Kyoto University Global COE Program
京都大学グローバルCOEプログラム

Energy Science in the Age of Global Warming

地球温暖化時代のエネルギー科学拠点

— Toward a CO2 Zero-emission Energy System —
— CO2ゼロエミッションをめざして —

Self-Inspection and Evaluation Report 2010

平成22年度 自己点検・評価報告書

Kyoto University Global COE Program

Energy Science in the Age of Global Warming

– Toward a CO2 Zero-emission Energy System-

Self-Inspection and Evaluation Report

2010

CONTENTS

1. Introduction

From FY2008, four departments of Kyoto University, Graduate School of Energy Science, Institute of Advanced Energy, Department of Nuclear Engineering, Research Reactor Institute have joined together, and also with the participation from Institute of Economic Research have been engaging in "Energy Science in the Age of Global Warming - Toward a CO2 Zero-emission Energy System " for a Global COE Program of the Ministry of Education, Culture, Sports, Science and Technology under the full faculty support taking advantage of characteristics of the university.

Securing energy and conservation of the environment are the most important issues for the sustainable development of human beings. Until now, people have relied heavily on fossil fuels for their energy requirements and have released large amounts of greenhouse gases such as carbon dioxide (abbreviated to CO2 below). CO2 have been regarded as the main factor in climate change in recent years. It is becoming a pressing issue in the world how to control over the CO2 release. The energy problem cannot be simply labeled as a technological one, as it is also deeply involved with social and economic elements. It is necessary to establish the “Low carbon energy science” in the interdisciplinary field adding the social science and the human science to the natural science.

This program aims to establish an international education and research platform to foster educators, researchers, and policy makers who can develop technologies and propose policies for establishing a scenario toward a CO2 zero-emission society no longer dependent on fossil fuels, by the year2100. In the course of implementing the Global COE, we place the GCOE Unit for Energy Science Education at the center, and we proceed from the Scenario Planning Group, the Advanced Research Cluster to the Evaluation, forming mutual associations as we progress. The Scenario Planning Group sets out a CO2 zero emission technology roadmap and establishes a CO2 zero emission scenario. They will also conduct analysis from the society values and human behavior aspect. The Advanced Research Cluster, as an education platform based on research, promotes the socio-economic study of energy, study of new technologies for solar energy and biomass energy, and research for advanced nuclear energy by following the road map established by the Scenario Planning Group. Evaluation is conducted by exchanging ideas among advisors inside and outside of the university and from abroad, to gather feedback on the scenario, education, and research.

For education, the central activity of the Global COE, we establish “the GCOE Unit for Energy Science Education” and select students from the doctoral course, and foster these human resources. The students plan and conduct interdisciplinary group research containing both the social and the human science and the natural science toward CO2 zero emission at the initiative of the students themselves. The students will acquire the faculty to survey the whole “energy system” through participation in scenario planning and interaction with researchers from other fields, and apply it to their own research. This approach is expected to become a major feature of human resources cultivation. We will strive to foster young researchers not only who will be able to employ their skills and knowledge with a wide international perspective as well as expertise in their field of study in order to respond to the needs of the society in terms of the variety of energy and environmental problems, but who will also lead people to a 21st century full of vitality and creativity, working towards harmony between the environment and mankind.

In FY2010, we continuously carried on full-scale operations at the education programs of the students, and also promoted the study at both the Scenario Planning Group and the Advanced Research Cluster earnestly. In order to report the developments and to discuss the future activities widely, we held the Second International Symposium of the Global COE titled “Zero-Carbon Energy, Kyoto 2010” on August, 2010 and the annual symposium of the Global COE on January, 2011. We also made a strong effort to the international exchange promotion activities such as co-hosting SEE (Sustainable Energy and Environment) forums held in Vietnam on September, 2010 and other related seminars and symposiums. We also established Network of Excellences (NOEs) to promote international collaborative research. We planned and conducted the Nuclear Energy Seminar in Thailand where Japanese experts gave various lectures for nuclear energy. We present here the self-inspection and evaluation report.

Program Leader Takeshi Yao

2. Purposes of the Program

Greenhouse gas emission (hereinafter called CO2 emission) is regarded as the main factor in global warming as stated in the IPCC report in 2007. A shortage of fossil fuels by the end of this century is also predicted. Consequently, showing possible paths to achieving a worldwide zero CO2 emission system independent of fossil fuels is not only a pressing issue for the world but also a research topic that should be initiatively pursued by Japan, as a developed country but poor in terms of energy resources. In energy issues, not only the natural science, but also the social science that seek new social systems and human science that consider social way are also deeply related. It is necessary to establish the "Low carbon energy science" in the interdisciplinary field adding the social science and the human science to the natural science.

This program aims to establish an international education and research platform to foster educators, researchers, and policy makers who can develop technologies and propose policies for establishing a scenario toward a CO2 zero-emission society no longer dependent on fossil fuels, by the year 2100. The students will acquire the faculty to survey the whole "energy system" through participation in scenario planning and interaction with researchers from other fields, and apply it to their own research. This approach is expected to become a major feature of human resources cultivation.

In the course of implementing the Global COE, we placed the GCOE Unit for Energy Science Education at the center, and we proceed from the Scenario Planning Group, the Advanced Research Cluster to the Evaluation, forming mutual associations as we progress. The Scenario Planning Group sets out a CO2 zero emission technology roadmap and establishes a CO2 zero emission scenario. They will also conduct analysis from the society values and human behavior aspect. This task is provided as an education platform, and is made useful for human resources development. The Advanced Research Cluster, as an education platform based on research, promotes the studies by following the road map established by the Scenario Planning Group. As Energy Science Research for no CO2 emission, from the point of view that the main cock should be turned off first, we targeted at Renewable Energy (Solar Energy and Biomass Energy), Advanced Nuclear Energy (Fission and Fusion), and Socio-economic Study of Energy because the energy issues cannot be simply considered as a technological problem, but it is deeply related to the social and economic elements. Evaluation is conducted by exchanging ideas among advisors inside and outside of the university and from abroad, through the establishment of an advisory committee consisted of external experts, implementation of external evaluation by external evaluating committee, implementation of self-inspection and evaluation and so on, to manage the platform by gathering feedback on the scenario, education, and research.

For education, which is the central activity of the Global COE, we establish "the GCOE Unit for Energy Science Education" and select students from the doctoral course, and we foster core human resources by making the students of the Unit participate in the Scenario Planning Group and the Advanced Research Cluster and receive a practical education.

The fundamental principle of the GCOE Unit for Energy Science Education is to foster a human resource:

(1) Who has comprehensive ability to have a profound knowledge regarding the energy and environmental issues, to understand both the social and human scientist and the natural scientist, and to carry out collaborative work,

and

(2) Who has independence to organize a research group for the intended research, and to perform the research cooperating with other researchers,

and

(3) Who has internationality to have an international perspective, communication ability, and world-class standard research ability,

and

(4) Who has potential to contribute in solving the energy and environmental issues which relate deeply to the sustainable development of human beings.

The "CO2 zero emission education program" provided by this unit has made the following compulsory subjects:

(1) "Open recruitment group research" to plan and conduct interdisciplinary group research containing both the social and the human science and the natural science toward CO2 zero emission at the initiative of the students themselves.
(2) "Advanced research" to participate in the Advanced Research Cluster as an independent researcher and to master creativity and independence.
(3) "Field training" to visit field site such as nuclear power plant or waste power plant or etc. and to make practical learning.
(4) "Research presentation" to make research presentation at an international congress or an industry-academia cooperate symposium or an international workshop.

Furthermore, the following subjects are also provided:

(5) International education through classes in English, invitation of researchers and strategists from abroad.
(6) Long-term overseas education and acceptance of foreign students.

And also, students in this unit are recruited as research assistants to provide adequate economic support. Annual wage system program-specific educators and researchers are recruited by international open recruitment, then are joined the scenario planning or advanced research as independent researchers, and are fostered as practical researchers. They also instruct the students' research, are cultivated their instructing skills, and are fostered as researchers who inherit the human resources cultivation to the next generation.

Furthermore, in order to transmit the achievement of this platform to public, we will promote,

(1) Information transmission through website,
(2) Publication of quarterly newsletters in English and Japanese,
(3) Hosting domestic and international symposiums and activity report meetings,
(4) Co-hosting related meetings domestic and international such as SEE (Sustainable Energy and Environment) forum and so on,
(5) Hosting of an industry-government-academia collaboration symposium and citizen lectures.

Based on the above-said activities, we foster every year academic researchers who will inherit the human resources cultivation, industrial researchers who will put the research achievements into practice, policy makers, and strategist who will support an international organization as becoming government representatives of the future COP.

And the followings are expected as the social value and the pervasive effect,

(1) Contribution toward realizing CO2 zero-emission, and policy proposal coordinated with government and autonomy, domestic or abroad, and international agencies,
(2) Spread of Energy Science as an interdisciplinary academic field and provide of new approach for the education and the research,
(3) Establishment of information channel, human exchange path and education system to solve the energy issues,
(4) Contribution to utilization of nuclear power with improved social acceptance,
(5) Contribution to prevention of global warming and energy security,
(6) Spread of the effective achievements to the south-east Asian Nations through international cooperation such as the SEE forum, activities at platform universities and so on.

In FY2010, we managed the organization set up last year to promote the program earnestly. The following activities were carried out.

1. GCOE Unit for Energy Science Education

(1) Implementing the education program and curriculum
(2) Open recruiting, detailed checking and grant for the Group Research
(3) Hearing and evaluation for the achievement of the Open Recruitment Group Research by the Scenario Planning Group
(4) Recruiting research assistants (RA) and teaching assistants (TA)

(5) Implementing the Overseas Study
(6) Hosting the GCOE Energy Seminars

2. Scenario Planning Group

(1) Construction of a CO2 zero-emission technology roadmap
(2) Planning of a CO2 zero-emission scenario
(3) Organizing the Scenario Strategic Research Committee as a place where information and ideas exchange between Global COE Scenario Research Committee and industry for issue of energy and environment
(4) Promoting the Open Recruitment Group Research at the GCOE Unit for Energy Science Education
(5) Holding Scenario Research and Advanced Research Group Joint Meeting

3. Advanced Research Cluster

(1) Drastic improvement measures of energy efficiency incorporating production, consumption and waste cycle.
(2) Study of novel technology for utilizing solar light energy to electric power or material transformation effectively.
(3) Characterization of biomass resources for biofuel production. Framework design for biomass utilization.
(4) Research on new-type safe and advanced nuclear reactors and accelerator driven subcritical reactors. Study of fundamental technology for nuclear fusion reactors.

4. International Exchange Promotion Committee

(1) Information transmission through website.
(2) Publication of newsletters in English and Japanese.
(3) Hosting the International Symposium and publication of the proceedings in English.
(4) Hosting the Annual Meeting.
(5) Hosting the industry-government-academia collaboration symposium and citizen lectures.
(6) Co-hosting related meetings domestic and international and making spread of the effective achievements to the south-east Asian Nations.
- Managing SEE (Sustainable Energy and Environment) forum, an Asia-Pacific academic forum for global climate and energy security issues of common concerning among an Asia-Pacific region.
- Affiliating CEREL (Council of Energy Research and Education Leaders), that of graduate schools and centers at universities of USA, for the first organization outside USA.

(7) Sponsoring Nuclear Energy Seminar in Thailand.
(8) Promoting exchange with Africa and South America nations.

5. Self-Inspection and Evaluation

(1) Publication of Annual Report in English and Japanese.
(2) Implementation of a self-inspection and evaluation and publication of the report in English and Japanese.

6. Advisory Committee and External Evaluation Committee

(1) Holding of the Advisory Committee.

3. Organization

3.1 Organization and Education/Research Program

Objective of this program is to formulate international center of education and research to foster distinguished researchers and policy-makers who can, respectively, invent new technologies and propose new policies to realize the scenario toward the zero CO2 emission energy system without utilizing fossil fuels. From the following viewpoints:

1) To prescribe energy supply and demand scenarios toward a zero CO2 emission system required for the latter half of the 21st century reflecting the results from advanced research clusters

2) To promote research tasks of socio-economic energy research, renewable energy research, and advanced nuclear energy research, in cooperation with the Scenario Planning

3) To give doctoral students an experience of mutual interaction with researchers in other fields through their own participation into scenario planning, to acquire the ability of globally looking down at entire energy system and to foster young researchers

GCOE Unit for Energy Science Education (GCOE Unit) comprising about 30 selected doctoral students per academic year from the Graduate School of Energy Science and the Department of Nuclear Engineering is set up in the center of this program as shown in Fig. 3-1 and a unique curriculum is formulated. Students belonging to the *Unit* participate in international internships and research workshops outside Japan. In addition, they belong to research group of scenario planning to draw up a road map toward a zero CO2 emission energy system as well as advanced research cluster which aims to conduct globally-advanced research in the system. The *GCOE Education Unit* allows the students to develop practical real-world skills.

In order to promote the project in Fig. 3-1, governing organization was set up as shown in Fig. 3-2. *Steering Committee of GCOE Unit for Energy Science Education* formulates the basic policies in not only the management of the GCOE Unit but also all organizations, controls the overall program, handles budget control and carries out decision-making. It is called as *Program Headquarters Committee* (PHC). PHC consists of the representatives from each working committee involved in this program except *Advisory Committee* as shown in Fig. 3-2 and academic staffs of four faculties (Graduate School of Energy Science, Institute of Advanced Energy, Department of Nuclear Engineering and Research Reactor Institute) take part in the committee. Secretariat performs administrative matters of this program and responds to all other inquiries according to the policy of PHC.

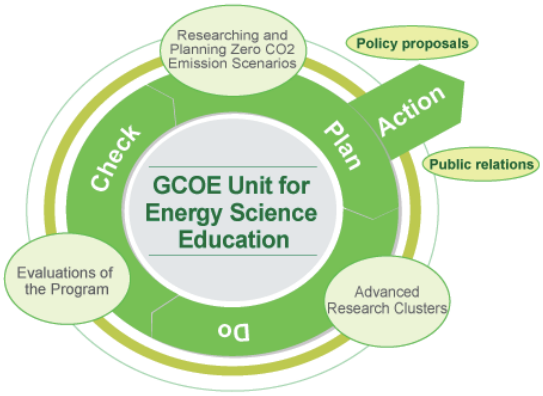


Fig. 3-1. Entire picture of this program.

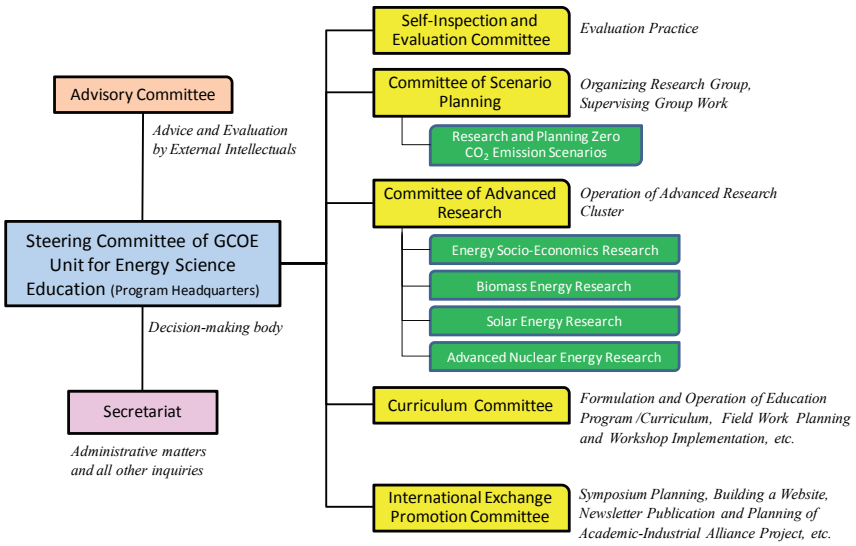


Fig. 3-2. Organization of this program.

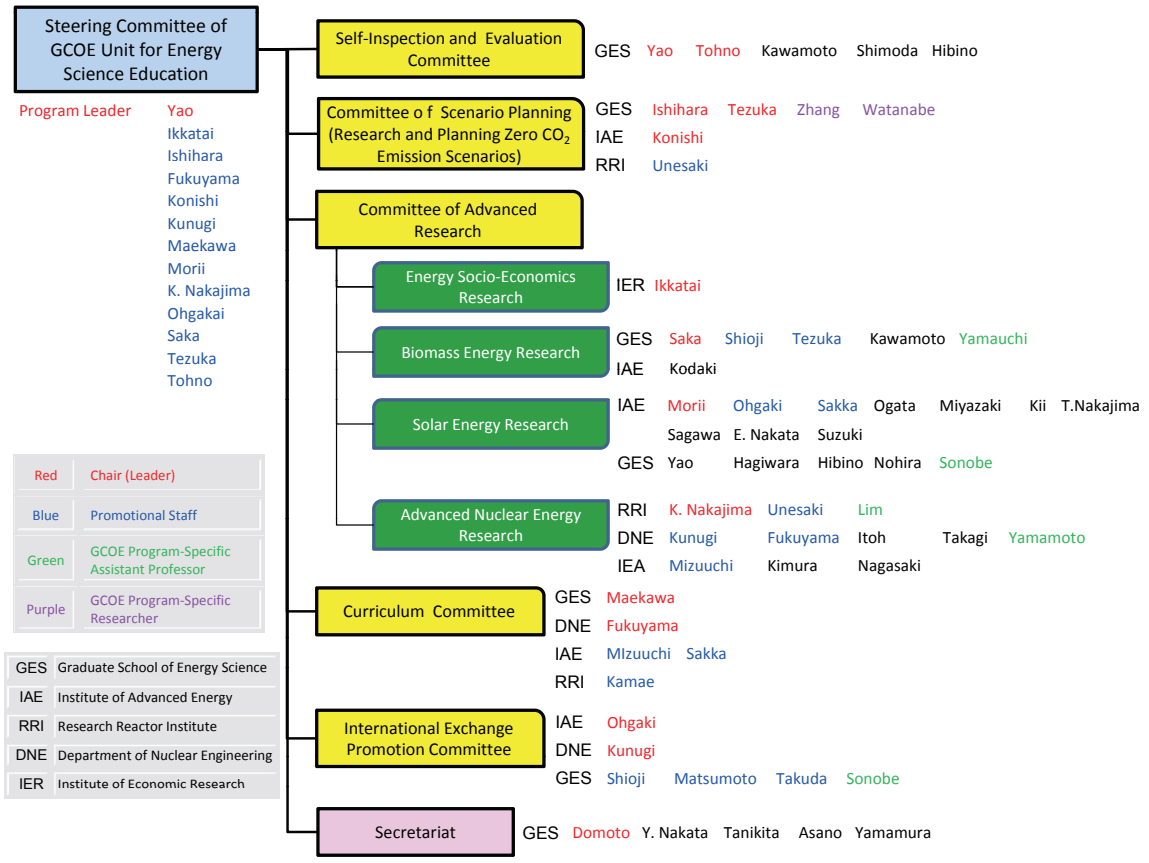


Fig. 3-3. Committee Composition as of March 31, 2011.

Curriculum Committee formulates a unique curriculum that includes basic energy science and advanced research results. The Committee also plans and implements other education programs such as field work or internship. Interdisciplinary group work of doctoral students in the GCOE Unit on a voluntary basis is managed by *Committee of Scenario Planning*. *International Exchange Promotion Committee* disseminates information by hosting international and domestic Japanese symposiums to promote communications with other countries regarding research results and international exchange among students and researchers.

Committee *of Scenario Planning* and *Committee of Advanced Research* perform the actual operation of research activities. *Committee of Advanced Research* consists of four research groups of Energy Socio-Economics, Biomass Energy, Solar Energy and Advanced Nuclear Energy. The two committees operate in close coordination and cooperation with each other such as the holding of joint workshops.

Self-Inspection and Evaluation Committee inspects and evaluates the above mentioned activities, and issues the report every year to pursue the continuous improvement of the program. Furthermore, *Advisory Committee* comprising external intellectuals is established to assess the development of the GCOE Program and offer the recommendations that will enhance quality of outcomes of the program. According to the recommendations, PHC makes some corrections if necessary to accomplish the goal.

In addition to *twenty* academic staffs in charge, a number of other academic staffs, GCOE researchers and graduate students in the four faculties participate in this program. Fig. 3-3 indicates the personnel distribution of academic staff and GCOE researcher who belongs to each committee.

