming to solve problems are being developed, by crossing the boundaries of natural science, social science, humanities and government, industry, and academia flexibly and systematics. By benchmarking such prominent cases in Europe and the United States, it is desirable to establish a concrete policy for promoting the cooperative research.

## 4 Conclusion and Proposal

Under the circumstances of expansion and the complication in the areas related to Global Warming, Sustainability Science has been further studied throughout the world as an approach of solving problems while crossing the boundaries of academic fields in the past. Considering this background, the expected issues are summarized and the following opinions are offered in order to develop Sustainability Science in Japan in the future.

**Table 7** : IPCC fourth assessment report: CLA/LA ratio and rank per country

| | Working group 1 (The physical science basis) | | Working group 2 (Impacts, adaptation & vulnerability) | | Working group 3 (Mitigation of climate change) | |
|---|---|---|---|---|---|---|
| 1 | U.S.A. | 22.5% | U.S.A. | 10.0% | U.S.A. | 18.3% |
| 2 | The U.K. | 10.4% | Australia | 6.3% | Japan | 7.9% |
| 3 | Australia | 8.1% | England | 5.9% | China | 6.8% |
| 4 | France | 7.5% | Canada | 5.9% | The Netherlands | 6.3% |
| 5 | China | 5.2% | India | 5.0% | Germany | 5.2% |
| 6 | Japan | 5.2% | Germany | 4.5% | England | 4.7% |
| 7 | Canada | 5.2% | Russia | 3.6% | Canada | 4.2% |
| 8 | Germany | 5.2% | Mexico | 3.2% | India | 4.2% |
| 9 | India | 4.6% | China | 2.7% | Australia | 2.6% |
| 10 | Norway | 3.5% | Japan | 2.7% | Russia | 2.6% |

Prepared by the STFC based on Reference[2-4]

**Table 8** : IPCC fourth assessment report: CA comparison ratio and rank of countries

| | The first working committee (grounds of natural science) | | The second working committee (influence / adaptation / vulnerability) | | A tertiary working committee (relaxation of climate change) | |
|---|---|---|---|---|---|---|
| 1 | U.S.A. | 34.0% | U.S.A. | 17.8% | U.S.A. | 13.3% |
| 2 | The U.K. | 12.4% | The U.K. | 12.6% | The Netherlands | 5.8% |
| 3 | Germany | 8.1% | Canada | 6.6% | Japan | 4.7% |
| 4 | France | 6.2% | Australia | 5.9% | The U.K. | 3.7% |
| 5 | Canada | 5.3% | Germany | 3.5% | China | 3.7% |
| 6 | Australia | 4.9% | France | 3.3.% | Canada | 3.3% |
| 7 | Japan | 4.0% | New Zealand | 3.0% | France | 3.3% |
| 8 | Switzerland | 3.5% | India | 3.0% | Germany | 3.0% |
| 9 | China | 3.4% | China | 2.8% | Austria | 2.8% |
| 10 | Norway | 1.9% | The Netherlands | 2.8% | India | 2.6% |
| | | | 14. Japan | 1.9% | | |

Prepared by the STFC based on Reference[2-4]

**Table 9** : Ratio of japanese academic papers of all quoted documents of IPCC assessment report

| | Working Group 1 (The Physical Science Basis) | Working Group 2 (Impacts, Adaptation & Vulnerability) | Working Group 3 (Mitigation of Climate Change) |
|---|---|---|---|
| The first report (1990) | 0.7% | 1.8% | No references |
| The second report (1995) | 1.1% | 2.2% | 1.3% |
| The third report (2001) | 2.2% | 1.8% | 2.4% |
| The fourth report (2007) | 3.4%<br>★ The field with many Japanese papers<br>・Ocean climate change observation: 8.0%<br>・Climate model assessment: 6.0%<br>・Global climate forecast：7.2%<br>・Regional climate forecast：4.4% | 1.7% | 2.9% |
| Share of Japanese papers of all concerning environment/ share of the number of quotation taken | 7.7% / 7.1% | | |

Prepared by the STFC based on Reference[14]

### (1) Promote the problem solving based research and accumulate knowledge centering on universities

In the same manner as Europe and the United States, the knowledge as the Sustainability Science should be systemized, as the universities play a key role to promotion in Japan. The University of Tokyo has started some approaches in part, such as a cooperative research organization. However, the first action should be to increase and accumulate the associated researchers' knowledge, by promoting a problem-solving-based cooperative research based on the needs of policy making. In order to achieve this, a concrete target is needed to set such an aim, in order to have a large contribution to WG2 of IPCC, etc.

