

Country Name	Sahara Solar Energy Research Center Project
People's Democratic Republic of Algeria	

I. Project Outline

Background	<p>The Algerian economy highly depended on the energy sector such as oil and natural gas, which accounted for approximately 98% of export, 50% of GDP and 75% of revenue of the country. However, employment absorption rate of this sector was subdued around 2% of the total employment. The country's unemployment rate in 2007 was 11.8%, and employment creation, fostering of new industries as well as human resource development responsible for the industries became important policy issues. Under those circumstances, there was an increasing expectation for possibility of solar power generation in Algeria as the country had a large land area on the African continent, and the volume of solar radiation in the southern region was 6kWh/m²/day, which was about twice as much as that of Tokyo. On the other hand, about 90% of the country's land was covered by Sahara Desert, and 3.5% of the land area was used only for the agricultural land. For these reasons, there are great expectations for (i) reducing silicon from the desert sand that was not used, (ii) using it as the main material for photovoltaic panels, (iii) using the reduced silicon to build a solar power plant in the desert area for utilizing it as an energy production base, and (iv) fostering research human resources through these joint studies. Internationally, Algerian government had played a leading role in establishment of African Energy Commission as well as advocating a clean development mechanism in the region, and promotion of a search of global warming prevention measures in Africa as African Group chairperson in the Conference of Parties of United Nations Conventions (COP)-new phase development.</p>										
Objectives of the Project	<p>Through development of silicon reduction process by designing new thermodynamics for silicon production and establishment of bases for energy engineering education in the Africa, the project aimed at verifying the feasibility of sustainable scaling up of the solar breeder concept and establishing basic research and education for new global energy supply system.</p> <ol style="list-style-type: none"> Expected Overall Goal: N.A. Project Purpose: The feasibility of sustainable scaling up of the solar breeder concept (construction of Si solar cell plants and solar power plants) is verified and the basic research and education for new global energy supply system are established. 										
Activities of the Project	<ol style="list-style-type: none"> Project Site: Oran, Saida, Adrar Main Activities: (i) To develop silicon reduction process by designing new thermodynamics for silicon production, (ii) to find new applications of solar energy in Africa, and (iii) to establish bases for energy engineering education in the Africa area and to perform remote education and research with the use of Web-Based E-Learning System (WebELS). Inputs (to carry out above activities) <table border="0"> <tr> <td>Japanese Side</td> <td>Algerian Side</td> </tr> <tr> <td>1) Experts: 46 persons</td> <td>1) Staff allocated: 37 persons</td> </tr> <tr> <td>2) Trainees received: 54 persons</td> <td>2) Facilities and land: Office spaces for Japanese experts and WebELS, and equipment in laboratories in USTO-MB</td> </tr> <tr> <td>3) Equipment: Solar panels, Scanning Electron Microscope (SEM-EDX), Atomic Force Microscope (AFM), Optical microscope, Deionized water (DIW), Solar Panel monitoring, Weather monitor, and WebELS server</td> <td>3) Local operation cost: salaries of counterpart staff, travel cost, workshop and meeting costs, etc.</td> </tr> </table>			Japanese Side	Algerian Side	1) Experts: 46 persons	1) Staff allocated: 37 persons	2) Trainees received: 54 persons	2) Facilities and land: Office spaces for Japanese experts and WebELS, and equipment in laboratories in USTO-MB	3) Equipment: Solar panels, Scanning Electron Microscope (SEM-EDX), Atomic Force Microscope (AFM), Optical microscope, Deionized water (DIW), Solar Panel monitoring, Weather monitor, and WebELS server	3) Local operation cost: salaries of counterpart staff, travel cost, workshop and meeting costs, etc.
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Project Period	November 2010 to November 2015	Project Cost	(ex-ante) 309 million yen, (actual) 338 million yen								
Implementing Agency	<p>Responsible Agency: Ministry of High Education and Science Research (MHESR) Implementing Agency: University of Science and Technology of Oran Mohamed Boudiaf (USTO-MB) Cooperation Agency: Saida University, Renewable Energy Development Center (CDER) Adrar</p>										
Cooperation Agency in Japan	<p>The University of Tokyo, Tokyo Institute of Technology, Hirosaki University, Chubu University, Tokyo University of Science, Nihon University, Tohoku University, National Institute of Informatics (NII), National Institute for Materials Science (NIMS), Shimizu Densetsu Kogyo Co., Ltd., and Taiheiyo Cement Corporation</p>										

II. Result of the Evaluation

<Constraints on Evaluation>

Due to the epidemic of COVID-19, in this ex-post evaluation, the evaluation judgement was made based on the information obtained through questionnaire survey and telephone interviewing with the people concerned to the project. The field visit to the project sites was not conducted.

<Special Perspectives Considered in the Ex-Post Evaluation>

- Since the Overall Goal for the project was not set in the project design matrix, "Utilization of the research outcomes" was verified by this ex-post evaluation as a part of expected positive impacts by the Project.

I Relevance

<Consistency with the Development Policy of Algeria at the Time of Ex-Ante Evaluation>

The Project was consistent with the Algeria's development policy of "the National Action Plan 2009" and "the National Action Plan 2014" emphasizing on the development of renewable energy and energy efficiency of the country.

<Consistency with the Development Needs of Algeria at the Time of Ex-Ante Evaluation>

¹ SATREPS: Science and Technology Research Partnership for Sustainable Development.

The Project was consistent with the Algeria's development needs to build a solar power plant in the desert area by utilizing silicon from the desert sand and to foster the research human resources through the joint studies of this Project.