3.2 GCOE Secretariat

The staff of GCOE secretariat consists of a Chief of the Administrative Office of the Graduate School of

Energy Science (double post), a Chief of the Academic Administration Affairs Division (double post) a specialist administrative staff, an assistant administrative staff and a temporary staff as of March 31, 2010. The main duties are budget management and administration of the cost involved with each committee (steering, self-inspection and evaluation, scenario planning, advanced research, curriculum, and international exchange promotion), application procedure, management and administration of young researchers expenses, completion of performance reports, etc., communications and coordination with the administrative headquarters of Kyoto University, and budget management and administration of the in-direct expenses.

3.3 Budget and Allocation Status for FY2010

In FY2010, the direct expense was 249,800,000 Yen, in-direct expense was 0 Yen, totaling to 249,800,000 Yen. The allocation by committees and departments are as follows. Additionally, Table 3-1 shows the expense breakdown for each committee.

✧ **Direct expenses allocation status**

・Graduate School of Energy Science	191,450,000 Yen
Breakdown	
Program Headquarters	113,250,000 Yen
Self-Inspection and Evaluation	1,800,000 Yen
Scenario Planning	67,500,000 Yen (58,500,000 Yen for Young Researchers)
Advanced Research	2,700,000 Yen
Curriculum	3,200,000 Yen
International Exchange Promotion	3,000,000 Yen
・Department of Nuclear Engineering	14,600,000 Yen
・Reactor Research Institute	6,750,000 Yen
・Institute of Advanced Energy	37,000,000 Yen
Direct expenses Total	249,800,000 Yen

✧ **In-direct expenses allocation status**

In-direct expenses Total	0 Yen

FY2010	Direct expenses	249,800,000 Yen
	In-direct expenses	0 Yen
	Total	249,800,000 Yen

Table 3-1 Final Budget and Allocation n FY2010

(1,000 Yen)

Expense Category	Direct Expenses						Sub-total	In-direct expenses	Total
	Program Headquarters	Scenario Planning	Advanced Research	Curriculum	International Exchange Promotion	Self-Inspection and Evaluation			
Equipment and facilities	10,633	0	0	0	839	0	11,472		
Domestic travelling	2,273	173	0	138	983	0	3,567		
Overseas travelling	22,075	940	0	1,907	19,805	0	44,731		
Salary									
Program-specific assistant professors	26,223	0	0	0	0	0	26,223		
Program-specific researchers	10,754	0	0	0	0	0	10,754		
RA	31,628	0	0	0	0	0	31,628		
TA	456	0	0	0	0	0	456		
Specialist administrative staff	6,091	0	0	0	0	0	6,091		
Assistant administrative staff	2,661	0	0	0	0	0	2,661		
Rewards	0	0	0	54	574	0	628		
Program promotion	22,523	7,877	2,700	956	17,634	1,725	53,415		
Young Researchers Group research	0	58,174	0	0	0	0	58,174		
Total	135,317	67,168	2,700	3,055	39,835	1,725	249,800	0	249,800
Budget Amount	134,600	67,500	2,700	3,200	40,000	3,000	249,800	0	249,800

1. Salaries allocated to Department of Nuclear Engineering and Reactor Research Institute are included in the Steering Committee (Program Headquarters) budget.
2. Budget incurred for the Secretariat is included in the Steering Committee (Program Headquarters).

4. Activities of Steering Committee of GCOE Unit for Energy Science Education

4.1 Outline

The committee consists of a program leader and the representatives of five committees (*Scenario Planning, Advanced Research, Curriculum, International Exchanger Promotion*, and *Self-Inspection and Evaluation*) and secretariat. Policies and planning of this program are deliberated in the committee meeting and the activities of the above five committees are confirmed and modified. The committee meeting has been almost regularly held once a month as follows:

The 23rd Committee Meeting: April 15, 2010
The 24th Committee Meeting: May 13, 2010
The 25th Committee Meeting: June 10, 2010
The 26th Committee Meeting: July 8, 2010
The 27th Committee Meeting: August 12, 2010
The 28th Committee Meeting: September 14, 2010
The 29th Committee Meeting: October 7, 2010
The 30th Committee Meeting: November 11, 2010
The 31st Committee Meeting: December 9, 2010
The 32nd Committee Meeting: January 13, 2011
The 33rd Committee Meeting: February 17, 2011
The 34th Committee Meeting: March 17, 2011

4.2 Movement of Program-Specific Assistant Professors and Researchers

One GCOE program-specific assistant professor who was adopted on November 1, 2008 moved on to become an assistant professor of the Faculty of Science, Fukuoka University on April 1, 2010. One GCOE program-specific researcher who was adopted on October 5, 2009 moved on to become an assistant professor of the Faculty of Science and Engineering, Waseda University on April 1, 2010. Four GCOE

assistant professors and two GCOE researchers are staffed as of March 31, 2011.

5. Committee of Scenario Planning (Research and Planning Zero CO2 Emission Scenarios)

5.1 Targets (Plan) and Achievements in FY2010

Targets in FY2010

(1) Hosting energy scenario strategy meetings with researchers from companies to discuss the energy scenarios proposed by the scenario planning committee
(2) Discussing energy system development strategy based on the energy technology roadmap jointly created by the scenario committee and advanced technology cluster
(3) Conducting case study based on energy scenario analysis framework

Achievements in FY2010

(1) Two energy scenario strategy meetings were held in May and December respectively to exchange opinions on the proposed energy scenarios.
(2) Development strategies for various energy systems were discussed with the advanced energy technology cluster. (nuclear power development, nuclear fuel recycle strategy (Kumatori Campus, Nov. 2010); biomass energy/biomass material development (Yoshida Campus, Oct. 2010))
(3) Case study of zero-carbon electricity system by 2100 was conducted based on the proposed scenario analysis framework. Furthermore, scenarios for low-carbon & safe electricity systems by 2030 in light of the Fukushima Accident were also analyzed

Therefore, the targets for FY2010 were met successfully. With the additional accomplishment of the energy scenario study for 2030 in light of Fukushima Accident we have gone beyond our original targets.

5.2 Committee Meeting Status

Targets in FY2010

GCOE scenario committee meeting is held every Tuesday. In the meeting, the daily operation of whole scenario committee including student group research, energy scenario study will be discussed and confirmed.

Achievements in FY2010

Members of the Scenario Planning Committee convened from 10:30 to 12:00 every Tuesday, except for national holidays, and there were a total of 47 meetings in FY2010. The committee discussed various issues such as management of group research, management of the committee, and deliberations on the scenario analysis study. We invited Prof. Morii and Prof. Yamauchi from advanced research committee to join the meetings to discuss the development of biomass energy and material in future energy system. Furthermore, a committee meeting was also held in Kumatori Campus on Nov. 12, 2010 with involved professors. The LiveOn web meeting system is used to facilitate participation of committee members from remote locations.

- 2010 Meeting Status of the Committee of Scenario Planning
  - 13th meeting April 7, 10:30－
  - 14th meeting April 14, 10:30－
  - 15th meeting April 21, 10:30－
  - 16th meeting April 28, 10:30－
  - 17th meeting May 12, 10:30－
  - 18th meeting May 26, 10:30－
  - 19th meeting June 2, 10:30－
  - 20th meeting June 9, 10:30－
  - 21st meeting June 16, 10:30－
  - 22nd meeting June 23, 10:30－
  - 23rd meeting June 30, 10:30－
  - 24th meeting July 7, 10:30－
  - 25th meeting July 14, 10:30－
  - 26th meeting July 28, 10:30－
  - 27th meeting August 8, 10:30－
  - 28th meeting August 13, 10:30－
  - 29th meeting September 1, 10:30－
  - 30th meeting September 18, 10:30－
  - 31st meeting September 25, 10:30－

- 32nd meeting October 6, 10:30－
- 33rd meeting October 13, 10:30－
- 34th meeting October 20, 10:30－
- 35th meeting October 27, 10:30－
- 36th meeting November 10, 10:30－
- 37th meeting November 17, 10:30－
- 38th meeting December 1, 10:30－
- 39th meeting December 8, 10:30－
- 40th meeting December 15, 10:30－

➢ 2011 Meeting Status of the Committee of Scenario Planning

- 1st meeting January 6, 10:30－
- 2nd meeting January 13, 10:30－
- 3rd meeting January 20, 10:30－
- 4th meeting January 27, 10:30－
- 5th meeting February 2, 10:30－
- 6th meeting February 9, 15:00－
- 7th meeting February 16, 13:30－
- 8th meeting February 23, 10:30－
- 9th meeting March 2, 10:30－
- 10th meeting March 9, 10:30－
- 11th meeting March 16, 10:30－
- 12th meeting March 23, 10:30－
- 13th meeting March 30, 10:30－

5.3 Meeting Status of the Scenario Strategic Research Committee

Targets in FY2010

The scenario committee has two scenario strategy meetings annually with researchers in companies related with energy systems. In the meeting, we share ideas of the energy scenarios we are trying to construct, to ensure they are as realistic as possible, based on the data provided by the companies.

Achievements in FY2010

In the fiscal year 2010, scenario strategy meetings were held twice. In the fourth scenario strategy meeting, the potential of nuclear power and renewable energy was discussed, and the economic analysis of the GCOE scenarios to 2050 was studied in the fifth meeting. The information and comments from industry committee members were absorbed and reflected in the final scenario analysis.

✧ The fourth energy scenario strategy research meeting
May 21, 2010
Topic: The potential of renewable energy and nuclear power to 2100 in Japan
Attendance: 16 (9 from university, 7 from companies)

✧ The fifth energy scenario strategy research meeting
Dec. 10, 2010
Topic: Economic analysis of GCOE energy scenario to 2050
Attendance: 16 (8 from university, 8 from companies).

5.4 Determination of Energy Scenario (Framework)

Targets in FY2010

An energy scenario analysis framework will be completed and case studies will be conducted based on the developed framework.

Achievements in FY2010

An integrated analysis model was developed to plan scenarios for a CO2 zero-emission society to 2100 based on socio-economic data and technology information. The developed model includes demand estimation, introduction of new technology with probability assessment of each technology and minimization of total CO2 emissions. Using the model, two original zero-emissions electricity system scenarios are proposed based on the latest socio-economic data and cutting edge technology information provided by GCOE Advanced Research Clusters and companies outside the university. One scenario assumes that nuclear energy is installed as much as possible; the other assumes that renewable energy is the key source and nuclear supplies the rest. In both scenarios, the technology for electricity storage becomes a bottleneck. It is shown that the effective utilization of batteries in electric vehicles and hydrogen energy can absorb the daily and seasonal electricity fluctuations. The scenario was also studied from the economic / investment aspect and the results show that in the first 10 years, more

investment will be necessary, however, from the long-term viewpoint, the least CO2 scenario will have much better economic performance. Furthermore, the scenarios were revised in light of the great east Japan earthquake and Fukushima nuclear accident which changed the energy demand-supply structure in Japan. In the future, the scenario analysis will be conducted considering the uncertainties from natural disasters and subsequent accidents.

5.5 Establishing the Energy Technology Roadmap (Collaboration with the Advanced Research Cluster)

Targets in FY2010

Energy technology roadmap will be established collaborated with the advanced research cluster.

Achievements in FY2010

In order to integrate various research results obtained in GCOE advanced technology cluster into the scenario analysis, we actively interviewed the researchers in the cluster or invited them to join our weekly committee meeting. On Nov. 12, 2010, scenario committee members visited Kumatori campus where experimental nuclear reactors are in operation and had a joint committee meeting with local professors. In the meeting, we discussed the extended lifetime operation and replace strategy of nuclear power plants, and nuclear spent fuel storage & recycle. We also invited members from the biomass study group advanced research cluster to talk about biomass power generation and biomass materials from biomass refineries. We also report our scenario analysis results and remaining problems to the GCOE advanced research cluster. In this way, both groups are trying their best to share their research results to complete the final technology roadmap.

5.6 Research Presentation and Workshop

The academic outputs of the GCOE scenario committee are shown in the following table. With the development of the scenario analysis model, more original papers were completed compared with the previous year.

	Original Papers	International Conference	Meeting
Number	10	8	8

5.7 Activity of Global COE Program-Specific Researchers

➢ **Dr. Qi Zhang**

Targets in FY2010

An energy scenario analysis framework will be completed and case studies will be conducted based on the developed framework. Energy technology roadmap will be established collaborated with the advanced research cluster.

Achievements in FY2010

(1) Development of an Integrated Scenario Analysis Model

The integrated scenario analysis model was completed, and contains three parts: <1> bottom-up simulation mode for electricity demand estimation; <2> least CO2 optimization model for long-term electricity system planning; <3> hour-by-hour simulation model for feasibility test of the obtained electricity system. The integrated model also can conduct economic / investment evaluation.

(2) Evaluation of nuclear and renewable energy potential

The investigations on research and development of renewable energy including road map and cost estimation were performed through Scenario Strategic Research Committee and interviews with specialists. Furthermore, the potential of nuclear power and renewable energy in Japan is investigated independently.

(3) Development of zero CO2 emission energy scenarios

Using the tools above mentioned, two zero-emissions electricity system scenarios were proposed. One is the scenario that the nuclear energy is installed as much as possible, the other is that the renewable energy is mainly used and nuclear is supplied the rest. In both scenarios, the technology for electricity storage becomes bottleneck. It is shown that the effective utilization of electric cars and hydrogen

energy can absorb the daily and seasonally fluctuations. The scenario was also studied from economy/ investment aspect, and the results show that in the recent 10 years, more investment will be necessary, however, from long-term viewpoint, the least CO2 scenario will have much better economy performance. Furthermore, the scenarios were revised in light of the great east earthquake and Fukushima nuclear accident which changed the energy demand-supply structure in Japan. In the future, the scenario analysis will be conducted considering the uncertainties from natural disasters and subsequent accidents.

(4) International Cooperation

The scenario committee joins in the activities of the SEE forum made up of Southeast Asia countries through the GCOE international cooperation committee, and carry out joint energy scenario analysis in Southeast Asia region together. Furthermore, we have constructed good cooperation relationships with China, South Korea, EU and Australia, and we are trying to make reasonable and realistic global energy scenarios using these relationships. In January, 2011, we visited the University of Technology, Sydney, the CSIRO Energy Centre and the University of Melbourne in Australia. I introduced the energy scenarios, and exchanged ideas actively with the scholars in Australia on the regional and global energy scenario construction. Finally, both sides showed their desires to strive for a long-term collaboration.

- **Dr. Yoshiyuki Watanabe**

In recent years, emissions of greenhouse gasses typified by carbon dioxide (CO_2) have drastically increased with increasing energy demand on a global scale. Consequently, global warming and various environmental issues have grown into serious problems. Total CO_2 emission in FY 2007 (except for CO_2 removals) was 1,374 million tons (in CO_2 equivalents), in which the emission was mostly from the sectors such as Energy Industries sector (34.4%), Industries sector (30.3%) and Transport sector (18.5%). On the other hand, forests are major land sinks of CO_2. In Japan, total forestland area is 25.0 million ha which is 66.1 % of the total national land area (37.8 million ha), where the net CO_2 removal by forests in FY 2007 was 82.9 million ton, accounting for 5.9 % of the total national emissions. Here, the net CO_2 removal by forests was estimated in accordance with the Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG-LULUCF) by the IPCC, in which for samples taken in each forest, carbon stock changes in living biomass are estimated by Tier 2 stock change method. In this method, a biomass stock change is the difference between the absolute amount biomass at two points in times. From the obtained carbon stock changes and the forestland area for each sample, the mean CO_2 removal at individual forest area is then estimated. However, the photosynthetic rate of forest depends on CO_2 concentration in the atmosphere. Thus, a forest in an area of high CO_2 concentration in the atmosphere (e.g. near a funnel draft of a cement factory or a thermal power plant) can absorb more amount of CO_2 than a forest at relatively low CO_2 concentration in the atmosphere, which might result in more net CO_2 removal over the 82.9 million.

In the present study, CO_2 absorption by forests at relatively high CO_2 concentration was evaluated focusing on forest area near cement factories, which is required for estimation of the net CO_2 removal by forest taking into account CO_2 absorption dependence of CO_2 concentration in the atmosphere.

5.8 Open Recruitment and Grant for Group Research

Targets in FY2010

Apart from the academic and international cooperation activities, the scenario committee also takes charge of the student group research in cooperation with the GCOE education unit.

Achievements in FY2010

Participant: 76 members, divided into 7 groups

Budget distribution: 0.5-1 million yen per student, totally 58.5 million yen

Group study presentations

Aug. 19-20, 2010, the second international GCOE symposium

Jan. 28, 2011, the annual report meeting of FY2010

In December 14, 2010, we had a joint meeting with the student delegates to exchange ideas and to learn from each other. One group in Uji campus joined the meeting using the LiveOn web system. Through discussions of more than 2 hours, each group described its own study topic clearly and came to understand the studies conducted in other groups.

5.8.1 Questionnaire and its results for the students joined in "Group Research"

Since "Group Research", as mentioned above, is aiming at fostering advanced research driving abilities such as problem finding, communication, multifaceted viewpoints and discussion, it is impossible to evaluate the effectiveness of the ability improvement by a simple written test. Accordingly, a questionnaire survey was conducted for the students who joined in the group work in order to subjectively evaluate the effectiveness in the same way as the past years. Considering the educational purposes of the group research, the questionnaire used a 5-point scale ranging from "Very effective" to "Not effective at all" to investigate the effectiveness of the improvement in research driving abilities of 13 items. Figure 5-1 shows the questionnaire results. In addition to the above, "good points" and "points to be improved" were also asked as free description. Table 5-1 shows the descriptions of "good points" by the students who gave high evaluations for the group research, while Table 5-2 shows those of "points to be improved" by the students who gave low evaluations.

As shown in Fig. 5-1, "Ability for cooperation in group research", "Ability for logical thinking" and "Multifaceted viewpoints" got high evaluation. This is because the students from various research fields cooperated to conduct the group research and it was effective to improve the abilities necessary to solve energy and environmental problems which have various viewpoints. On the other hand, "Amount of knowledge related to research work" got low evaluation comparing with other factors. It is supposed that they could not improve the knowledge directly related to their own research themes because they tackled the unique research theme apart from their own research fields in the group research.

As shown in Table 5-2, it was found that the group research could not be conducted smoothly because of the difficulty to conduct the group research with the students from different research fields and a little incentive to join the group research. Especially eleven out of 30 students indicated that the contribution to the group work varied greatly among students. This is because there were some students who didn't understand the significance of the group research and there was no penalty even if they didn't join it. This situation may have a negative influence on the motivation of other members.

Next, the result of questionnaire in this fiscal year is compared with those of the past years. The group work started in F.Y.2008 and the questionnaire survey has been also conducted since that year. Fig. 5-2 shows the average and the standard deviation of the scores in each question item for the answers from F.Y.2008 to F.Y.2010. Each item was rated on a 5-point scale where: "very effective" = 5, "effective" = 1, "acceptable" = 3, "not effective so much" = 2, to "not effective at all" = 1.

As shown in Fig. 5-2, all the results of the questionnaire except "Ability for English communication" in F.Y.2010 are evaluated more effective than those in F.Y.2009.

On the other hand, the degree of commitment was also surveyed in a 4-point scale (4: I greatly committed, 3: I fairy committed, 2: I slightly committed, 1: I rarely committed). Figure 5-3 shows the result. Although the average answer score of 3.40 is relatively high, the number of the students who answered this questionnaire survey was 30 out of 76 registered students in the group research. Students who rarely committed themselves to group research are likely not to answer the survey. It is necessary to survey their commitment by other survey method.

Because there was an opinion that "it took much time to set up the research theme" in the questionnaire survey of the last year, some candidates of research themes have been presented to the students for their reference in this year. In order to examine the effectiveness of this trial, the degree of reference was surveyed in a 4-point scale (4: chose your research theme from the candidates, 3: referred the candidates much, 2: referred the candidates a little, 1: did not refer the candidates at all). Figure 5-4 shows the result.

As shown in Fig. 5-4, most of the students referred the theme candidates and only two students did not refer them at all. Furthermore, there was no opinion of "It took much time to set up the research theme" in their free descriptions of the questionnaire. It was demonstrated that presentation of theme options for group research was effective for students.

The questionnaire sheet for the evaluation is shown below ("Group Work" is used instead of "Group Research" in the questionnaire).