### (2) Use power of private sectors and secure various career paths

In order to further promote Sustainability Science

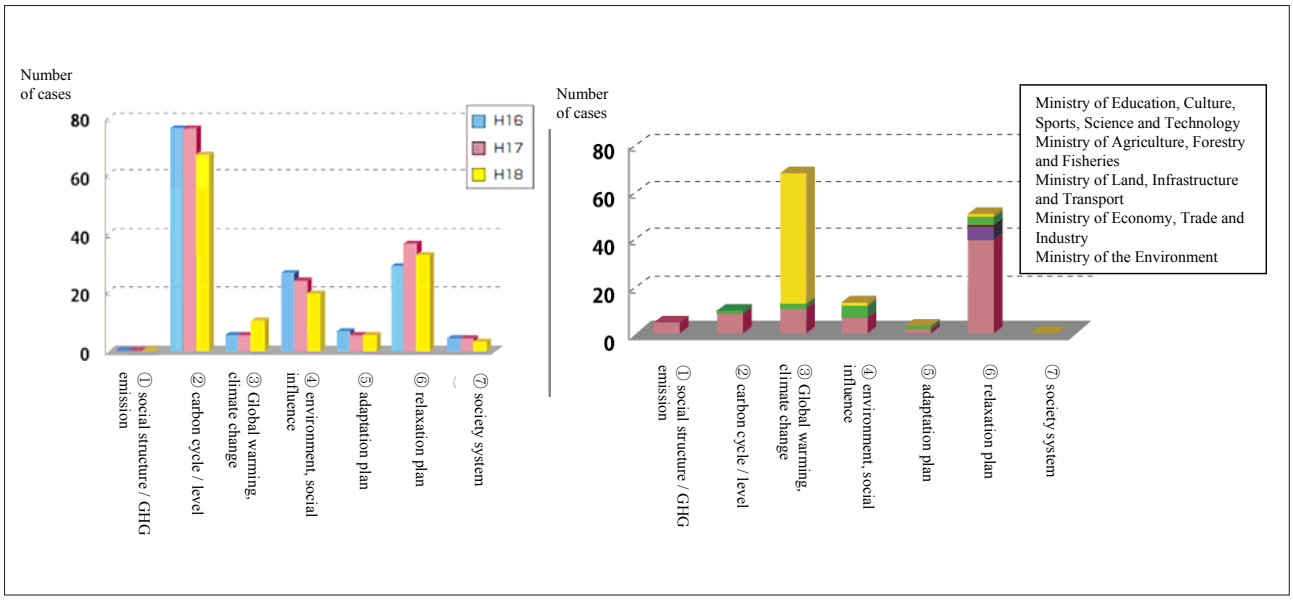


**Figure 5** :Number of projects adopted per research topics in Japan
( left: science laboratory, right: ministries project)

Source : Reference[26]

research, which leads to problem -solving based measures in universities and public research institutions in Japan, the topics that should be considered from Japan's viewpoint should be done through exchanges with policy makers. Moreover, by making closer relationships between the universities and the industries, the technological capability in the environmental field and private sector's vitality should be used for promotion of research in the universities for Sustainability Science, as this is an aspect that Japan is proud of. If the universities provide the practical study opportunities and the places to establish wider human relationships with the industries, it would be possible to further improve human resources. If human resource development meets with the industrial needs, implementation of the problem solving based research in the universities will increase employment opportunities for private sectors, and for planning and corporate management divisions. This may help secure future posts for young researchers in this field and other various career paths.

**(3) Improve presence in the international research communities through the new research initiatives**

In the IPCC, the impending activities for 5th Assessment Report (AR5) have already started, and are expected to be publicized in around 2013. In order for Japan to further contribute to the AR5 in terms of the research, needless to say, it is considered necessary to improve its presence in the international research communities, and each researcher should announce their research results of Sustainability Science by academic papers in English, in order to actively participate in international conferences, etc. In addition, an organization to promote associated research is essential in Japan, for promoting an integrated problem-solving based research approach, such as the "Global Warming Research Initiatives", which was established in the Council for Science and Technology Policy during the period of 2nd Basic Plan of Science and Technology. It is important to increase the Japan's presence with their research results, by establishing a framework to increase the opportunities to strongly promote the research papers to international research communities. This will require networks provided by the Initiative. The human network crossing the boarders of countries will as a result be expanded, and this will contribute to set research topics to meet the needs of international societies. It will then create a favorable cycle for researchers to appeal their research results with bigger impact to the world.