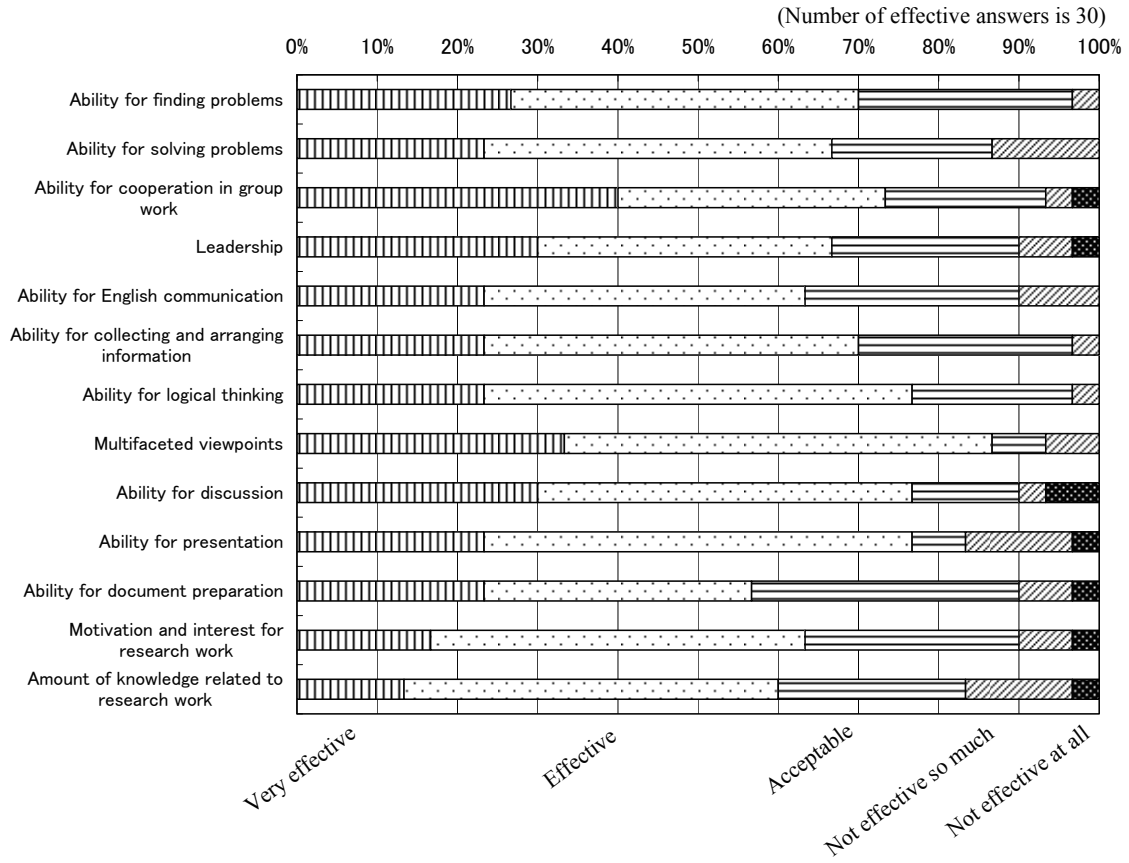


Fig.5-1. Questionnaire results of effectiveness for fostering abilities.

Table 5-1 "Good points" described by the students who gave high evaluations

I have become able to communicate in English. Discussion on research theme apart from my own with group members expanded the horizons of my thinking. I noticed that there was more possibility to reduce CO2 emission than expected. *(Translated from Japanese)*
・communication ・leadership ・friendship
In my opinion, the group work program is very interesting and I have had a good opportunity to work with many students who came from different countries as well as different laboratories. From this point, I learned many things not only my major field but also the related field to reach the target of zero carbon emission. Moreover, this program provided me a valuable experience, such as a leadership, sharing an idea with group members, and studying how to move forward the group work etc.
・ It is good to collect information and ideas through discussion and communication; ・ It is good to train cooperation ability; ・ It is good to improve English expression; ・ It is good to expend knowledge.

Before entering the new group work, I was expecting to participation of group activity, presentation our working and writing report, and to see lot of other interesting such as making new friends and so on. As expected, I and my group members had done it well. Also, we have become grown very close through this program. That is good points.

Table 5-2 “Points to be improved” described by the students who gave low evaluation

1. Contribution on group work from each member should be optimized by group supervisor 2. The assessment of the group results should not be solely rely on the output of group work, but also the process of making the result
Because of my previous experiences, I keep a bad memory on this last group research experience because I found that the new members were not motivated enough. When we started the GCOE program in 2008, it was new and we were all wanting to make it work, and we saw our research budget as a reward of our commitment. However, the new members consider that it is normal to get some money and therefore do the minimum to invest themselves in the project. As the other students are already busy with their final year, I found disappointing that younger students did not take active roles and leading roles in the group. Because of the previous student’s experiences, they think they will get the money even if they do nothing. I think that this experience is a great advantage for young researchers to interfere with other students, but all they think about is the GCOE money. It is very sad. Also, I find that there is not enough commitment, or not at all, from the group advisor. This is something to be improved, because students coming from different fields need a mentor to organize their thoughts. It is difficult to interact with other people having a different character and the group advisor did not help at all. What is the point of having an advisor if he never comes and is not aware of our group research?? I think that was an important factor in my disappointment this year.
The group should have measured targets and timeline. Some groups do not have certain regular schedule to obtain the group goals. Thus, the group work does not effective so much.
I have joined GCOE group work for these two years and was a leader this year. In general, the attendance rate of Japanese students was low and the reason for their absence was often not enough. Not only students but also supervisors should value the group work, or the students of lower grade will participate as little as possible. Because attendance and contribution to the group work are not reflected in research budget of each student at all, I could do nothing against the students who ignored the group work as a leader. In the future, there will be no student who wants to be a leader. *(Translated from Japanese)*

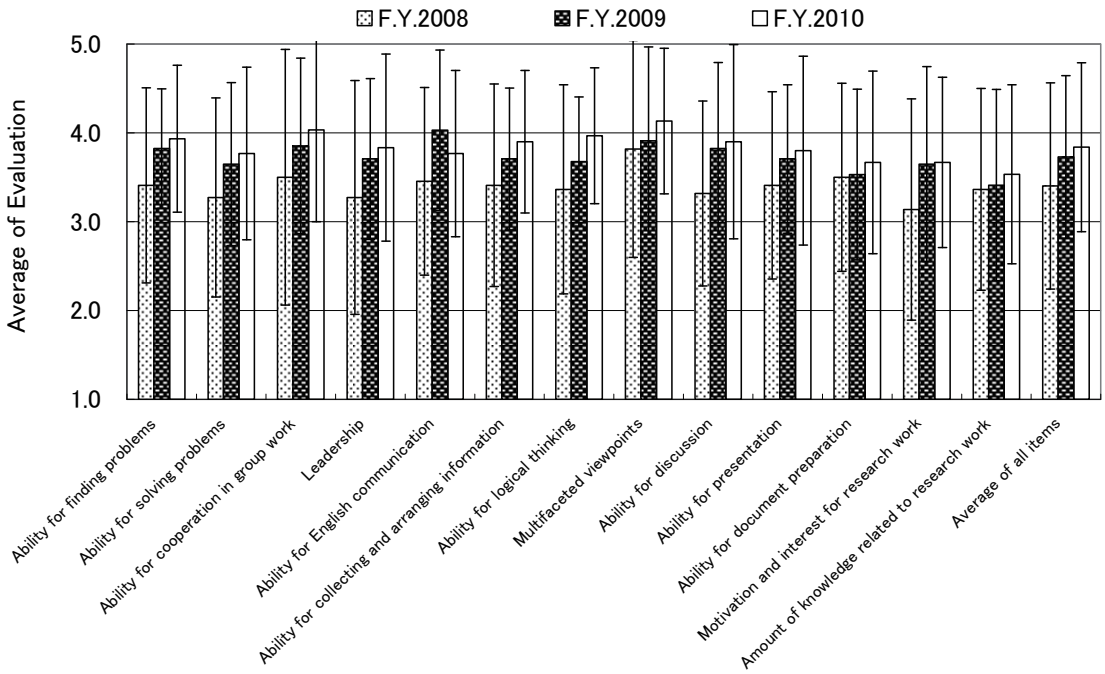


Fig.5-2. Comparison of answers of questionnaire between FY2008 and FY2010.

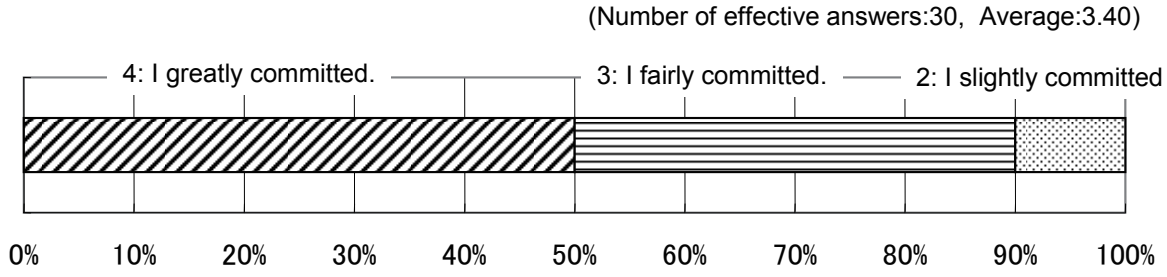


Fig.5-3. The result of survey on degree of commitment.

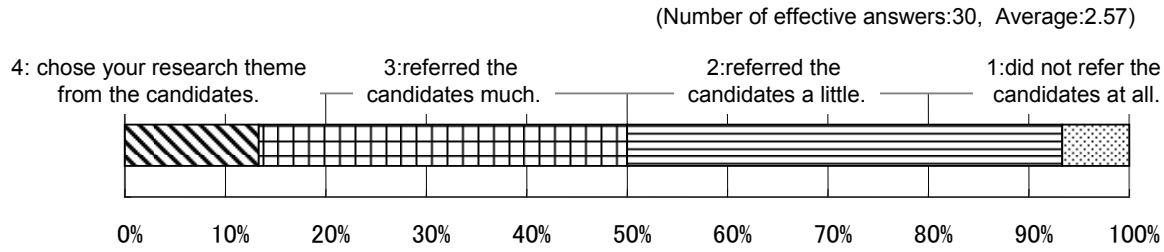


Fig.5-4 The result of survey on degree of reference to research theme candidates.

15th, March 2011

To: the students who join “Group Work” program.

Self-inspection and evaluation committee of GCOE

Questionnaire for “Group Work” program of GCOE

The self-inspection and evaluation committee of GCOE is conducting a questionnaire survey of “Group Work” program to evaluate and improve educational programs of GCOE.

The results of the survey will be processed statistically so that no individual student is identified and the results do not affect the evaluation of your group work. Even though we are asking you to write your name on the face sheet of this questionnaire, it is used only for a follow-up survey and your name is not identified. The questionnaire results will be reported as a proposal for the improvement of “Group Work” program. We would appreciate your taking a few minutes to complete this questionnaire.

Your name		Sex	Male Female
Graduate School, Department	Year of entrance	Age	Date of questionnaire
			, March 2011

Please answer whether “Group Work” program is effective in improving the following abilities.
(Check “✓” mark in the following boxes as your answers.)

Items for questionnaire survey	Not effective at all	Not effective so much	Acceptable	Effective	Very effective
Ability for finding problems					
Ability for solving problems					
Ability for cooperation in group work					
Leadership					
Ability for English communication					
Ability for collecting and arranging information					
Ability for logical thinking					
Multifaceted viewpoints					
Ability for discussion					
Ability for presentation					
Ability for document preparation					
Motivation and interest for research work					
Amount of knowledge related to research work					

Please choose one of the followings about your commitment to your “Group Work”. (Check “✓” mark in the following box as your answer.)

☐ I greatly committed. ☐ I fairly committed. ☐ I slightly committed. ☐ I rarely committed.

Please describe the reason if you checked “I slightly committed” or “I rarely committed” in the above.

Some candidates of research theme were presented by GCOE scenario planning committee in the beginning of the program. Did you refer to the candidates when deciding the research theme of your group?

☐ chose your research theme from the candidates.
☐ referred the candidates much.
☐ referred the candidates a little.
☐ did not refer the candidates at all.

Please describe the reason why you checked the above selection.

Please describe good points and the points necessary to be improved for “Group Work” program.
Good points;

Points necessary to be improved;

Please submit this questionnaire sheet to GCOE office (Room 103 in the Faculty of Engineering Building No.2) no later than the 1st of April, 2011, or send this sheet as an attached file via e-mail (gcoe-office @energy.kyoto-u.ac.jp).
Thank you for your cooperation.

Please contact us at the following address if you have any questions concerning this questionnaire.

Prof. Susumu Tohno, Graduate School of Energy Science, E-mail: tohno@energy.kyoto-u.ac.jp

6. Committee of Advanced Research

6.1 Energy Socio-Economics Research

6.1.1 Drastic Improvement Measures of Energy Efficiency Incorporating Production, Consumption and Waste Cycle

Seiji Ikkatai (Institute of Economic Research)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Based on the research outcome 2009, the tables on the drastic improvement factors of energy efficiency by classifying end use service would be refined, and the potential of energy efficiency improvement would be quantified. Also, the policy measures would be explored.

Achievement

1) Making tables on the drastic improvement factors and quantification of the potential of the energy efficiency improvement

2009 tables have been refined and improved by analyzing additional information on factors of energy and resource efficiency improvement in the end use service on "transport", "food", "heating and cooling", "power", "access to information", "lighting" so on. The potential of energy efficiency improvement on each sector by classified above fields by 2050 has been quantified by referring a research result by Dr. Jurian Allwood in Cambridge University

2) Policy measures on energy efficiency improvement

There are many factors related with energy efficiency improvement. Variety of existing policy measures have been practiced and analyzed.

The research target 2010 has been sufficiently achieved and next target would be refining the quantification and establishment of the policy measures.

6.1.2 Research Presentation and Workshop

Research results of Energy Socio-Economic Group are presented in domestic conferences. The presentation numbers in FY2010 are as follows:

	Scholarly Journal, etc.	International Conference	Domestic Conference	Workshop	Patent
Number	0	1	2	0	0

6.2 Solar Energy Research

6.2.1 Highly Efficient Solar Cells Research

[1] Improvement of Efficiencies of Organic Solar Cells: Development of Materials and Novel Design of Device Structure

Takashi Sagawa (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Polymer solar cells are a promising new type photovoltaic conversion device with the advantages of lightweight, flexible and low cost roll-to-roll production by using the convenient well-developed solution-based thin film deposition technology as compared to conventional silicon and III-V group inorganic semiconductors. For the sake of highly efficient photocurrent conversion efficiencies of organic thin film solar cells in terms to reduction of carbon dioxide emissions, we intended to develop some materials for such organic thin film solar cells and designed and evaluated novel device structures in FY2010.

Achievement

In the FY of 2010, we developed donors such as polythiophenes and acceptors of fullerenes, which are consisting of active layer, and the construction and examination of single-cells were performed. Novel donor PCDTBT and acceptor $PC_{71}BM$ have been prepared and applied for organic photovoltaics (OPVs) as alternatives for poly(3-hexylthiophene) (P3HT) of conventional donor material and (6,6)-phenyl C_{61} butyric acid methyl ester ($PC_{61}BM$) of donor. Improvement of 5.6% of power conversion efficiency using glass–ITO/PEDOT:PSS/ PCDTBT–$PC_{71}BM$ /TiO_x/Al has been achieved by 1.2 times and 1.4 times enhancement of the short circuit current density and

open circuit voltage, respectively as compared with those of the P3HT–$PC_{61}BM$ system.

We prepared electrospun nanofiber composed of regioregular poly(3-hexylthiophene) (*rr* P3HT) with poly(vinyl pyrrolidone) (PVP). Composite electrospun *rr* P3HT–PVP shows homogeneous one-dimensional fibers confirmed by SEM observation. After the selective removal of PVP, fragmental *rr* P3HT fibrils were observed. This result indicates that phase separation of *rr* P3HT and PVP occurs during the spinning process in the range of sub-micron scale. Both of the emission peaks of *rr* P3HT film and *rr* P3HT–PVP one were observed at 1.9 eV, which shifted lower than those of the solutions (2.2 eV). Lowering the electron transition energy was brought by the densely intermolecular lamellar packing of *rr* P3HT in the solid state as compared with that of the solution, in which the solute dispersed homogeneously. Such electrospun *rr* P3HT–PVP nanofiber is thus promising as a hole transporting part for highly efficient solar cells.

[2] Development and Evaluation of Novel Materials for the Future Solar Cells

Hideaki Ohgaki (Institute of Advanced Energy)
Taro Sonobe (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Our research group aims at developing a novel evaluation method for solar cell materials by use of a Mid-Infrared Free Electron Lasers (KU-FEL), as well as investigating a new material processing to control the energy bandgap structure of wide-bandgap semiconducting materials for high efficiency solar cell by use of KU-FEL as well as microwave heating. Particularly, we will study the selective excitation of lattice vibration (*phonon*) of metal oxides using KU-FEL with short pulse, high energy, and tunable wave length, while paying attention to the direct observation through Raman scattering, temperature dependency of electric resistivity, as well as changes in electronic states through Photoluminescence at low temperature.

Achievement

Toward a low carbon society, the new collaborative research facility for photo-energy material has been established at KU-FEL of Institute of Advanced Energy, Kyoto University, in which four advanced analytical systems combined with KU-FEL were installed, such as photoelectron spectroscopy, Super centrifuge and high performance liquids chromatography, ICP emission spectroscopy, and high speed atomic force spectroscopy. This facility aims at promoting and accelerating an innovation and collaboration toward a development of next generation solar cell with more than 10 % efficiency and photosynthesis systems applied for the advanced organic function.

6.2.2 Artificial Photosynthesis Research

[1] Development of Biomaterials that Mediate Electron Transfer

Eiji Nakata, Takashi Morii
(Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Chemical conversion of solar energy as artificial photosynthesis is potentially promising for efficient utilization of renewable energy sources in addition to the well-established thermal and electrical utilization of solar energy. To develop the photo-driven oxidase, which would mimic the material conversion process in photosynthesis, we designed and constructed photoelectric transducers consist of light-harvesting antenna and charge transporter. DNA scaffold would be appropriate for hole transporter because the double stranded DNA forms highly organized self-assembly and hole migration process through DNA have been studied extensively. The ruthenium(II) (Ru(II)) complex would serve as an attractive photosensitizer as many Ru(II) complexes are tunable for the excitation by visible light. We designed DNA-modified films containing Ru(II) complex as a photoelectric transducer. Ru(II) complex tethered complementary DNA was constructed and immobilized on a Au surface.

Achievement

A stable cathodic photocurrent was immediately

observed under the photoirradiation of the modified gold electrode at 436 nm, whereas the photocurrent was instantly disappeared in the absence of the photoirradiation. In order to investigate the detail mechanism of the induction of photocurrent, the cathodic photocurrents were measured under different O_2 concentrations. As the results, the cathodic photocurrent was observed only under O_2 existence. Further understanding the detail of the mechanism would lead to the construction of the light energy induced artificial enzyme.

6.2.3 Materials for Sustainable Energy Systems Research

[1] Electrode Materials for Lithium-Ion Battery with High Energy Density and High Power Density

Takeshi Yao, Mitsuhiro Hibino
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

For effective use of renewable energy and various electric vehicle systems such as HEV, P-HEV and pure EV, there is a growing need for electric energy storage with high power density as well as high energy density. Iron oxide is one of the most promising materials as an electrode of lithium-ion batteries due to its low toxicity and low cost. To develop iron oxide electrode material, it is important to investigate the diffusion behavior of Li ion during both charge and discharge. When Li is inserted into γ-Fe_2O_3 electrochemically, prolonged potential change is observed after the insertion. It is considered that this phenomenon reflects some continuing crystal structure change even after Li insertion. In this study, we inserted Li into γ-Fe_2O_3 electrochemically, analyzed the crystal structure change, then tried to make the diffusion behavior clear.

Achievement

Li was inserted into the γ-Fe_2O_3 synthesized by the aqueous solution method, by discharging at a current density of 0.1 Ag^{-1}. After the Li insertion, the circuit was opened immediately. XRD patterns of thus obtained Li inserted γ-Fe_2O_3 were measured for each elapsed time. The XRD patterns were analyzed by the Rietveld method using RIEVEC program. In the analysis, the crystal structure was represented by space group Fd3m, and the occupancies of Fe at 8a, 8b, 16c, and 16d sites were investigated. In the process of the electrochemical Li insertion, the occupancy of 8a site decreased and that of 16c site increased. After Li insertion, the occupancy of 8a site increased and that of 16c site decreased gradually with time. Fe occupancy at 16d site dose not so changed all over the process. At Li insertion process, it is indicated that Fe moved from 8a site to 16c site, and then it is suggested that Li is inserted at 8a site and Fe is pushed out from 8a site to move into 16c site. After Li insertion, it is indicated that Fe returns from 16c site to 8a site, and then it is suggested that Li moved from 8a site to 16c site from the behavior of Fe. From this point of view, it is considered that Li prefer 8a site to occupy kinetically, on the other hand, prefer 16c site thermodynamically.

[2] Development of Low-cost Production Method for Solar-grade Silicon

Rika Hagiwara, Toshiyuki Nohira
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Crystalline silicon solar cells currently hold more than 80% of the total solar cell production. Since they have high conversion efficiency, high reliability and low environmental impact, they are expected to be mass-produced and widely used all over the world in the future. However, the cost is rather high for conventional production methods of solar-grade silicon, which is the most important challenge for the silicon solar cell industry. Thus, the purpose of this project is to develop a new and low-cost production method of solar-grade silicon. We focus on the electrochemical processing in molten salts for this purpose. The plan of FY2010 was to develop a faster reduction method using SiO_2 powder as feedstock.

Achievement

Silicon powder was added to SiO_2 powder to enhance the electronic conduction. The mixture was pressed into a donut-shaped pellet, which was then attached to a silicon rod. This (SiO_2+Si) pellet was successfully reduced to silicon in molten $CaCl_2$ at 1123

K. The reduction rate was increased to 1.5 times faster compared with the pellet containing no silicon powder. The produced silicon was analyzed by GD-MS. It was confirmed that most of the impurity elements were below our target levels which were calculated from the acceptable impurity levels for SOG-Si and the segregation coefficients for the impurity elements.

6.2.4 Solar Energy Conversion Research

[1] Nanoprocessing with Femtosecond Laser Pulses for the Development of Efficient Solar Cells

Kenzo Miyazaki, Godai Miyaji
(Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

The goal of our study is to establish a new approach to laser nanoprocessing technology that should contribute to the development of efficient solar cells. The study was concerned with (1) the femtosecond (fs)-laser ablation experiment for semiconductors under different environments to see the applicability of our physical model of nanostruturing, and with (2) the high-order harmonic generation (HHG) with fs laser pulses to understand the molecular orbital responsible for the nonperturbative nonlinear interaction.

Achievement

1) Femtosecond-laser ablation experiments were made for Si, InP, GaAs, InAs, and GaN in air and water. We have found that two kinds of nanostructures are formed with the periods of ~ 150 nm and ~ 400 nm at low fluence. The observed property of nanostructuring, as well as the nanostructure size, can be illustrated with our physical model.
2) The HHG from aligned molecules was observed with the pump and probe technique using fs-laser pulses. We have successfully developed a new technique for retrieving the HHG distribution for a single molecule.

[2] Evaluation of Interfaces for Solar Energy Conversion

Tetsuo Sakka, Kazuhiro Fukami, Yukio H. Ogata
(Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

Efficiency of solar energy conversion by semiconductors depends on their microstructures as well as chemical components of the surfaces. In the present program we aim at the development of highly-functional novel microscopic structures of interfaces, and the evaluation of interfaces in situ in the fabrication processes to control the process parameters. In the present academic year we aim at the understanding of the relationship between surface plasmon resonance on microscopic metal surfaces and semiconductor electrodes. We prepare gold nanostructures by using porous silicon as electrode for electrodeposition, and investigate their surface plasmon properties.

Achievement

The electrodeposition of gold proceeded preferentially on the porous silicon surface and the pores were still empty when a solution containing $HAuCl_4$ and NaCl was used. On the other hand, the pores were completely filled with gold when using a solution containing $HAuCl_4$, Na_2SO_3 and $Na_2S_2O_3$. As a result, we succeeded in obtaining gold nanorod arrays as replicas of porous silicon. The gold nanorod arrays with 300, 600 and 900 nm length were prepared by controlling the depth of the porous layer. The measurements of Raman scattering were conducted by using the gold nanorod arrays with different lengths. The optimum length of the nanorods was 600 nm for surface-enhanced Raman spectroscopy of 4,4'-bipyridine using a He-Ne laser (wavelength: 633 nm) as the incident beam.

[3] Frequency-Conversion of Mid-Infrared Laser Pulses

Takashi Nakajima (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Target (Plan)

The free-electron laser (KUFEL) which has been developed at our institute is a light source in the

mid-infrared region with a possible application to evaluate the properties of new materials for solar cells. For the efficient evaluation of the material properties it is important to extend the working wavelength region of KUFEL, and for that purpose we employ the frequency up-conversion techniques with a nonlinear crystal. With the nonlinear crystal we can also measure the pulse duration. This is so-called autocorrelation and if we employ the fringe-resolved autocorrelation (FRAC) technique we can obtain information not only on the pulse duration but also on the chirp. This year, in addition to the standard usage of FRAC, we explore the possibility of using FRAC as a tool to diagnose the beam quality of KUFEL.

Achievement

Through the realistic calculations for the FRAC signal by taking into account for the fluctuation of the pulse intensity, pulse duration, pulse interval, and wavelength, we have found that the FRAC signal is mainly distorted by the wavelength fluctuation. In particular we have seen the gradual but very notable distortion of the FRAC signal if the amount of the wavelength fluctuation is 0.5-1.5 % of the central wavelength, which is actually the typical value for any FEL. Our calculations have shown that the FRAC signal can be a new tool to diagnose the beam quality (wavelength stability) of KUFEL.

6.2.5 Activity of Global COE Program-Specific Assistant Professor

- **Development and Evaluation of Novel Materials for the Future Solar Cells**

Taro Sonobe (Graduate School of Energy Science)

The objective is to develop a novel evaluation method for solar cell materials by use of a Mid-Infrared Free Electron Lasers (KU-FEL), as well as investigating a new material processing to control the energy bandgap structure of wide-bandgap semiconducting materials for high efficiency solar cell by use of microwave heating. For the above purpose, the developments of microwave based ZnO thin film fabrication process and material evaluation system upon KU-FEL (Kyoto University Free Electron Laser) in wide-bandgap semiconducting materials such as TiO_2, ZnO and SiC were promoted. In particular, the Photoluminescence measurement cavity with simultaneous irradiation of UV-Visible laser and FEL at low temperature was established.

6.2.6 Research Presentation and Workshop

Research results of Solar Energy Group are presented in domestic and international conferences, and published in scholarly journals. The presentation numbers in FY2010 are as follows:

	Scholarly Journal, etc.	International Conference	Domestic Conference	Workshop	Patent
Number	33	70	56	2	5

6.3 Biomass Energy Research

6.3.1 Characterization of Biomass Resources for Biofuel Production

[1] Characterization of Biomass Resources for Biofuel Production

Shiro Saka (Graduate School of Energy Science)

- Target (Plan) and Achievement in FY2010

Although various biomass resources are available for biofuels production, their characteristics affect the properties of produced biofuels. Therefore in this study, basic characteristics of biomass resources were investigated and their potentials were planned to be evaluated. In this year, chemical constituents of various biomass resources such as cellulose, hemicelluloses, lignin, extractives and inorganic constituents were continued to be studied quantitatively, and their chemical characteristics were elucidated. In addition, the standardized methodology applicable for any biomass species was proposed for quantification of their chemical compositions.

6.3.2 Bioethanol

[1] Ecoethanol Production by Acetic Acid Fermentation with Hydrogenolysis from Lignocellulosics

Shiro Saka, Haruo Kawamoto, Kazuchika Yamauchi
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Compared to starch and molasses, lignocellulosics are difficult to convert to ethanol by yeast. Therefore, innovative technology for ethanol production is highly anticipated for lignocellulosics. A two-step hot-compressed water treatment process coupled with acetic acid fermentation and hydrogenolysis was thus proposed to produce bioethanol from lignocellulosics. The various products obtained by hot-compressed water treatment, such as monosaccharides, oligosaccharides, their decomposed products, lignin-derived products and organic acids, were found to be used as substrates for acetic acid fermentation in the co-culturing system of *Clostridium thermoaceticum* and *C. thermocellum.* Consequently, hot-compressed water treatment with Japanese beech (*Fagus crenata*) and Japanese cedar (*Cryptomeria Japonica*) woods resulted in 94 and 87wt% substrate yields on wood basis, respectively. In acetic acid fermentation, these obtained products were found to be effectively converted to acetic acid by its co-culturing. Produced acetic acid was found to be converted to ethyl acetate, and then, to ethanol effectively by hydrogenolysis. Based on these results, our proposed process would be a good candidate for 3rd generation bioethanol production from lignocellulosic biomass.

[2] Prospect of Nipa Palm for Bioethanol Production

Shiro Saka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

The current study was initiated to characterize various parts of nipa palm to establish whole utilization of this biomass as potential raw material for fuels and chemicals. Nipa consisting of frond, shell and husk was chemically characterized for cellulose, hemicellulose, lignin, starch, protein, extractives and inorganic constituents. The total chemical composition showed that the cellulose and hemicellulose contents were in the range of 28.9 – 45.6 wt% and 21.8 – 26.4 wt%, respectively. The hemicellulose was rich with glucuronoxylan. The lignin content was 19.4 to 33.8 wt%. Starch, protein and extractives were also present in a significant amount from 2 to 8 wt%. Additionally, the ash content as an inorganic constituent was high from 5.1 to 11.7 wt%, consisting of the major inorganic elements being Na, K and Cl with minor inorganic elements of Mg, Ca, Si, P, S and Al. Overall, nipa palm could be exploited as lignocellulosic resources for fuels and chemicals.

[3] Development of Highly Efficient Bioethanol Production Yeast Using Protein Engineering

Tsutomu Kodaki (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Since Xylose is one of the major fermentable sugars present in lignocellulosic biomass, the efficient fermentation of xylose is required to develop economically viable processes for producing bioethanol. Although a few xylose fermenting yeasts are found in nature, *Saccharomyces cerevisiae* is used universally for industrial ethanol production because of its ability to produce high concentrations of ethanol and high inherent ethanol tolerance. However, native *S. cerevisiae* cannot ferment xylose, so engineering *S. cerevisiae* for xylose utilization has focused on adapting the xylose metabolic pathway from the xylose-utilizing yeast such as *Pichia stipitis*. We have already developed the mutated xylitol dehydrogenase (XDH) by protein engineering and the change of coenzyme specificities of XDH has been shown to have the positive effects on the production of bioethanol from xylose. In this study, construction of the first strictly NADPH dependent xylose reductase (XR) from *Pichia stipitis* was succeeded by site directed mutagenesis, where two double mutants with almost the same activity of wild-type were generated. By introducing the strictly NADPH dependent XR with the strictly $NADP^+$ dependent XDH, the more efficient xylose fermentation is expected to be observed, probably due to the full recycling of coenzymes between the mutated XR and XDH. The goal of this fiscal year was sufficiently accomplished by constructing the first strictly NADPH dependent XR.

6.3.3 Biodiesel

[1] New Biodiesel Production Process from Oils/Fats by Supercritical Carboxylate Esters

Shiro Saka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

As worldwide biodiesel production increases recently, the overproduction of glycerol has lowered its economical value. A non-catalytic supercritical process utilizing twelve carboxylate esters has been explored and successfully demonstrated to produce fatty acid alkyl esters (FAAE) and triacins, instead of glycerol. The highest yield was achieved by supercritical methyl acetate, which evidently converted triglycerides into fatty acid methyl esters (FAME) and triacetin as one of the triacins. The mixtures of FAAE and triacin showed hardly any detrimental effects on fuel properties and even improving its oxidation stability and cold flow properties. Certainly, this glycerol-free process can maximize the use of both product and by-product in biodiesel production.

[2] New Biodiesel Production Process from Oils/Fats by Supercritical Neutral Esters

Shiro Saka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Biodiesel production by supercritical neutral esters has been investigated, not only to prevent glycerol by-production, but also to minimize possible corrosion problems faced by supercritical carboxylate esters. Supercritical non-catalytic dimethyl carbonate as one of the neutral esters has demonstrated that it converted triglycerides into fatty acid methyl esters with glycerol carbonate and citramalic acid as the by-products. These by-products are much higher in value than glycerol produced by the conventional methods. Furthermore, to establish the mild reaction condition for practical application, the two-step supercritical dimethyl carbonate process has been proposed. Without doubt, this study could charter the path towards exploration of novel and alternative biodiesel production process for the future.

[3] Ignition and Combustion Characteristics in Various Kinds of Biodiesel Fuels

Masahiro Shioji
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Jatropha curcas is currently regarded as the most suitable crop for the production of carbon neutral biodiesel fuel (BDF) of FAME, due to some of its interesting properties such as higher yield of seeds with oil abundantly contained, resistance to drought and including poisonous component without competition with food. While those features of Jatropha exhibit a candidate as the promising material, the adequate combustion control requires an understanding of the characteristics of spontaneous ignition in a variety of conditions at the engine operation. From this point of view, experiments were carried out in a constant-volume vessel under diesel-engine conditions to investigate the spray developments, ignition delays and heat-release rates with different injection pressures and nozzle-orifice diameters. Experimental results successfully provide the valuable data for design and operation in diesel engines fuelled by Jatropha FAME targeted in this year: both a higher injection pressure and a smaller diameter of nozzle orifice promote the atomization and shorten the period required for the mixture formation, then reducing the ignition delay at a higher temperature region above 800 K. Also, at the temperature region from 650 K to 800 K, though exhibiting a similar combustion process with premixed combustion followed by diffusive one in different injection pressures, a smaller nozzle-orifice enables the gradual rise of heat-release rates with a lower peak value due to a smaller amount of fuel injected in a unit time.

6.3.4 Biomass Conversion to Liquid Biofuels and Useful Biomaterials

[1] Biomass Conversion to Liquid Biofuels and Useful Biomaterials by Supercritical Fluid Technologies

Shiro Saka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

In this study, liquefaction of wood is being studied to produce liquid biofuels by supercritical (or subcritical) alcohol technology. In liquefaction of woody biomass by supercritical alcohol, there exist characteristics such as i) the obtained liquefied products can be directly utilized together with alcohol which is itself a kind of fuels, and ii) various alcohols such as methanol, ethanol, 1-butanol and 1-octanol can be produced from biomass resources. Therefore, by liquefying biomass with these alcohols, 100% biomass-based liquid biofuels can be achieved. In this study, therefore, phenol species as a solvent were also used to liquefy the biomass resources and its optimum treatment conditions were studied and clarified.

[2] Production of Biofuels and Biomaterials by Pyrolysis

Haruo Kawamoto, Shiro Saka
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

In this study, pyrolysis and gasification mechanisms of woody biomass are studied at the molecular level, aiming at the development of effective conversion methods to liquid biofuels and useful biomaterials. The following results were obtained in this year. As for lignin pyrolysis, gas and solid/liquid phase pyrolytic reaction mechanisms were clarified for softwood and hardwood lignins, focusing on their different chemical compositions of aromatic nuclei. The reactions starting from the hemolytic cleavage of the O-CH_3 bond were found to be key reactions for formation of gaseous products and coke (a carbonaceous substance via volatiles). A new concept was proposed for control of the pyrolytic reactions occurring in polysaccharide such as cellulose. Intra- and inter-molecular hydrogen bondings act as acid and base catalysis, and the former acid catalysis promotes various acid-catalyzed reactions including transglycosylation and dehydration at relatively low pyrolysis temperature.

[3] Biofuel and Biomaterial Production by Ionic Liquid Treatment

Hisashi Miyafuji (Graduate School of Life and Environmental Science, Kyoto Prefectural University)
Shiro Saka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

For production of biofuel and biomaterial, wood samples were treated with ionic liquid was studied. The objectives and results of the research in this year were the followings; liquefaction behaviors of wood in 1-ethyl-3-methylimidazorium chloride, 1-ethyl-3-methylimidazorium acetate, and so on were clarified, and the products were characterized with various analytical methods. Furthermore, utilization of such ionic liquid treatment as a pretreatment method for enzymatic hydrolysis of cellulosic substances in wood was studied.

[4] Oil Palm (*Elaeis guineensis*) Chemical Characteristics for Its Efficient Utilization

Shiro Saka, Haruo Kawamoto
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Oil palm plantation is rapidly expanding especially in south-east Asian countries such as Malaysia and Indonesia to produce palm oil. With this trend, a huge amount of oil palm wastes is produced, which includes trunk, frond, fresh fruit bunch (mesocarp and shell), kernel cake and empty fruit bunch (EFB). In this study, chemical compositions of these different oil palm parts were investigated. As a result, it was found that all parts except for kernel cake were composed of cellulose, hemicellulose and lignin. Kernel cake has, however, no lignin. Furthermore, the fractionated products by supercritical water treatment were characterized chemically. As a result, the fractionated water-soluble portion could be utilized for organic acid production, whereas the methanol-soluble portion and its insoluble residue for phenolic chemical production. Moreover, from a viewpoint of chemical composition, oil palm trunk showed similarity to hardwood, but with higher ash and phenolic hydroxyl contents.

6.3.5 Framework Design for Biomass Utilization

[1] Modeling of Biomass Utilization in a Region and Framework Design of Autonomous Decentralized Energy Supply-demand System with Biomass Use

Tetsuo Tezuka (Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

This study aims to design a new framework for realizing desirable future energy supply-demand scenarios. Especially, the biomass utilization is taken as a study target, and the benefit of biomass utilization is to be quantitatively evaluated, and the acceptable biomass utilization scenario is to be identified concretely. The research work of this year is focused on the "Extended Model" newly proposed in this study. The "Extended Model" includes the decision process related to a variety of assumptions which are required to make the future scenarios. The assumptions are related to availability of various technologies in future, implementation of energy-related regulation policy, and so on. The "Extended Model" also makes it possible to solve the inverse problem which is to get the sets of assumptions necessary to give the designated scenarios as optimal solutions. This year the methodology for solving the inverse problem based on genetic algorithm is proposed, and its performance is verified. Next year the autonomous decision-making model for biomass use will be developed by clarifying several types of stakeholders in the biomass utilization. And the approach developed in this study will be applied to design the framework for realizing the acceptable scenarios about stable biomass utilization.

6.3.6 Activity of Global COE Program-Specific Assistant Professor

➢ **Effective Hydrolysis of Lignocellulosics and Utilization of Hydrolysates**

Nobuchika Yamauchi
(Graduate School of Energy Science)

Various hydrolysates from lignocellulosics treated with hot-compressed water were studied. Lignocellulosics consisted of cellulose, hemicelluloses and lignin. By two-step hot-compressed water treatment, hemicelluloses and cellulose were found to hydrolyze efficiently and separately. In order to characterize oligo-saccharides from hemicelluloses and cellulose, MALDI-TOF/MS method was performed. Lignin-derived products obtained by the hot compressed water treatment were also studied. These results of this study led to develop a high efficiency ethanol production process, utilization as chemicals and new materials of lignin-derived products.

6.3.7 Research Presentation and Workshop

Research results of Biomass Energy Group are presented in domestic and international conferences, and published in scholarly journals. The presentation numbers in FY2010 are as follows:

	Scholarly Journal, etc.	International Conference	Domestic Conference	Workshop	Patent
Number	37	43	34	2	2

6.4 Advanced Nuclear Energy Research

6.4.1 Research on New-Type Nuclear Reactors and Accelerator Driven Subcritical Reactors

[1] Development of New-Type Nuclear Reactors

Tomoaki Kunugi, Zensaku Kawara
(Graduate School of Engineering)

➢ Target (Plan) and Achievement in FY2010

In order to realize high efficiency and safety for new-type nuclear reactors as promising advanced nuclear energy source, precise knowledge is essential on the coolant flow, which is gas-liquid two-phase flow in complex system. Measurement and analytical technology for multi-phase flow are needed as the fundamental technology. In this study, measurements are taken for the temporal-spatial behavior of gas-liquid interface at various two-phase flow regime by using two-phase flow experiment loop, and its experimental database are used for development of high-accurate and

high-speed analytical technology on multiphase flow. In this year, numerical method which is available for more flexible grid system is investigated for gas-liquid multiphase flow by MARS method using collocated grid system, interfacial transport method for unstructured grid system, investigation on speeding-up and parallelization by using GPU for development of large-scale and highly-efficient direct numerical method. The experimental work was conducted on rod vibration by two-phase droplet flow for the development of experimental database for validation of numerical simulation. Measurement system for multiphase flow was also sophisticated by optical probe system and flow visualization system with high resolution of spatial and temporal.