**(4) Benchmarking the developing countries and the international cooperative research network to lead the public opinions of the international community**

Japan did not tackle the international cooperation research for Sustainability Science adequately for

**Table 10** : Problems associated with the cooperative researches between environmental field and humanities sociology field

| Issue | Solution |
|---|---|
| 1. Research project administration led by natural science researchers<br>As problem solving type of projects of environmental issues are raised mainly by researchers of natural science, in most cases, they ask researchers of humans science later. Therefore, it is hard to share the problem consciousness among them, consequently lack of involvement and achievement of the researchers of human science.<br><br>2. Problems concerning arts and social science<br>In the research communities of human science field in Japan, problem-solving type researches are not always appreciated. No incentives for them to positvely tackle the issues.<br><br>3. Lack of common understanding<br>Lack of understanding on predicate and study logics of natural science and social science system.<br><br>4. Lack of information exchange<br>Lack of information exchange with policymakers or NGO etc. who directly involved in the real environmental issues<br><br>5. Fostering young researchers<br>There is lack of instructors to teach young researchers of necessary skills (wide range of knowledge and specialty) for the environmental researches of problem-solvingYoung researchers hardly draw their future career path in the new field. | 1. Promotion of policy study by collaboration of liberal arts and science<br>In order to achieve the environmental innovation aiming sustainable society, it is essential to promote the problem-solving type researches. More strong and broader policy studies to realize the results of studies into the reality are need. Study promotion of problem solution type is indispensable for the environmental innovation realization that aimed at sustainable society, and expansion should strengthen a policy study to tie result to a real problem.<br><br>2. Establishment / reinforcement of policy study network<br>It is necessary to establish a network between policy makers, NGO and researchers who intend to solve problems, in order to achieve the results reflecting on the policy making by using the research seeds of science and humanities<br><br>3.Activation of Exchange of Personnel<br>By promoting exchanges of personnel between the laboratories and administration/policy making and raise the issue of political needs, the researches are conducted aiming to implement the result of studies for policy making eventually.<br><br>4. Enhancement of Human Development<br>It is necessary to foster young researchers by introducing sub-curriculum system or enhancement of the context of the curriculums beyond the border of different fields, in order to eliminate the barriers of the education system to separate humanities and science. |

Source : Reference[27]

oversea areas, though it is necessary for promotion in the future. In addition to this, universities and public research institutions should make efforts to increase the opportunities of international cooperative research independently. The Japanese government and industries should also be required to participate in the action actively.

It may be necessary to establish an international cooperative research network through the adaptability measure research and flagship projects, in cooperation with government officials and the industries of other countries, by actively inviting researchers, especially from China and India, for Sustainability Research of Japan. . Such networking is effective and useful for the private sectors in Japan, which would have expertise in the environmental field, in order to plan a new business model establishment in developing countries, starting with China, one of the promising markets of the future. Through collecting local information with high quality and establishing human relationships, it will be possible to promote the practical use of research promptly by integrating a new technology with the implementation measures of the associated countries from an early the stage. It is also effective for researchers to strategically bring up research and development topics. Enriching the area of internationally cooperative research, will define and help make understood the political needs in areas other than within its country. This is thought to be an effective way to increase the contribution level of Japan in solving various issues in terms of the IPCC Assessment Report.

### (5) Enforce the cooperation among the associated ministries on international cooperation projects in the environmental field

A review on the current status is required in order to promote international cooperation on the problem solving based Sustainability Science research, as mentioned above. In the past, various associated organizations of the ministries and departments conducted support individually for not only environmental issues, but also for promoting international cooperation in science and technology, and in each phase of research, development, practical approach and technical transfer. It is now important to promote practical problem-solving based Sustainability Science research in international cooperation projects for the environmental field, through the initiatives of the Council for Science and Technology Policy, by improving cooperation between various ministries and departments.

## 5 Conclusion

Japan hosts the G8 Summit which will be held in Toyako in July 2008 and the Global Warming problem is planned to be the main agenda. The Global Warming problem is an urgent issue for Japan in the current situation. At the Davos Forum in January 2008, the Prime Minister Fukuda mentioned when he presented the "Cool Earth Promotion Program",[28] is that the keyword for confronting the challenges of the 21st century is the "participation of all relevant stakeholders" and the necessity of cooperation among government, industry, civil society, and academia. This will provide a good opportunity for all associated scientists in Japan to question themselves on how they contribute to the Global Warming issues and to appeal once again, the Sustainability Science of Japan.

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