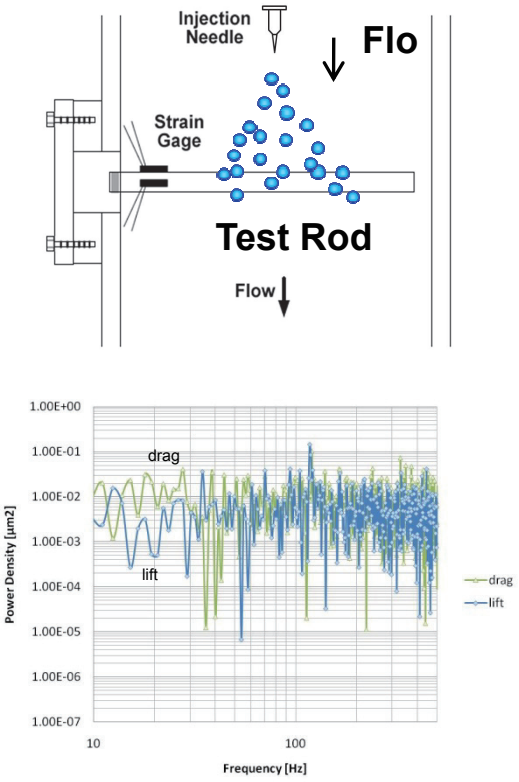


Fig. 6-1. Test section and typical PSD of rod vibrations induced by two-phase droplet flows.

[2] Research on Reactor Physics of Accelerator Driven Subcritical Reactors

Tsuyoshi Misawa, Hironobu Unesaki, Ken Nakajima
(Research Reactor Institute)

➢ Target (Plan) and Achievement in FY2010

In the accelerator-driven system (ADS) coupling with the Fixed-Field Alternating-Gradient (FFAG) accelerator, on 3rd March 2010, the high-energy neutrons generated by spallation reactions with 100 MeV proton beams were successfully injected into the thorium (Th) and thorium-graphite (Th-Gr) systems at the Kyoto University Critical Assembly (KUCA). The ADS experiments with high-energy protons (100 MeV energy and 30 pA intensity) were carried out in the condition that proton beams were increased to be 10 times compared with previous experiments in 2009, whereas an initial desired condition was in 150 MeV energy and 1 μA. The main objective of these experiments was to confirm experimentally the thorium fission reactions by spallation neutrons generated at tungsten target through the Th-loaded ADS experiments. Prior to these experiments, beam profile (protons and neutrons) were experimentally examined through irradiations: a proton beam configuration was observed to be improved from the results of Gafcromic films, and an improved neutron generation at the target was attained at the target position from the results of ^{115}In(n, n')^{115m}In (0.32 MeV neutron threshold) reaction rates, rather than previous experiments. However, the thorium fission reactions were not found experimentally to be in low intensity 30 pA. On the other hand, in the Th-loaded ADS experiments, measured results in ^{115}In(n, n')^{115m}In reaction rates were reproduced accurately by those in MCNPX, and the thorium fission reactions were considered to be confirmed numerically through the MCNPX calculations. In the Th-Gr-loaded ADS experiments, the effects of neutron scattering and neutron leakage by reflector (graphite) and large size core, respectively, were experimentally revealed in the reaction rate analyses. And these analyses could be expected to accomplish more neutron multiplication largely in upcoming Th-loaded ADS experiments at KUCA than the previous Th-loaded ADS experiments.

[3] Development of FFAG Proton Accelerator

Yoshiharu Mori, Yoshihiro Ishi
(Research Reactor Institute)

➢ Target (Plan) and Achievement in FY2010

Study of the beam performance improvement of the 150MeV FFAG(Fixed Field Alternating Gradient) proton accelerator, which was developed for the ADSR(Accelerator Driven Sub-critical Reactor) at KURRI, has been carried out. The high energy ring accelerator such as FFAG or synchrotron has an advantage to use a charge-exchange beam injection with H- ions for increasing the beam intensity and brightness and this scheme has been applied to the 150MeV FFAG proton accelerator at KURRI as the world-first demonstration. The injector for this purpose composes an H^- ion source, RFQ and DTL and the final beam energy is 11MeV. While, in the charge-exchange injection, a very thin carbon foil whose thickness is about 20 $\mu g/cm^2$ is to be used, the beam injection efficiency should largely depend upon the beam emittance growth caused by Rutherford multiple scattering and the betatron mismatch at the injection point. Intensive beam simulations for various conditions at the beam injection have been carried out. A small horizontal mismatch of about 2.6mm apart from the closed orbit at beam injection gives an optimum condition at beam injection obtained by these simulations. The estimated beam emittance for the horizontal and vertical directions after 150 turns are 25mm.mrad and 7.7mm.mrad, respectively, which are both well below the machine acceptance. The high energy beam transport line (HEBT) has been completed in this year and the beam was transported to the main ring of FFAG accelerator successfully. The equivalent beam current of about 1μA at beam injection was obtained at 10 Hz operation.

[4] Development of Materials for Accelerator Driven Subcritical Reactors

Toshimasa Yoshiie, Qiu Xu, Koichi Sato
(Research Reactor Institute)

➢ Target (Plan) and Achievement in FY2010

At the end of last year, the materials irradiation chamber with 2 MeV protons was installed at Ion Bata of FFAG complex in the Research Reactor Institute. This year, a new materials irradiation facility with 150 MeV protons was planed. A beam duct and irradiation chamber will be installed at the Main Ring of FFAG complex. Specimens in the chamber are possible to be cooled by 20 K and heated by 700 K. After irradiation, damaged structures of specimens are investigated by using positron annihilation lifetime spectroscopy and electrical resistivity measurements.

6.4.2 Research on Nuclear Fusion Reactors

[1] Research on Plasma Confinement with Heliotron J

Tohru Mizuuchi (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Objectives

1. Development of advanced diagnostic systems for fusion plasma
   1-1 A microwave reflectometer system for detailed electron density profile measurement of fusion plasmas
   1-2 A charge exchange recombination spectroscopy (CXRS) system for the measurement of the high time/spatial resolved impurity ion temperature and plasma rotation velocity profiles
2. Development of modules for an integrated code which is capable of performing hierarchical simulation for plasmas in a non-axisymmetric fusion reactor

Progress in 2010

1-1 By introducing a Q-band amplifier, 200MHz modulation detector, phase detector, etc, we successfully measured the electron density profile in Heliotron J. We found that the electron density profile is hollow in low-density ECH plasmas and it is a peaked one in NBI plasmas. By using this reflectometer in density modulation experiments in Heliotron J, particle transport analysis is examined. The preliminary study shows that the density increase by the modulation component of gas puff fueling propagated from the plasma edge region to the core region. The detailed analyses are in progress.

1-2 A charge exchange recombination spectroscopy system has been developed for the measurement

of the high time/spatial resolved impurity ion temperature and the rotation velocity profiles. In order to improve the spatial resolution, new sight lines are introduced by aligning them with the three-dimensional shape of the magnetically confined plasma. This optimization enables us to measure the ion temperature and rotation velocity profiles with the spatial resolution less than $\Delta r=0.05$. Based on CXRS data, profile change of T_i and v_ϕ, has been analyzed to understand plasma transport. In order to observe the whole plasma region, modification of new sight lines is scheduled next year.

2 Development of an advanced three-dimensional MHD equilibrium cord with highly precise and a simulation cord for time evolution of plasma current density distribution is in progress. By using the developed code, demonstrated are strong effects of electron temperature on time evolution of net plasma current and resistive diffusion time. Moreover, it is shown that the special distribution of Flux Conservation Torus current depends on the time evolution of temperature and the magnetic field.

[2] Development of Integral Tokamak Simulation Code

Atsushi Fukuyama
(Graduate School of Engineering)

➢ Target (Plan) and Achievement in FY2010

As a part of the integrated tokamak modeling code, the Fokker-Planck component, which describes the time evolution of the momentum distribution functions of plasma species, was extended to include the effect of radial transport and the fast ion effect on fusion reaction rate as well as to reduce the computation time by parallel processing. It has enabled us to simulate the time evolution of multi-species momentum distribution functions (electrons, deuterons, tritons and alpha particles) in the presence of multi-scheme heating (wave heating, neutral-beam heating and alpha-particle heating) simultaneously.

[3] Development of Compact Tokamak Fusion Reactor

Takashi Maekawa
(Graduate School of Energy Science)

➢ Target (Plan) and Achievement in FY2010

Start-up experiment for advanced torus has been performed. The toroidal plasma current has been started up to ~10 kA by microwave injection (2.45 GHz, 60 kW, 0.2 s pulse) in the Low Aspect ratio Torus Experiment device. The line averaged density reaches up to 7 times the plasma cutoff density, suggesting the plasma is sustained by electron Bernstein waves mode-converted at the Upper Hybrid resonance (UHR) layer from the injected electromagnetic waves. The plasma current Ip is carried by a fast electron tail. The evolutions of impurity line radiations and soft X-rays suggest that the bulk electron temperature also increases as Ip increases. The UHR layer is estimated to be located behind the second EC resonance layer. These results show that mode-converted EB waves may be cyclotron-absorbed by tail and bulk electrons during their propagations toward the fundamental EC resonance layer, showing that this scheme is effective to startup of low aspect ratio torus plasmas in compact tokamak fusion reactors.

[4] Fusion Reactor System Design

Satoshi Konishi (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Plan

The research plan in the fiscal year 2010 is focused on the plasma parameter, blanket and tritium system for the fusion-biomass hybrid concept. Blanket is planned to be designed with specific parameters for hybrid high temperature concept, and evaluated for tritium safety as one of the most critical feasibility issue. In order to provide input for the scenario group, conceptual design study of the zero-emission energy system based on fusion-biomass fuel production is also started in this year.

Accomplishments

Plasma and reactor parameters were evaluated for

more realistic design in the near future, and tokamak reactor GNOME was designed. Plasma parameters are similar to the ITER steady state scenario and technical difficulty is equal to the currently constructed ITER. High temperature liquid metal blanket was evaluated to satisfy the TBR and thermal performance. Tritium system was designed, and based on the experiments, vacuum sieve tray was proposed for tritium recovery. The designed realistic device was proved to remove tritium from the fuel product with the contamination below regulation limit.

On the other hand, because the fuel supply by fusion can be introduced earlier than electricity, its contribution for the de-carbonization of fuel consumption and the supply for the fuel cell was evaluated to be significant for the zero-emission energy scenario.

These results satisfied the research plan for the fiscal year 2010. The accomplishment will be provided for the scenario study in the next year and will suggest a proposal for the zero-emission energy system.

6.4.3 Development of Advanced Nuclear Materials

[1] Research on Thermal Diffusivity Estimation of Irradiated Ceramics

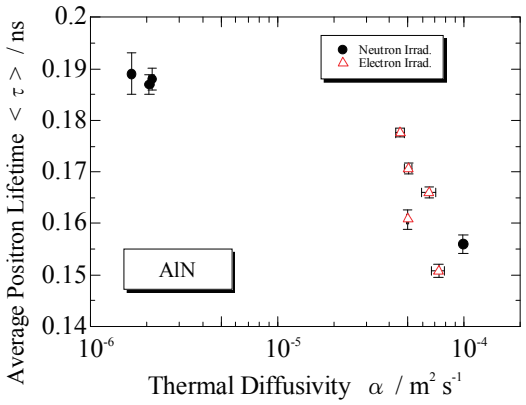
Masafumi Akiyoshi
(Graduate School of Engineering)

➢ Target (Plan) and Achievement in FY2010

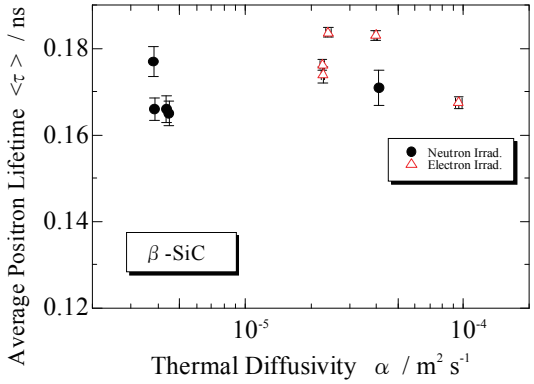
Material that survives under severe irradiation environment is the key factor to develop the future fusion reactor and other nuclear applications, such as high-temperature gas cooling fission reactor. These reactors are designed to operate at high-temperature, and ceramics are one of the candidate materials. It has been reported that the thermal diffusivity of neutron-irradiated ceramics showed significant degradation. Changes after the irradiation that depend on the irradiation conditions were clarified step by step with the past study, still changes during the irradiation is not estimated, and that inhibit to obtain the guide to develop materials.

The thermal diffusivity at the irradiation temperature is evaluated from the dependence of thermal diffusivity on measurement temperature, and it can be considered to represent the thermal diffusivity during irradiation with several assumptions. In this work, 30MeV electron accelerator is used to induce defects to ceramic materials up to 0.01dpa, and then the thermal diffusivity and positron annihilation lifetime (PAL) of post-irradiation specimens is measured. Specimens are radio activated with the irradiation, so all measurements are operated in radiation controlled area at Radiation Laboratory, Uji campus.

All α-Al_2O_3, AlN, β-Si_3N_4, β-SiC specimens showed degradation in thermal diffusivity with the irradiation dose, and α-Al_2O_3 and AlN specimens showed some correlation between thermal diffusivity and PAL (Fig. 6-2(a)), while β-Si_3N_4 and β-SiC showed no change in PAL after the irradiation (Fig. 6-2(b)). Now we operate isochronal annealing to the irradiated specimens and measure thermal diffusivity and PAL to obtain the correlation systematically.



(a) AlN



(b) β-SiC

Fig. 6-2 Correlation between thermal diffusivity and average positron life time in irradiated ceramics.

[2] Research on Radiation Defects in Materials during Irradiation

Hidetsugu Tsuchida
(Graduate School of Engineering)

➢ Target (Plan) and Achievement in FY2010

Studies of radiation defects in materials have been carried out for many years. Recent investigations focus on an understanding of a characteristic of defects under irradiation to reveal the dynamics underlying defect production, accumulation and evolution. To this end, various apparatus or techniques have been developed for performing in situ observation of irradiation behaviour in materials.

In this work, we performed experiments on in situ study of atomic-vacancy production and its evolution occurring during irradiation by using a positron. The experiment was carried out with a specially developed system that consists of a positron annihilation spectroscopy apparatus and a high-energy ion accelerator. The system enables us to obtain information about subsequent evolution of vacancies produced during ion irradiation. We studied temperature dependence of vacancy evolution during irradiation. A specimen of well-annealed Ni (at 1523 K for 1 h in vacuum) was used. The specimen was irradiated with 400 keV He^+ ions at three different temperatures of 296 (RT), 368 and 713 K (vacancies in Ni become mobile at the temperature of above 473 K). For the specimen during irradiation we performed in situ measurements of the positron annihilation Doppler-broadening spectroscopy. Variation of the line-shape parameter *S* was observed under beam-on (during irradiation) and beam-off (non-irradiation) conditions which change alternately.

Figure 3 shows a typical result for *S* parameter variation measured sequentially during irradiation (closed symbols) and non-irradiation (open symbols) at the temperatures of 368 and 713 K. Interesting results include that (1) values of *S* observed during irradiation are larger than those measured under non-irradiation condition and the result becomes significant at the higher temperature of 713 K, and (2) increase in *S* strongly depends on the specimen temperature, indicating that the effect of mobile vacancy induces inhibition of defect evolution or decrease of defect concentration at the high temperature of 713 K. We also performed experiments of positron annihilation lifetime spectroscopy to characterize the type of defect survived after irradiation.

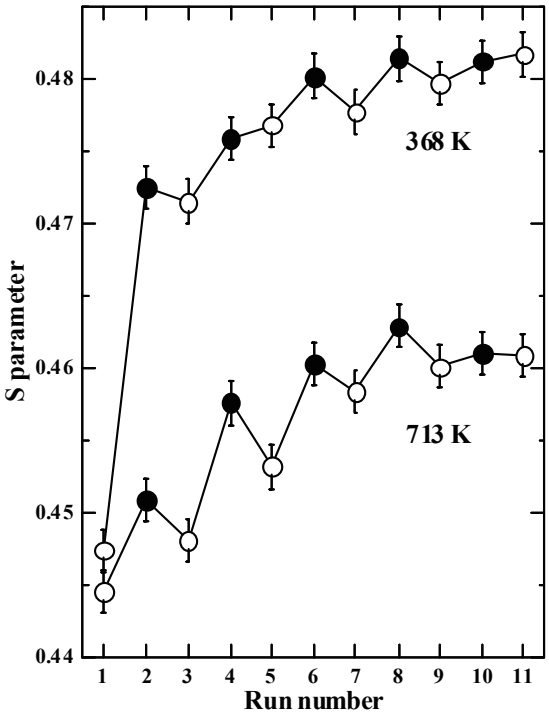


Fig. 6-3. S parameter variation during irradiation (●) and non-irradiation (○).

[3] Development of Structural Materials for Advanced Nuclear Systems

Akihiko Kimura (Institute of Advanced Energy)

➢ Target (Plan) and Achievement in FY2010

Objectives

The objective of this research is to develop joining and welding technologies for innovative nuclear materials to realize safe and efficient operation of advanced nuclear systems under zero-emission of CO_2 scenario. In 2009, material development was performed for ODS steels to improve performance of the materials, and a 16Cr-2W ODS steel was selected as a candidate of fusion blanket structural materials. The objective of this year is to develop adequate joining techniques for nano-oxide dispersion strengthened steels and small specimen test technique (SSTT), which are considered to be critical technologies to fabricate blanket.

Research Plan and Results

Ph.D course students discussed on the requirements for structural materials for advanced nuclear systems and fusion blanket systems, resultantly, it was concluded that joining technology was one of the critical techniques for the application. Joint performance was evaluated by tensile test and impact fracture test. In both of TLP joint and SSD bonding, tensile strength of the joints was almost same as those of base metal. However, tensile elongation of the TLP joint was reduced to almost a half of the base metal, while that of SSDB joints showed same tensile ductility as base metal. Impact fracture tests sometime showed a superior characteristic feature of SSDB than base metal. Thus, SSDB method is considered to be the most adequate joining method for ODS steels.

R&D of reduced activation ferritic steel (RAFS), which was considered to be the candidate structural material for fusion blanket systems, started under this program. Because the temperature window of the RAFS application is limited, design margin is small in the case of the application of RAFS to advanced blanket systems. To expand the design margin, the coupling application of RAFS and ODSS will be effective, since the temperature window of the ODSS application is much wider than RAFS. The joining technique of RAFS and ODSS is essential for the coupling utilization of those two steels.

Small specimen test technique was developed to estimate irradiation embrittlement of structural materials for advanced nuclear systems. The validity of Master Curve (MC) method is applicable to a reduced activation ferritic steel weld bond with use of 1/3 sized miniaturized specimens. It was also shown that intergranular embrittlement can be evaluated by MC method, although MC method was developed for lattice embrittlement accompanied by cleavage fracture.

Surveillance tests of pressure vessel are inevitable to operate for extended lifetime of advanced light water reactor. Manganese is the main steel element of the light water pressure vessel steel and appears to accelerate irradiation embrittlement of the steel. According to ion-irradiation experiments using DuET accelerator, it was cleared that the number density of interstitial type dislocation loops remarkably increased in Fe-Mn model alloy in comparison to pure Fe. This Mn effect appears at higher neutron doses, the estimation of irradiation hardening of Mn containing steel is essential for lifetime extension of the reactors.

6.4.4 Activity of Global COE Program-Specific Assistant Professor

Two program specific assistant professors have been working for Advance nuclear Energy Research since 2008. They have been performing the following researches and their activities have reported as 6 papers in scholarly journals and 4 papers in the proceedings of international conferences in FY2010.

1) Development of high-precision numerical simulator for multi-physical thermofluid dynamics

   Upgrading the direct numerical simulation to speed-up the thermofluid dynamics calculations in a nuclear reactor.

2) Research on Reactor Physics of Accelerator Driven Subcritical Reactors

   Validating the accuracy of neutronic calculations by comparing the calculation results with experimental data.

They also have educated the GCOE students as advisors of “group-research” in the GCOE education unit.

6.4.5 Research Presentation and Workshop

Research results of Advanced Nuclear Energy Group are presented in domestic and international conferences, and published in scholarly journals. The presentation numbers in 2010 are as follows:

	Scholarly Journal, etc.	International Conference	Domestic Conference	Workshop	Patent
Number	59	82	66	6	0

In the session of Advanced Nuclear Energy Research at the 3rd International Symposium of Kyoto University G-COE of Energy Science, “ZERO-CARBON ENERGY Kyoto 2010” held on August 19-20 at Obaku Plaza, Kyoto University Uji Campus, Prof. Masahiro Kawaji (City College of the City University of New York) presented the recent US status on the nuclear energy R&D, as an invited speaker. In

addition, the recent activities on the advanced nuclear energy research were presented as follows.

- Ken Nakajima, “Activities of Advanced Nuclear Energy Research Group”
- Jae-Yong Lim, “Nuclear Characteristics Transition depend on the Position of External Source on the Accelerator-Driven System using KUCA and FFAG Accelerator”
- Yoshinobu Yamamoto, “Development of a comprehensive and high-precision simulator for multi-physical thermofluid dynamics on the advanced nuclear energy - In case of fusion engineering and design –“

On January 28th, 2011, the GCOE annual report meeting was held at Obaku Plaza, Kyoto University Uji Campus, the outline of the group activity was reported.

7. Curriculum Committee

7.1 Curriculum Implementation in GCOE Unit for Energy Science Education

7.1.1 Operation of Education Unit and CO2 Zero Emission Education Program

Full-scale operation of the Education Unit and the CO2 Zero Emission Education Program started from April 2009. This is the second year and 82 students have registered for Education Unit in the academic year 2010. The registered students are allowed to submit an application form for participation in subjects in the Education Program. They are eligible for research-related financial support, such as GCOE employment as an RA or TA, financial assistance for travels associated with presentation of their research, and research grant for participants of the subjects "International Energy Seminar (group-research)" in the Education Program. The overview of the Education Unit and main subjects in the Education Program are presented below.

➢ Breakout by origin countries of students

Japan(39), Korea(10), Malaysia(6), China(5), Indonesia(4),Vietnam(3), Thailand, Egypt, France (2 each), Bangladesh, Germany, India, Madagascar, Mexico, South Africa, Taiwan, Tunisia, Philippines (1 each)

I. Those eligible to register for the Education Unit

Those who can join the GCOE Education Unit for Energy Science are the doctoral students who are enrolled in the following departments of the graduate school.

- Graduate School of Energy Science
  - Department of Socio-Environmental Energy Science
  - Department of Fundamental Energy Science
  - Department of Energy Conversion Science
  - Department of Energy Science and Technology
- Graduate School of Engineering
  - Department of Nuclear Engineering

II. Research Support for Registered Participants of the Education Unit

Those who had signed up for this education unit will be eligible to be appointed as GCOE-RA or GCOE-TA.

(1) Those who signed up for this education unit can receive grants for travelling expenses for research presentation.

(2) As for those who signed up for this education program subject, “International Energy Seminar (Group Research)”, based on the research plan submitted by each group, the required research expenses will be supported, amounted to the maximum of 1.0 million yen a year per person.

III. CO2 Zero Emission Education Program

Those who registered to join the Education Unit, and acquired the total of 14 credits and above from the following subjects within the course period will be certificated as graduates of the education program, and a completion certificate will be issued for each student. The number of credits and the number of registered students (at the end of January, 2011) for each subject are indicated below.

(1) International Seminar on Energy Science I, II, III, IV (Including Group Research) (Each 2 credits,

compulsory 4 credits, maximum 8 credits)
Number of registered students:
III (first semester, 2010) 65
IV (second semester, 2010) 72

(2) Advanced Research for CO2 Zero-Emission I, II (Each 1 credit, compulsory 2 credits)
Number of registered students:
I (first semester, 2010) 39
II (second semester, 2010) 26

(3) Field Practice (Compulsory 2 credits)
Number of registered students: 29

(4) Research Presentation I, II, III (Each 1 credit, compulsory 1 credit, maximum 3 credits)
Research presentation at academic meetings
Number of registered students:
to be counted at the end of academic year

(5) Overseas Practical (1 – 4 credits)
Research or practical at international institutions
Number of registered students:
to be counted at the end of academic year

(6) Classes in English (Half term: 2 credits, quarter term: 1 credit)
Number of registered students: 27

Main Subjects

Subject title	International Seminar on Energy Science I, II, III, IV
Place	To be determined by the Advisor
Time	International Seminar on Energy Science I: First semester of 2009 International Seminar on Energy Science II: Second semester of 2009 International Seminar on Energy Science III: First semester of 2010 International Seminar on Energy Science IV: Second semester of 2010 Participants will be informed of the details separately.
Instructor	Academic staff in charge of the Committee of Scenario Planning (Ishihara, Tezuka, Konishi, Unesaki)
Credits	2 credits each (Compulsory 4 credits, maximum 8 credits)
Course Description	The class will be organized with small groups (7-8 people/group). Students learn techniques and strategies for the Zero CO2 Emission Energy Society through group discussions in English based on Problem Based Learning (PBL).

Subject title	Advanced Research for CO2 Zero-Emission I, II
Place	Not particularly specified
Time	Advanced Research for CO2 Zero-Emission I: First semester Advanced Research for CO2 Zero-Emission II: Second semester
Instructor	Supervisor and academic staff in charge of Advanced Research Committee (Ikkatai, Morii, Saka, Nakajima)
Credits	1 credit each (Compulsory 2 credits)
Course Description	To conduct energy socio-economics research to evaluate the feasibility of the scenario and advanced energy technology development research without fossil fuel while systematically coordinating with the Energy Scenario Planning Research. To promote the "Energy Socio-Economics Research", "Renewable Energy (Solar Energy, Biomass Energy) Research" and "Advanced Nuclear Energy Research" that are integrated with a variety of fundamental researches and elemental technologies for a sustainable energy system, and to conduct researches related to the CO2 Zero Emission Energy Scenario Planning, which is based on the outcome of each research.

Subject title	Field Practice
Place	On-campus practice: Research Reactor Institute (Kumatori-cho, Sennan-gun, Osaka) External practice: Scheduled at Japan Atomic Energy Agency (the Monju fast-breeder reactor), Kansai Electric Power Co., (Ohi)
Time	First semester (Intensive) On-campus practice: 3 days in August External practice: 2 days in September to November Details will be announced separately.
Instructor	Academic staff in charge of Curriculum Committee (Kamae, Mizuuchi)
Credits	2 credits
Course Description	1. On-campus practice Address experimental subjects related to fundamental reactor physics using the Kyoto University Critical Assembly (KUCA), which is a small-sized nuclear reactor with low output and to further conduct reactor operation practice for all students. The practical is for 3 days, the first day is for maintenance lesson, facility visit and lectures on reactor physics, the second day is for dynamic behavior experiment of the reactor (measuring the reaction level of the control rod), and the third day is for conducting the reactor operation practical. 2. External practice Learn about the nuclear power plant design and safety through operation practice by nuclear power plant visit and operation simulator. Additionally, in the field learning about the contents, issues, and future prospect of the living together activities in the nuclear power plant area.

IV. Research Practice

Purpose:

Dispatched to places that have tense relationship with the public such as nuclear power plants, and learn about the problems out in the field.

Contents:

1. Research Reactor Institute (Kyoto University)

The first field practice was held at Research Reactor Institute (Kumatori) from August 25 to 27, 2010, and 17 students participated. The practice included fundamental reactor physics and reactor operation practice using Kyoto University Critical Assembly (KUCA). After security lesson and lectures on reactor physics and calibration of control rods, dynamic response experiments of the reactor (calibration of control rods and access to critical state) and operation practice of KUCA were carried out. At the end of field practice, the participants drew up their reports and held a discussion meeting.

2. Ohi Nuclear Power Plant (Kansai Electric Power Co., Inc.) and Monju fast-breeder reactor (Japan Atomic Energy Agency)

The second field practice was held at Ohi Nuclear Power Plant of Kansai Electric Power Co., Inc. (Ohi-machi, Ohi-gun, Fukui) and Monju fast-breeder reactor of Japan Atomic Energy Agency (Tsuruga) from November 23 to 24, 2010, and 20 students participated. At Ohi Nuclear Power Plant, students learned various parts of the nuclear power plant by guided tour and also living together activities in Fukui prefecture and exchanged opinions. At the fast-breeder reactor, Monju, they visited the facility of Monju and Sodium operation practice, learned the operation simulator and exchanged opinions.

3. Field practice in Negara Brunei Darussalam

The third field practice was held in Brunei from September 13 to 16, 2010, and 5 students participated. Several students from Brunei University also participated. The students stayed two days at Kuala Belalong Field Studies Center, where they learned

various aspects of tropical rainforest including canopy, the upper part of plants and insects and animals by lectures and a guided tour. On the third day they visited Brunei University and exchange information on activities on various energies of both Brunei and Kyoto universities. On final day they visited various energy plants including Brunei Methanol Company, Tenaga Suria Brunei (Solar plant) and Brunei Liquid Natural Gas.

V. The First Graduate

Dr. Mohammad Lutfur Rahman had completed *The Educational Program on Zero CO2 Emissions* that was certificated September 24, 2010 from the Leader of GCOE program Prof. Yao. He is the first graduate of the program.

VI. Research Presentation

Research presentation and patents related to the doctoral students (April 1, 2010 – March 31, 2011) are as follows. The detailed listing is recorded in the Appendixes.

	Scholarly Journal, etc.	International Presentation	Domestic Presentation	Award	Patent
Number	120	180	134	29	1

7.2 RA/TA Program

Five judges evaluated RA candidates using their application forms (blank form is shown in Table 7-1) based on the following evaluation points and the appointment was determined based on the 5 judges' total scores. Especially the top candidates were appointed on special hourly unit price. As shown in Tables 7-2 and 7-3, a total of 32 RAs and 4 TAs were appointed (6 RAs were appointed from the second semester). Among these, 9 RAs were appointed based on the special hourly unit price.

Evaluation points: Each item carries 25 points full mark, and total 100 points full mark.

1. Contribution to this GCOE program
2. Academic importance and achievement in the concerned field
3. Research prospects and comprehensive evaluation
4. Research performance

(Concerning research performance, the grade (the number of years since starting the research) is considered)

Table 7-1 Application form for GCOE-RA

Applicant name			
Research plan as RA (Relation to GCOE Program should be given.)			
Comments by advisor (In case of D3, submission date of a dissertation should be given.)			
Signature (advisor)		Date of signature	

Publications and others（Write the following items on separate A4 sheets of paper in order）

(1) Scholarly Journal (including bulletin, transaction, proceeding)

Note: State “with or without reviewing”. In case of “with reviewing”, write down only accepted one. If it is not published yet, attach the letter of acceptance.

Authors (same order as publication), title, journal name, publisher, volume, year, first page to last page

(2) Presentations in international conference

Note: State oral or poster presentation, “with or without reviewing”

Authors (same order as publication), title, conference name, presentation number, place, year, month, day

(3) Presentation in domestic meeting

Note: ibid

(4) Others

Table 7-2 Appointed RA List

(D1, D2: April 2010 – March 2011, D3: April 2010 – February 2011)

Department	Grade	Name	Research Subject	Hourly unit price (Yen)
Fundamental Energy Science	D2	Kenichi Amano	Crucial importance of translational entropy of water in biological processes: Statistical-mechanical analyses	2,500
Fundamental Energy Science	D1	Tsukasa Mashima	Structure and interaction of RNA aptamer with prion protein	2,500
Fundamental Energy Science	D1	Ayumi Sumino	Construction and evaluation of photosynthetic membrane protein assemblies on a DNA nanostructure	2,500
Fundamental Energy Science	D1	Kenji Yasuda	Statistical thermodynamics on water roles in the functioning of transporters	2,500
Energy Science and Technology	D1	Takaaki Koyanagi	Development of prediction model for the strength of silicon carbide composites under neutron irradiation	2,500
Socio-Environmental Energy Science	D3	Kousuke Hara	Mechanism of phase transformation during mechanical milling	1,400
Socio-Environmental Energy Science	D3	Seiji Matsuoka	Molecular mechanism of wood polysaccharide pyrolysis for improving the product selectivity in fuels and materials production from biomass	1,400
Socio-Environmental Energy Science	D3	Wu Yun Ga	Analysis of sustainable energy supply and demand systems in pasture area: A case study in erodes of inner Mongolia, China	1,400
Socio-Environmental Energy Science	D2	Saizou Aoyagi	A proposal and practice of a method for accustomation of pro-environmental behavior by awaking chances in daily life and loose relation in computer network	1,400
Socio-Environmental Energy Science	D1	Shota Higashikura	Efficient use of industrial waste heat for residential heat supply	1,400
Socio-Environmental Energy Science	D1	Aretha Aprilia	Waste management analysis for developing and tropical country	1,400
Fundamental Energy Science	D2	Ryota Kodama	Statistical thermodynamics on interactions between a protein and heme or ATP	1,400
Fundamental Energy Science	D2	Yueh-Tsung Tsai	Development of organic solar cells for next generation	1,400
Fundamental Energy Science	D1	Hyunyong Lee	Study of ion temperature and plasma rotation by using CXRS in Heliotron J	1,400

Fundamental Energy Science	D1	Ryo Iwaoka	Elucidation of the reaction mechanism of deamination enzyme APOBEC3F	1,400
Fundamental Energy Science	D3	Akihiro Sugahara	Development of remote collaboration system for large scale energy simulations	1,400
Fundamental Energy Science	D1	Hongmei Li	Zinc finger protein-mediated organization of biological macromolecules on a DNA tile	1,400
Fundamental Energy Science	D3	Takahiro Yagi	Research on radiation measurement technique for development of new nuclear energy system and application of neutron field	1,400
Fundamental Energy Science	D1	Ryosuke Taniki	A study to develop high functional electrochemical device using fluorohydrogenate ionic liquids as electrolytes	1,400
Energy Conversion Science	D3	Toshihiro Shibata	Estimation of the behavior of tritium in the environment based on compartment model and assessment of sustainability by hydrogen cycle analysis using tritium as a tracer	1,400
Energy Conversion Science	D2	Kouichi Yokota	Development of procedure for evaluating fatigue strength properties in lightweight alloys metals toward lightening practical machinery	1,400
Energy Conversion Science	D2	Kenzo Ibano	Studies of interactions between advanced plasma facing components and high energetic ions in the divertor simulator	1,400
Energy Conversion Science	D2	Hirokazu Kojima	A study on advanced control of transient fuel spray combustion	1,400
Energy Conversion Science	D1	Taijyu Kajihara	Study of beam-beam fusion reactions in an inertial electrostatic confinement fusion device	1,400
Energy Science and Technology	D2	Kazuoki Toyoshima	Creep fracture behavior of advanced ceramic matrix composites	1,400
Nuclear Engineering (Graduate School of Engineering)	D2	Yasuo Ose	Study on mathematical modeling of boiling phenomena and establishment of numerical prediction method for multi-phase flow	2,500
Nuclear Engineering (Graduate School of Engineering)	D2	Yuuki Sato	Compound semiconductor InSb for photon detector	1,400
Nuclear Engineering (Graduate School of Engineering)	D2	Kazuhito Fukasawa	Study on the chemical separation of actinide elements in molten salt system for the advancement of partitioning and transmutation technology	1,400
Nuclear Engineering (Graduate School of Engineering)	D1	Yoshio Masaoka	The high energy particle confinement included in the nonlinearly collision effect with the δf simulation	1,400
Nuclear Engineering (Graduate School of Engineering)	D1	Takaaki Fujii	Advance of boron neutron capture therapy using nuclear reactor	1,400
Nuclear Engineering (Graduate School of Engineering)	D1	Emi Yamakawa	Study of new type scaling FFAG accelerator for ADS	1,400

Table 7-3 Appointed TA List

Department	Grade	Name	Assigned Subject	Hourly unit price (Yen)
Fundamental Energy Science	D1	Yuto Noguchi	Assistance of Advanced Study on Fundamental Energy Science	1,400
Department of Nuclear Engineering (Graduate School of Engineering)	D2	Jiao Lifang	Assistance of Seminar on Nuclear Engineering	1,400

8. International Exchange Promotion Committee

8.1 Activity Objectives

The international exchange promotion committee supports both for student and for researcher activities via international exchange programs, international symposiums, as well as domestic symposium. The committee collaborates with the oversea research organizations to set up the energy scenarios in each country. The committee serves the updated information of the G-COE activities. Aiming at these purposes,

1) planning and operation of the international/ domestic symposium,
2) advertisement of G-COE activities,
3) collaboration between oversea/national organization

have been performed.

8.2 Newsletter

We have issues the GCOE Newsletter written in Japanese and English, and upload on the GCOE website. Two newsletters (No. 5 and No. 6) have been issued in this year.

8.3 Public Information

We have been promoting our GCOE program to public while issuing a GCOE pamphlet as well as updating GCOE homepage, where the latest activities of research and education are updated in Japanese and English. We are also paying attention to the individual privacy as well as human right during the public information.

A staff has been appointed as a web manager who has updated the latest information of GCOE programs, such as an upcoming symposium/seminar, announcement of educational program by GCOE Unit for Energy Science Education, Image share of Zero CO2 emission Scenario by Research and Planning Zero CO2 Emission Scenarios group, and Research plan by Advanced Research Clusters (Energy socio-economics, solar energy, biomass energy, advanced nuclear energy groups).

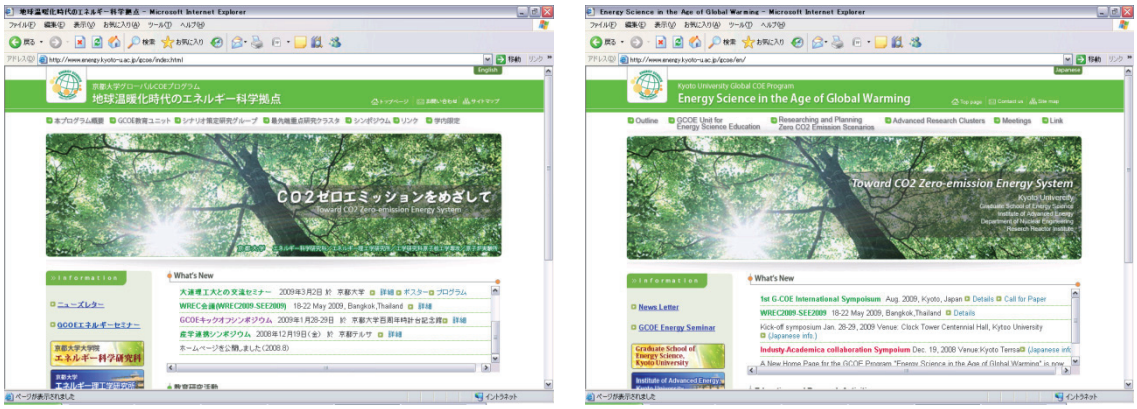


Fig. 8-1. GCOE homepage.

Fig. 8-2. GCOE pamphlet.

8.4 International and Domestic Symposiums (Workshops)

➢ **ZERO-CARBON ENERGY Kyoto 2010 (19 – 20 August, 2010)**

2. The Second International Symposium of Kyoto University G-COE of Energy Science, "ZERO-CARBON ENERGY Kyoto 2010" was held on August 19-20 at Kyoto University Obaku Plaza and brought together 182 participants in total. On 19th August, the chairman, Prof. Satoshi Konishi (IAE, Kyoto University) declared the symposium open. At first, Prof. Kiyoshi Yoshikawa (Executive Vice President of Kyoto University) gave an opening address, Followed this, Dr. Yoshikazu Nishikawa (Emeritus Prof. of Kyoto University), and Prof. Mohamed A. Abdou (Distinguished Professor at UCLA) gave us an opening remarks. Prof. Takeshi Yao (G-COE Leader) introduced the G-COE activities. After that, 5 distinguished speakers from each group made a plenary lecturer, and then 80 posters were presented by G-COE Unit students as well as international participants. At the end of reception party, several presentation awards were provided to those excellent students. On 20th, each group invited some distinguished researchers and organized a parallel session. At closing session, each research groups reported their summary.

Photo 8-1. Prof. Kiyoshi Yoshikawa (Executive Vice President of Kyoto University), Dr. Yoshikazu Nishikawa (Emeritus Prof. of Kyoto University), Prof. Mohamed A. Abdou (Distinguished Professor at UCLA), Prof. Takeshi Yao (G-COE Leader, Kyoto University), and Poster Awards.

Photo 8-2. 2nd G-COE International Symposium participants.

- **Kyoto University Global COE Workshop on Country Report 2010: Current Status of Renewable Energy Research, Development and Policy in Asian countries (1 July, 2010)**

Kyoto University Global COE Workshop on Country Report 2010: Current Status of Renewable Energy Research, Development and Policy in Asian countries was held in Yokohama, Japan along with Renewable Energy 2010 on 1st July 2010, in cooperation with SEE Forum. Current status of Energy Policy and Renewable Energy R&D in 10 Asian Countries: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand, Vietnam, and India. At final stage, the leader of GCOE Program, Prof, Yao mentioned that Kyoto University Global COE Program can be a platform for; Multilateral Cooperation for the development of RE, Multidisciplinary Collaboration; Technology, Social Science, Economy, Human Capacity Building in the field of Energy and Environment.

Photo 8-3. Participants of the Kyoto University Global COE Workshop on Country Report 2010.

- **CREST Symposium on Organic Solar Cell "Development from photo-, nano-, and bio-technologies to functions of photoelectric conversions" (16 – 17 July, 2010)**

A symposium on organic solar cells was held from the 16th to the 17th of July 2010 at Uji Obaku Plaza (Kihada Hall), Kyoto University, under the auspices of Core Research for Evolutional Science and Technology (CREST) program of "Development of highly efficient organic thin-film solar cells," which is one of the themes of "Creation of innovative technologies to control carbon dioxide emissions" of Japan Science Technology Agency (JST), with Society of Organic Solar Cell and GCOE. 25 Invited speakers presented their recent topics of organic thin-film solar cells and dye-sensitized solar cells such as design and evaluation of novel organic/inorganic semiconducting materials, developments of thin-film making process, new device structure, new analytical method in addition to the topics of artificial photosynthesis such as photo-induced electron transfer, hydrogen evolution, carbon dioxide fixation using bio-related dye, membrane-protein, enzyme, and their mimics. After the presentations, ca 150 participants made active and wide spread discussions on photovoltaics.

Photo 8-4. Participants of the CREST Symposium on Organic Solar Cell.

- **8th Eco-Energy and Materials Science and Engineering Symposium (EMESE) in Kyoto (21 August, 2010)**

Institute of Advanced Energy of Kyoto University, Kyoto University Global COE program, and Rajamangala University of Technology Tanyaburi (RMUTT) co-hosted 8th Eco-Energy & Materials Science and Engineering Symposium (8th EMSES) on 21st August 2010 at Obaku Plaza, and about international 100 participants gathered. At opening session, Prof. Kiyoshi Yoshikawa, executive vice president of Kyoto University, Prof. Namyoot Songthanapitak, President of RMUTT, and Prof. Susumu Yoshikawa gave an opening address. Followed this, there were 3 technical sessions on Energy and Environment Management, New Energy Technology, and Nano-Material Technology as oral session, and 20 posters were presented.

Photo 8-5. 8th-EMSES participants

- **7th SEE Forum & INTERNATIONAL CONFERENCE ON INNOVATIONS FOR RENEWABLE ENERGY 2010 (20-22 September, 2010))**

From the 20th to 22nd September 2010, Sustainable Energy and Environment (SEE) Forum, Hanoi University of Science, Vietnam National University Hanoi, Kyoto University co-hosted a meeting of 7th SEE Forum in Hanoi, Vietnam. The meeting was convened to further discuss research and education cooperation on new energy initiatives among Asian Countries and brought together over 100 participants from 10 countries who were committed to this objective. Emeritus Professor Susumu Yoshikawa of Kyoto University, Japan, and Professor Luu Duc Hai, Hanoi University of Science, Vietnam chaired and co-chaired the meeting.

The meeting focused on human capacity building and research collaboration among Asian countries toward a low carbon economy and a sustainable society. In the meeting, the current status of national SEE Forum activities in member countries was reported. 6 bilateral-based research collaborations among SEE Forum members towards a low carbon energy society through JST-JICA SATREP Program were discussed during “Network of Excellences” (NOE) roundtable meetings. Human capacity building was further discussed in conjunction with the ASEAN University Network Program and New Energy Consortium for Sustainable Environment (NECSE). Current status of E-learning program led by UNESCO was also reported.

Photo 8-6. Participants of the 7th SEE Forum & International Conference on Innovations for Renewable Energy 2010.

- **University of Science and Technology of China - Kyoto University Joint Doctoral Workshop on CO2 Zero Emission Energy Science and Technology (9 –10 September, 2010)**

On 9th and 10th September 2010, Executive Vice-President Kiyoshi Yoshikawa, Program Leader G-COE Prof. Takeshi Yao, Professor of Graduate School of Energy Science, Professor of Institute of Advanced Energy Hideaki Ohgaki and Assistant Professor of HAN Liyou the International Center visited to University of Science and Technology University of China (USTC), Hafei, Anhui to promote the cooperation between USTC and Kyoto University in the research field of energy science and technology including student activities.

In the first day of the visiting, Vice President of USTC Dr. Chunsheng Chen made a brief introduction of USTC. USTC has a special educational program for very young students (from 16 years) and successfully awards Ph.D degree even in 20 years old students. Most of them are working in US as faculty staff now. From Kyoto University Executive Vice-President K. Yoshikawa made a brief introduction of Kyoto University. Then 4 professors from USTC introduced their researches on the energy field and Prof. T. Yao introduced our G-COE program.

In the second day, 10th September, we visited to National Synchrotron Radiation Laboratory, Solar Energy Center and Biomass Clean Laboratory in USTC. Since USTC is the only university which belongs to the Chinese Academy of Science, these laboratory are well maintained and advanced researched have been performed. In the afternoon "University of Science and Technology of China - Kyoto University Joint Doctoral Workshop on CO2 Zero Emission Energy Science and Technology" was held. Five Ph. D course students (Mohammad Lutfur Rahman, Seiji MATSUOKA, Kosuke O. HARA, Toshihiro SHIBATA, and Yasuo OSE) of GCOE Unit for Energy Science Education, Kyoto University, and 5 students (4 Ph. D course and 1 master course) presented their research topics. About 40 participants joined the workshop and had active discussion. This visit is a starting point of the academic exchange and scientific advancement of knowledge with the cooperation between USTC and Kyoto University.

Photo 8-7. Presenters of the USTC - Kyoto University Joint Doctoral Workshop on CO2 Zero Emission Energy Science and Technology.

- **India-Japan Symposium on Emerging Technologies-2010 (7 October, 2010)**

The first India-Japan symposium was held on 7th October 2010, by Indian Scientists Association of Japan (ISAJ) at Indian Embassy, Tokyo. It was inaugurated by Shri. Prithviraj Chavan, Honorable Minister of State, Science & Technology and Earth Sciences, Government of India. In his speech, he mentioned about the growing interests between India and Japan in the fields of Science and Technology. The inaugural speech was followed and supported by other eminent speaker like Mr. Itaru Watanabe, Dy. Director General, MEXT, Japan. In his speech, he mentioned about the steps taken by Japanese Government in order to invite more of Indian Students and to strengthen the ties between India and Japan for research & development in the fields of Science and Technology. After the inaugural session, 4 different plenary sessions were taken up. The plenary sessions

have witnessed the invited lectures from leading scientists from Japanese institutes/organizations, followed by the short presentations made by Indian and Japanese researchers working in Japan.

During the plenary sessions, poster session was also organized and around 61 researchers participated. One special poster from Kyoto University on its Global COE program was also presented and highlighted in the poster session. After the plenary sessions, Prof. Satoshi Konishi, Kyoto University, made special presentation on GCOE program run by Kyoto University, highlighting the impetus on establishing an international education and research platform to foster educators, researchers and other policy makers.

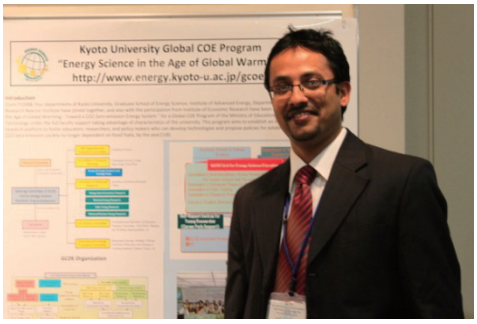


Photo 8-8. Poster presentation by Mr. Gaurav Mishra.

- **SustaiN 2010 (11 – 12 December, 2010)**

SustaiN 2010 or Sustainable Future for Human Security is the first International conference organized by the Indonesian Student Association in Kyoto and the Indonesian Embassy. It was held on 11-12 December 2010, at Inamori building, Center of South East Asia Studies, Kyoto University. The event was supported mainly by G-COE Energy Science. One hundred and nine (109) extended abstract had been submitted from countries such as Australia, Netherlands, South Africa, South Korea, Nigeria, India, Japan and ASEAN countries. Seventy five papers are presented and more than one hundred fifty participants were joining the conference. The conference was officially opened by the Indonesian ambassador to Japan and Micronesia (Mr. Muhammad Lutfi), followed by plenary speaker from key note speakers such as Prof. Susumu Yoshikawa (SEE Forum International), Prof. Djoko Santoso (Directorate General of Higher Education, Ministry of Education Indonesia) and Prof. Wawan Kadir (Vice President for Research and Innovation, ITB).

Photo 8-9. SustaiN 2010 participants.

- **G-COE Annual Report Meeting 2010 (28 January, 2011)**

The GCOE annual report meeting was held at Obaku Plaza, Kyoto University Uji Campus, on 28th January 2011. In this meeting, each committee as well as research group presents their annual progress and report. In addition, 30 GCOE/RA students and 7 GCOE Group research make a short oral presentation as well as poster presentation. At the final stage, 5 RA students and 2 G-COE group received the best poster awards.

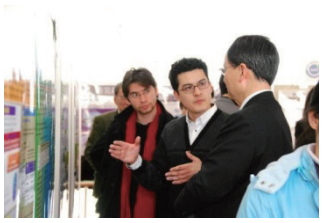


Photo 8-10. Participants of G-COE Annual Report Meeting 2010, poster presentation, excellent poster award winners.

➢ **AUN-KU Student Mobility Workshop (8 – 9 March, 2011)**

The AUN – Kyoto University Workshop on Building Academic Partnership through Collaboration and Exchange was held at Chulalongkorn University in Bangkok, Thailand on 8–9 March 2011. The workshop was held in collaboratively by Kyoto University and the ASEAN University Network (AUN). In 2009, Kyoto University signed a general memorandum of academic cooperation and exchange with the AUN The workshop aimed to consolidate the cooperation initiated with the memorandum, and determine the direction of future collaborative efforts. The workshop was attended by approximately 60 delegates from the AUN universities and Kyoto University, and was supported by 5 Japanese companies. The G-COE Program contributed as a secretariat for this workshop in cooperation with AUN secretariat office.

The first day of the symposium began with welcome addresses by Dr. Kalaya Tingsabadh, vice-president of Academic Affairs of Chulalonkorn University; Dr. Sumate Yamnoon, chairman of the AUN and secretary-general of the Office of the Higher Education Commission of Thailand; Mr. Shigeharu Kato, deputy director-general of the Higher Education Bureau of the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) and Prof. Junichi Mori, vice-president for international relations of Kyoto University. The workshop then proceeded with the first session of presentations, which featured keynote lectures by Mr. Munenori Yamada, president of the Japan External Trade Organization (JETRO) in Bangkok; Mr. Shigeharu Kato of MEXT, Vice-President Mori of Kyoto University and Dr. Nantana Gajaseni, executive director of the AUN. The presentations covered a range of topics relating student mobility and the cultivation of international human resources.

At day's second session, which featured detailed reports by AUN and Kyoto University members on topics such as student exchange, joint degrees and collaborative research. This was followed by the final session of the day which featured presentations by Dr. Wataru Takeuchi, director of the Bangkok Office of the Japan Society for the Promotion of Science (JSPS), and Mr. Kenichi Shirouzu, chief coordinator of the Japan International Cooperation Agency (JICA), introduced their programs in ASEAN countries. The second day of the workshop began with a parallel session of four round-table discussions covering topics such as the implementation of student exchange programs, credit transfer and research collaboration. The sessions were then summarized by Professor Hideaki Ohgaki of Kyoto University. The sessions produced concrete examples of possibilities for developing mobility and research activities within the AUN network, and identified topics for further discussion and development within the AUN – Kyoto University partnership.

Photo 8-11. Participants of AUN-KU student mobility workshop.

8.5 Industry-Academia Collaboration

➢ **Industry-University Cooperation Symposium**

On March 8th, 2011, we held the Global COE industry-university cooperation symposium at Kyoto Terrsa (Kyoto Citizen's Amenity Plaza), where we got 72 participants from companies, many were manufacturing industries, research organizations and universities. The Program was composed of two parts: lectures by invited speakers and seeds presentations by members of departments moving ahead with the G-COE program. The invited speakers were Professor Tatsuhiko Nariu, titled "Technology and Economy", who is Professor of Graduate School of Management, Kyoto University and Head of Green Innovation Management Education Unit, Kyoto University and Dr. Yoshihiko Nagasato, titled "Light and Shadow of Industry-Government-Academia Collaboration －From the Side of Human Resource Utilization－", who is Chairman of Sub-Committee on Industry-University-Government-Research Cooperation, Committee on Industrial Technology, Nippon Keidanren (Japan Business Federation) and President of Asahi

Research Center Co., Ltd. At seeds presentation session, 15 investigations were presented as seeds first by oral and then at poster booths. Active discussion and information exchange were conducted.

8.6 Other Activities

8.6.1 Domestic Collaborative Activities

- **Japan SEE Forum General Meeting (30 October, 2010)**

Japan SEE Forum general meeting was held on 30th August 2010 at Kyoto University Tokyo Office. The forum is the domestic organization of international SEE Forum, which is academic network toward "New Energy Initiatives", and aims at promoting the development of regionally adaptable New Energy System through cooperation in research and education in order to achieve low carbon society. In the general meeting, we discussed on the formation of JST-JICA STREPS Program with Asian Countries, and exchanged information regarding to the status of collaboration research, education cooperation, and networking.

- **Public Lecture on Energy and Environment (23 July, 2010)**

Kyoto University Global COE 2nd Public Lecturer on "Energy and Environment Issues" was held at Hyatt Regency Kyoto on July 23rd 2010. The chairman, G-COE Assist. Prof. Taro Sonobe declared the opening, and Prof. Hideaki Ohgaki introduced the outline of the GCOE Program. Followed this, Prof. Tetsuo Tezuka gave a lecturer on "Energy Saving from the view point of Energy Science" and Prof. Kazuo Nakajima gave a lecturer one "Issues on Solar Cells toward main energy source and Prospect for Poly-Crystal Si solar Cells". There was a very active discussion among lecturers and citizen.

Photo 8-12. Public lecture.

8.6.2 International Collaborative Activities

- **Indonesia SEE Forum Meeting (14 – 15 April, 2010)**

Indonesia SEE Forum meetings were arranged to discuss a multilateral proposal for JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) with Prof. Sudharto P. Hadi (Rector of Diponegoro University), Prof. Harwin Saptoadi (Gadjah Mada University), Ari Pasek (Bandon Institute of Technology). Prof. Hideaki Ohgaki and Asst. Prof. Taro Sonobe attended the meeting. Based on the meeting among SEE Forum member, we had a discussion with JICA Indonesia Office about possible option for multilateral project.

We had also a meeting UNESCO Jakarta Office regarding to the UNESCO COMETENCE Program to cooperate in the e-learning program.

- **Memorandum Of Understanding for Educational and Scientific Cooperation between Graduate School of Engineering, Graduate School of Energy Science, and Institute of Advanced Energy of Kyoto University and Energy Institute of the City University of New York (18 May, 2010)**

The Graduate School of Engineering / Graduate School of Energy Science / Institute of Advanced Energy of Kyoto University and the Energy Institute of the City University of New York (hereafter, referred to as 'the two parties') agreed to enter into this collaborative Memorandum of Understanding in order to promote

mutual cooperation on education and scientific research.

The two parties will promote in particular the following activities:

1) Exchange of scientific materials, publications and information, and teaching resources
2) Exchange of faculty members
3) Exchange of students
4) Joint research proposals for collaborative research and meetings for research

Photo 8-13. Prof. Komori (dean of the Graduate School of Engineering, left) and Prof. Banerjee (director of the Energy Institute of the City University of New York, right)

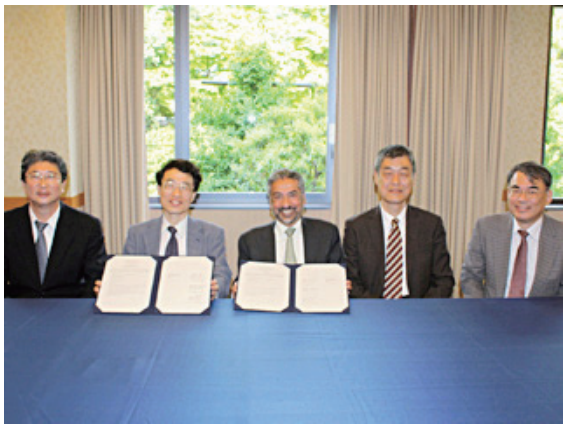


Photo 8-14. Starting from left, Prof. Takuda (dean of the Graduate School of Energy Science), Prof. Komori, Prof. Banerjee, Prof. Ogata (director of the Institute of Advanced Energy) and Prof. Kunugi.

- **2nd Japan-ASEAN Science and Technology Cooperation Committee: AJCCST (19 – 20 May, 2010)**

Emeritus Prof. Susumu Yoshikawa and Asst. Prof. Taro Sonobe attended 2nd Japan – ASEAN Science and Technology Cooperation Committee during 19-20 May 2010, in Vientiane, Laos PDR as a member of delegate from Japanese Government. Prof. Yoshikawa reported a progress of the International Meetings on Sustainable Energy and Environment Protection during 23 – 25 November 2009, in Yogyakarta, Indonesia, which was a joint workshop with AJCCST. The multilateral project concept proposal between Japan and ASEAN was also proposed. At final stage, Deputy Minister of MEXT Japan remarked that Japan wants to start the synergetic activities among Japan and ASEAN, not only binds of bilateral program, but multilateral program through JST-JICA SATREPS, even though it poses several barriers to be overcome.

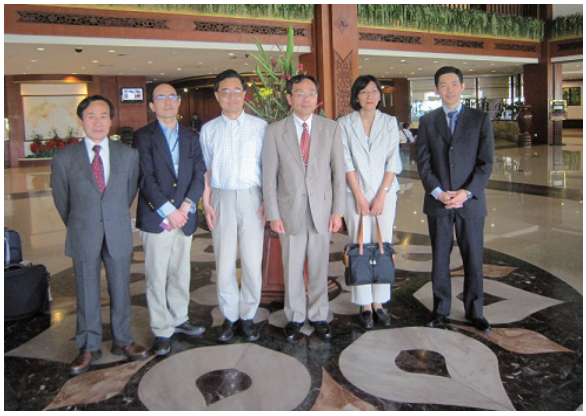


Photo 8-15. (top) AJCCST meeting, (bottom) Prof. S. Yoshikawa, Mr. N. Fukazawa (JST), Dr. A. Nakanishi (Director, JST), Mr. Y. Moriguchi (Deputy Minister, MEXT), Mr. H. Kumekawa (Director, MEXT).

- **Vietnam SEE Forum Meeting (21 – 22 May 2010)**

Vietnam SEE Forum meetings were arranged to discuss a multilateral proposal for JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) with Prof. Luu Duc Hai from Hanoi University of Science, Vietnam National University Hanoi et. al. Asst. Prof. Taro Sonobe attended the meeting. Based on the meeting among SEE Forum member, we had a discussion with JICA Vietnam Office about possible option for multilateral project.

- **UNESCO COPETENCE Workshop (21 – 22 May, 2010)**

The COMPETENCE project focuses on rethinking science education to put it in the context of Education for Sustainable Development (ESD), and introduces innovations into the teaching of science, technology and engineering in higher institutions of learning and research and development bodies in Asia and the Pacific to make it a more effective tool to build their knowledge, skills and attitudes for sustainable living.

One of the project activities is to create a multi- and inter disciplinary higher education renewable energy course as a model course for regional countries to advocate the creation of a new discipline for sustainable development, and also to raise awareness of the issues involved in the use of renewable energy resources for its equitable, optimal and sustainable development. To create this model course, the project needs to conduct a study that reviews the key regional initiatives in energy education and their contribution to sustainable development in terms of heightened public awareness and addressing developmental issues for sustainable development.

To conduct the review study and setting the target and the contents, GCOE and SEE Forum cooperates with UNESCO and had an expert or experts group meeting in Yogyakarta. From GCOE, SEE Forum, Prof. Ohgaki attended the meeting.

To settle the COMPETENCE program we had long time discussion for whole two days. Through the course, students will gain the following knowledge, understanding and awareness.

- Understanding of sustainable development
- Understanding linkage between Energy and MDGs
- Knowledge and understanding of type of energy resources and technologies- focusing on country, region and world
- Understanding of current energy situation and needs to transform toward sustainable system.
- Understanding of the role of renewable energy and energy efficiency in the context of environment, economics, technology, society and politics. (Asian context)
- Understanding of the role and options of renewable energy and energy efficiency as alternative solutions for sustainable energy system in Asian context
- Increasing awareness of energy ethics and behavioral change issues
- Appreciation of innovation of technology developed at the bottom of the pyramid
- Increasing awareness and willingness of students to empower people utilizing available energy resources.
- Main target audience are university (undergraduate) students (not limited to engineering students) and teachers who have access to SOI, NRENs, or TEIN, but the audience shouldn't be limited to university students. The course should also be open to NGOs, local communities, etc. Therefore the contents should be general and multidisciplinary.
- The course will be disseminated mainly through SOI and NRENs (CONNECT-Asia)
- SOI connects 27 universities in 13 Asian countries (TL will be added soon)
- INHERENT connects over 350 universities in Indonesia
- MYREN connects 17 universities in Malaysia
- ThaiREN and PREGINET connect universities and governmental agencies in Thailand and the Philippines

The "Energy for Sustainable Development in Asia, UNESCO E-learning Course" has been started on 10th February 2011 with more than 400 registered students. Prof. T. Tezuka, Prof. H. Ohgaki, and Prof. K. Ishihara gave lectures with 10 other Professors from Asia region.

Fig. 8-3. Program of UNESCO e-learning course, the "Energy for Sustainable Development in Asia".

➢ **Nuclear Energy Seminar in Thailand (Jan. 17-21, 2011)**

Nuclear Energy Seminar was held in Thailand from 17th to 21st January 2011. The seminar was planned to answer the demand from Thailand where a nuclear power plant will be built in 2020. The aim of this seminar is to deliver a fundamental knowledge of nuclear energy. In this time a concentrated seminar was planned. Prof. Kunugi, Prof. Unezaki, Prof. Sakurai, Prof. Sasaki, and Prof. Ohgaki gave their lectures. Prof. Yao, GCOE leader, delivered certification cards to participants.

Program of Nuclear Energy Seminar in Thailand

Jan.17 - 21, 2011 at RMUTT, Thailand

Sponsor: Kyoto University Global COE program, "Energy Science in the Age of Global Warming"
Co-sponsor: Rajamangala University of Technology Thanyaburi (RMUTT), Nuclear Forum Thailand

Date	Time	Title	Speaker
Jan.17,2011 (Mon) Mangagala Ubon Meeting Room Office of the President Building	9:00-9:30	Opening address on the seminar	Numyoot Songthanapitak (President, RMUTT) Hideaki Ohgaki (Professor, Kyoto University) Sivanappan Kumar (AIT) Masato Otaka (Embassy of Japan) Sueo Machi (Advisor to MEXT, Former Commissioner of Atomic Energy Commission)
	9:30-11:00	Nuclear Energy for Sustainable Development and Human Welfare	Sueo Machi (MEXT)
	11:00-12:00	Nuclear Energy Demanded in Thailand	Arthit Sode-Yome (Head of DTS Section, EGAT)

	13:00-14:30	Trends of Energy Direction of Thailand	Amnuay Thongsathitya (Ministry of Energy, Thailand)
	14:30-16:30	Radiation biology and radiology	Y. Sakurai (Kyoto University)
Rinla Ubon	17:00-21:00	Welcome Party	
Jan.18,2011 (Tue) Fac. Of Science and Technology	09:00-10:00	Small and Medium Sized Nuclear Reactors (SMRs) for Development	Vutthi Bhanthumnavin (SIU)
	10:00-12:00	Nuclear Physics for Nuclear Power Generation Application (Part I)	Hideaki Ohgaki (Professor, Kyoto University)
	13:00-14:30	Nuclear Physics for Nuclear Power Generation Application (Part II)	Hideaki Ohgaki (Professor, Kyoto University)
	14:30-16:30	Trends of Energy Direction of Thailand	Somporn Chongkum (Executive Director, Institute of Nuclear Technology, TINT)
Jan.19,2011 (Wed)	10:00-12:00	Nuclear Fuel (Nuclear Chemistry) I	T. Sasaki (Professor, Kyoto University)
	13:00-15:00	Nuclear Fuel (Nuclear Chemistry) II	T. Sasaki (Professor, Kyoto University)
Jan.20,2011 (Thu)	10:00-12:00	Nuclear Regulation and Policy - I	Hironobu Unesaki (Professor, Kyoto University)
	13:00-15:00	Nuclear Regulation and Policy - II	Hironobu Unesaki (Professor, Kyoto University)
Jan.21,2011 (Fri)	10:00-12:00	Reactor Thermal Hydraulic - I	Tomoaki Kunugi (Professor, Kyoto University)
	13:00-15:00	Reactor Thermal Hydraulic - II	Tomoaki Kunugi (Professor, Kyoto University)
	15:00-16:00	Discussions on Future Collaboration and Closing Address	Numyoot Songthanapitak (President, RMUTT) Hideaki Ohgaki (Kyoto University) Takeshi Yao (Kyoto University)

Fig. 8-4. Program of the 2nd Nuclear Energy Seminar in Thailand

- **SEE Forum Young Researcher Workshop (June 7 -11, 2010)**

For sustainability of the academic network and further facilitation of the joint activities under SEE Forum, it is necessary to satisfy the number of dedicated young researchers in each country as a facilitator (common medium). In order to increase the number of facilitators as well as developing intensive and efficient communication in the future , technical workshop towards sustainable energy and environment network was organized through inviting one young researcher from Asian country at same location to train their capacity as a facilitator as well as strengthen their collaboration for future SEE Forum network. The workshop was organized by Global COE Program in cooperation with UNESCO Jakarta Office. Asst. Prof. Taro Sonobe and Dr. Nuki Agya Utama coordinated the workshop. At final stage, young SEE Forum members agreed to closely cooperate

each other to facilitate the SEE Forum activities in each country, and develop the JST-JICA Multilateral Proposal.

Photo 8-16. Participants of SEE forum young researcher workshop.

- **Malaysia SEE Forum Meeting (14 – 15 June, 2010)**

Malaysia SEE Forum meetings were arranged to discuss a multilateral proposal for JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) with Prof. Nasrudin Abd Rahim et. al. Prof. Hideaki Ohgaki and Asst. Prof. Taro Sonobe attended the meeting. Based on the meeting among SEE Forum member, we had a discussion with JICA Malaysia Office about possible option for multilateral project. In addition, we had a further discussion with Ministry of Higher Education (MOHE), Ministry of Science and Technology (MOST), and Ministry of Energy, Green Technology and Water about possible collaboration through JST-JICA scheme.

Photo 8-17. Participants of Malaysia SEE Forum meetings.

- **Philippine SEE Forum Meeting (16 – 17 June, 2010)**

Philippine SEE Forum meetings were arranged to discuss a multilateral proposal for JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) with Prof. Rizalinda L. De Leon and Prof. Gregory Tangonan et. al. Prof. Hideaki Ohgaki and Asst. Prof. Taro Sonobe attended the meeting. Based on the meeting among SEE Forum member, we had a discussion with JICA Philippine Office about possible option for multilateral project. In addition, we had a further discussion with Ministry of Science and Technology (MOST), President of National Research Council, Prof. Alvin Cuba about possible collaboration through JST-JICA scheme.

Photo 8-18. (top) Philippine SEE Forum meeting at UP, (bottom) Meeting at MOST.

➢ **India SEE Forum Meeting (27 − 29 July, 2010)**

India SEE Forum meetings were arranged to discuss a multilateral proposal for JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) with Assoc. Prof. V. K. Vijay and Prof. H. P. Garg et. al. Prof. Hideaki Ohgaki and Asst. Prof. Taro Sonobe attended the meeting. Based on the meeting among SEE Forum member, we had a discussion with JICA India Office about possible option for multilateral project. In addition, we had a further discussion with Ministry of Science and Technology (MOST), Ministry of New and Renewable Energy about possible collaboration through JST-JICA scheme.

➢ **Japan-German Six Presidents' Conference (29-30 July, 2010)**

On 29th and 30th September 2010, President Hiroshi Matsumoto, Executive Vice-President Kiyoshi Yoshikawa, Director General of the Organization for the Promotion of International Relations Zyuniti Mori, Director General of the Office of Society-Academia Collaboration for Innovation Keisuke Makino, Program Leader G-COE Takeshi Yao, Professor of Institute of Advanced Energy Research Akihiko Kimura and six teachers attended to Japan-German Six Presidents' Conference held at University of Heidelberg, Germany. This meeting was brought realization by a call from Germany, the Six Presidents of Heidelberg University, University of Göttingen, Karlsruhe Institute of Technology, Germany, and Kyoto University, Osaka University, Tohoku University, Japan, the researchers and JSPS staffs, 110 members total, attended the Plenary Meeting, the Working Group for constructing a scheme of academic exchange, and seven Special Committee at various Thematic Groups such as " Materials for Energy Technologies ". The issues were discussed such as the expansion of exchanges between the two countries in each study area. Finally, the Joint Declaration was adopted by the six residents with an attendance of Japanese Ambassador to German Takahiro Jinyo. The Six Presidents signed the joint declaration under the confirmation that this Conference is the beginning of the academic exchange and scientific advancement of knowledge with the cooperation of the Six Universities.

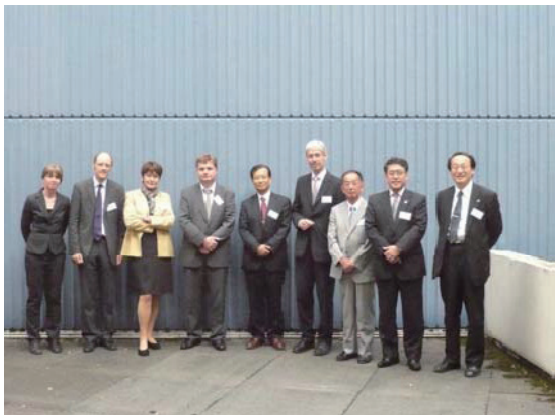


Photo 8-19. Japan-German Six Presidents' Conference.

➢ **Preliminary meeting on Design of Regionally Adaptable Energy Systems in Botswana (2 − 6 August, 2010)**

Meeting the request of expert dispatch from Republic of Botswana, the research group in G-COE visited University of Botswana and the candidate of joint research site, an off-grid village in Eastern Kalahari Desert, from 2nd to 6th, August 2010. The country is located the north of Republic of South Africa, and 80% of the electricity is relying on the import from South Africa. The population is about 2 millions and the main industry is a diamond mining and GNI (Gross National Income) per capita is $6640. Since it used to be a British colony, the town in Habanera (the capital) is a modern city that is recalled the countryside of England to mind.10

Firstly, we introduced each university on 2nd, Aug. at UB. After the researches in UB are presented, we visited research facilities on 3rd, Aug. We realized their research and education are active, especially when we saw the new analytical equipments were working.

Succeeding day, we had visited several villages in East Kalahari Desert, where the electricity service was not available, by the guide of researchers in UB. Near the communities, a lot of cattle are put out to grass, which means a lot of biomass fuel resources were scattered. They use those resources for the wall of their house. Furthermore, it is impressed for us to hear the story that one family occupies five head of cattle and each family donated one head of cattle to establish UB. On 5th, we discussed about the international joint research and leave for South Africa on 6th. The joint research will start in this fiscal year by a part of JSPS-JICA program and we will further support the program in our G-COE.

Photo 8-20. University of Botswana (upper) and the Eastern Kalahari Desert (bottom).

8.7 Activity of Global COE Program-Specific Assistant Professor

- **International Survey on the Zero CO2 Emission Energy System**

  Taro Sonobe (Graduate School of Energy Science)

The planning and operation for various G-COE international cooperative exchange and networking activities, such as (1) SEE Forum young researcher workshop (June, Jakarta), (2) Renewable Energy 2010 Country Report (July, Yokohama), (3) 8th EMSES (August, Kyoto), (4) 7th SEE Forum and IRE2010 (September, Hanoi), (5) KU-AUN Workshop (2011 March, Bangkok) were carried out, and the participation in 2nd Japan-ASEAN Science and Technology Cooperation Committee was made as a representative of Japanese Delegate. In addition, 2nd G-COE International conference and 2010 Annual report meeting were planned and operated as a member of working group. At same time, a continuous information exchange with the relevant governmental and funding agencies in Japan and abroad, such as MEXT, JSPS, and JST for promoting the G-COE activity.

9. Self-Inspection and Evaluation Committee

The committee consists of a chair (Prof. Yao, program leader), one secretary and three members. The main activity is to evaluate the result of activity plan and goal during FY2010 and achievement in this program and to issue the report as a summary early in FY2011. At first, the contents of the report (items should be included in the report) were presented at the eighteenth meeting of PHC and some discussions were made. Based on the program developments, modified contents of the report were submitted to the thirty-fifth meeting of PHC and approved. Then, the committee asked the members in charge to write the manuscripts of the report and edited the submitted manuscripts. Major contents of the report are goal of the program, organization setup, activities of the *Steering Committee of GCOE Unit for Energy Science Education* as well as other committees, and summary. In addition, questionnaire survey was carried out about the group research of doctoral students under the supervising of the *Committee of Scenario Planning*. Furthermore, the committee considered the contents of GCOE annual report in 2010 and the report was issued on March 2011.

10. Advisory Committee

Advisory Committee comprising external intellectuals is organized to assess the activity plan and development of the GCOE Program and to offer the opinions and recommendations that will improve the program activity. At the meetings, five committees making up this program (*Scenario Planning, Advanced Research, Curriculum, International Exchanger Promotion*, and *Self-Inspection and Evaluation*) reported their activities and future plans, and then exchange of opinions between the participants with confirmation of future directions were conducted. Insightful comments and valuable recommendations of the members of the *Advisory Committee* are essential for this program. Table 10-1 shows the members of the advisory committee and a committee meeting was held during FY2010 as follows.

The 4th Committee Meeting: August 19, 2010
The 5th Committee Meeting: January 28, 2011

Table 10-1 Members of Advisory Committee

Chair	Yoshikazu Nishikawa	Professor Emeritus at Kyoto University Professor Emeritus at Osaka Institute of Technology Chairman, Research Institute for Applied Sciences
Member	Kenji Ohta	Director and Senior Executive Managing Officer, Group General Manager, Tokyo Branch, Sharp Corporation
	Keiji Kanda	Professor Emeritus at Kyoto University Director, Japan Energy Policy Institute
	Shigeru Sudo	Fellow, Professor, National Institute for Fusion Science
	Hideki Toyomatsu	Managing Director, Representative Director, the Kansai Electric Power Co., Inc.
	Kenji Yamaji	Director-General, Research Institute of Innovative Technology for the Earth
	Shinya Yokoyama	Professor Emeritus at the University of Tokyo, Adviser, National Institute of Advanced Industrial Science and Technology

11. Conclusions

This is the report of the self-inspection and evaluation for FY2010 of the Global COE Program "Energy Science in the Age of Global Warming – Toward a CO2 Zero-emission Energy System". In FY2010, we continued and developed the programs earnestly.

GCOE Unit for Energy Science Education open recruited International the Seminar on Energy Science (the Open Recruitment Group Research) at which the students plan and conduct interdisciplinary group research containing both the social and the human science and the natural science toward CO2 zero emission at the initiative of the students themselves. The Scenario Planning Group conducted hearing and evaluation for the achievement of the International Seminar. GCOE Unit for Energy Science Education implemented the education program and curriculum: Advanced Research for CO2 Zero-Emission, Field Practice, Research Presentation as compulsory subjects and Overseas Practice, Classes in English as elective subjects. GCOE Unit for Energy Science Education recruited research assistants (RA) and teaching assistants (TA) for economic support of students. Scenario Planning Group and Advanced Research Cluster promoted their research further on the research achievement accumulated until now. They held Scenario Research and Advanced Research Joint Meeting and promoted cooperation between them. Scenario Planning Group organized the Scenario Strategic Research Committee as a place where information and ideas exchange between Scenario Planning Group and industries for issue of energy and environment. They discussed about availability and effectiveness of scenario proposed by Scenario Planning Group and gave feedback to the scenario planning. International Exchange Promotion Committee actively carried out events such as publication of newsletters in English and Japanese, hosting the International Symposium and publication of the Proceedings in English, hosting the Annual Meeting, hosting the industry-government-academia collaboration symposium and citizen lectures, co-hosting related meetings domestic and international and making spread of the effective achievements to the south-east Asian Nations, sponsoring Nuclear Energy Seminar in Thailand, promoting exchange with Africa and South America nations and so on. We implemented a self-inspection and evaluation and published the report in English and Japanese, and published the Annual Report in English and Japanese. Activities of the program were also checked and evaluated by the Advisory Committee.

In recent years, the climate changes due to global warming have progressed until it is easily recognized widely, and energy and environmental problems have become main concern of public. However, generally speaking, when a problem is recognized apparently by public, it has already proceeded considerably. It is important to address the problem at an earlier stage. From this point of view, it is a matter of excellent in foresight that Graduate School of Energy Science and Institute of Advanced Energy Research, both are promoting this Global COE, conducted the 21st COE program for the “Establishment of COE on Sustainable Energy System” with Institute for Sustainable Humanosphere from FY2002 to FY2006, and accumulated research achievement and information, and that this Global COE made an initiative proposal of a CO2 Zero-emission Energy System. Due to these, the importance of the activities of this Global COE is being strongly recognized.

It is expected by this self-inspection and evaluation that the activities of this Global COE are evaluated from many directions and that this Global COE will develop further.

Program Leader, Chair of Self-Inspection and Evaluation Committee
Takeshi Yao

Appendixes

付　録

Ⅰ. List of Publications and Contributed Papers with Doctoral Students
(Student names are underlined)
博士後期課程学生の関係する研究発表等一覧（該当 DC 学生は下線で示す）

A Scholarly Journals (including bulletin, proceedings, etc.)
学術雑誌等（紀要・論文集・プロシーディングも含む）

1. Ken-ichi Amano, Daisuke Miyazaki, Liew Fong Fong, Paul Hilscher, and Taro Sonobe, Temperature control technology by heat capacity change upon lock and key binding, *Physics Letters* A, Elsevier, 375 (2011) 165-169. (with review)
2. Ken-ichi Amano, Hiraku Oshima, and Masahiro Kinoshita, An efficient method for analyzing conformational properties of a polymer in solvent, *Chemical Physics Letters*, Elsevier, 504 (2011) 7-12. (with review)
3. Ken-ichi Amano and Masahiro Kinoshita, Model of insertion and release of a large solute into and from a biopolymer complex, *Chemical Physics Letters,* Elsevier, 504 (2011) 221-224 (with review)
4. Saizo Aoyagi, Hirotake Ishii, Hiroshi Shimoda, Yuto Itami, Hiroshi Tomie, Kinnya Kitagawa, Megumi Kawahara, Debate Learning Program for Cultivating Critical Thinking Attitudes, *Educational Technology Research*, 33 (2010) 167-178. (with review)
5. Aretha Aprilia, Tetsuo Tezuka, Gert Spaargaren, Municipal solid waste management with citizen participation: an alternative solution to waste problems in Jakarta, Indonesia, "Zero-Carbon Energy Kyoto 2010", T. Yao ed., Springer, 2011, 56-62. (with review)
6. Mahmoud Bakr, H. Zen, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, R. Kinjo, Y. W. Choi, T. Sonobe, T. Kii, K. Masuda and H. Ohgaki, Analysis of Transient Response of RF Gun Cavity due to Back-Bombardment Effect in KU-FEL, "Zero-Carbon Energy Kyoto 2010", T. Yao ed., Springer, 2011, 193-200. (with review)
7. Mahmoud Bakr, K. Ishida, N. Kimura, K. Yoshida, S. Ueda, M. Takasaki, R. Kinjo, Y. W. Choi, T. Sonobe, T. Kii, K. Masuda and H. Ohgaki, Characteristic of Six Hexaboride Materials as Thermionic Cathode in RF Gun against Back Bombardment Effect, *Korean Journal of Physical Society*, in press.
8. Mahmoud Bakr, R. Kinjo, Y. W. Choi, M. Omer, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, T. Kii, K. Masuda, and H. Ohgaki, Back Bombardment for Dispenser and Lanthanum Hexaboride Cathodes, *Journal of Physical Review*, in press.
9. T. Fujii, H. Tanaka, A. Maruhashi, K. Ono, Y. Sakurai, Study on optimization of multi ionization-chamber system for BNCT, *Applied Radiation and Isotopes*, Elsevier, 2011, in press. (with review)
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その他特記事項（特許，受賞等）

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Energy Science in the Age of Global Warming

— Toward a CO2 Zero-emission Energy System —

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地球温暖化時代のエネルギー科学拠点

— CO2ゼロエミッションをめざして —

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