<Consistency with Japan's ODA Policy at the Time of Ex-Ante Evaluation>

The Project was consistent with Japan's ODA policy for Algeria at the time of ex-ante evaluation putting priority on technical cooperation for strengthening basic technology and fostering industrial human resources in order to promote the industrial base².

<Evaluation Result>

In light of the above, the relevance of the Project is high.

2 Effectiveness/Impact

<Status of Achievement of the Project Purpose at the time of Project Completion>

The Project Purpose was achieved by the time of project completion. The feasibility of sustainable solar breeding approach with solar power plants and cell project plants at the time of project completion was as follows. Firstly, the generation of a high-purity silica and silicon reduction, which was the core of the technology in the Project, were carried out in both Japan and Algeria. The silicon reduction from sand was achieved. Secondly, the cost and energy balance of silicon reduction with the technology, which was more efficient than that of the current silicon manufacturing, was established. The silicon reduction from diatom was successfully implemented in USTO-MB. Thirdly, the silicon reduction from the sand had been continuously carried out in Algeria as planned after installation of a test plant in June 2015. Fourthly, the five (5) types of solar cells were installed, their operational records were obtained at least for 2 years, and quantitative data about cell performance such as efficiency and reliability were accumulated as planned (Indicator 1).

The situation of sustainable basic research and education for new global energy supply system at the time of project completion was as follows. Firstly, the human resource had been developed steadily based on the Project's research results through the dispatch of students and researchers to Japan. Secondly, USTO-MB established a PhD and master's degree courses related to solar cells and superconductivity for platform of technology introduced from Japan. Eleven (11) master and five (5) PhD theses were submitted under the framework of this Project. Thus, the institutional capacity of the research institutes also had been strengthened through the Project. Thirdly, the researchers and students in Algeria had continued their research activities by utilizing the project equipment and technologies introduced from Japan. Fourthly, the remote education system utilizing WebELS was established, and USTO-MB signed MOU with Japanese universities for joint studies. Fifthly, the experimental sites in Saida University were of great help for USTO-MB and Saida University to continue research. Other universities were also concerned such as Pan African University Institute of Water and Energy Sciences (PAUWES) which was a center of excellence at the University of Tlemcen in Algeria (Indicator 2).

<Continuation Status of Project Effects at the time of Ex-post Evaluation>

The project effects have been sustained by the time of ex-post evaluation. The key research outputs produced by the Project such as the silicon reduction process using silica stone, the silicon production test plant and the solar cell have been utilized at the Semiconductor Research Center for Energy (CRTSE) in Algiers. For example, CRTSE conducts diverse research for instance in processing and enrichment of the raw material and crystal growth of silicon. It also developed knowhow of putting crystal growth technology into industrial use in photovoltaic and silicon electronics. Furthermore, the cooperation between Japanese universities/research institutes and USTO-MB has been maintained and a collaborative research on silicon production from sand and diatom has been undertaken. A Japanese professor and an Algerian researcher jointly attended to the International Conference on Renewable Energy and Energy Conversion organized in November 2019 at USTO-MB.

<Status of Achievement for Expected Overall Goal at the time of Ex-post Evaluation>

Since no Overall Goal was set, utilization of the research outcomes was verified to evaluate positive impacts by the Project. Based on the scientific knowledge and research output acquired in the Project, "the Strategic Energy Research and Innovation Plan for Transition and Security in Algeria" (2020-2030) was formulated by Commission for Renewable Energies and Energy Efficiency, a public body responsible for designing the national strategy for the development of renewable energies and energy efficiency. The representative researcher of the Project was involved in the formulation of this plan as an expert and was in a position to give advice, which made it possible to reflect the project results in the policy aspect. In addition, the High Commission for Renewable Energies provides for the establishment of a coordination between the scientific community and the industry.

<Other Impacts at the time of Ex-post Evaluation>

The cooperation between Japanese universities/research institutes and USTO-MB has been expanded to other related joint activities such as (i) Monitoring and evaluation of photovoltaic modules in Saida, (ii) Modelling of photovoltaic modules installed in Saida University by design of experiment, (iii) Experimental implementation of photovoltaic module emulator, and (iv) Performance assessment of the five different photovoltaic module technologies under outdoor conditions in Algeria.

<Evaluation Result>

Therefore, the effectiveness/impact of the Project is high.

Achievement of Project Purpose and Overall Goal

Aim	Indicators	Results
(Project Purpose) The feasibility of sustainable scaling up of the solar breeder concept (construction of Si solar cell plants and solar power plants) is verified and the basic research and education for new global energy supply system are established.	(Indicator 1) Current feasibility situation of sustainable solar breeding with solar power plants and cell project plants.	<u>Status of the achievement: achieved (continued)</u> (Project Completion) <ul style="list-style-type: none"> The generation of a high-purity silica and silicon reduction, which was the core of the technology in the project, were carried out in both Japan and Algeria. The silicon reduction from sand was achieved. The cost and energy balance of silicon reduction with the technology, which was more efficient than that of the current silicon manufacturing, was established. The silicon reduction from diatom was successful in USTO-MB. The silicon reduction from the sand had been carried out continuously in Algeria as planned after installation of a test plant in June 2015. The five (5) types of solar cells were installed, their operational records were obtained at least for 2 years, and quantitative data about cell performance such as efficiency and reliability were accumulated as planned.

² ODA data book 2011, Ministry of Foreign Affairs, Japan.

		<p>(Ex-post Evaluation)</p> <ul style="list-style-type: none"> The key research outputs produced by the Project such as the silicon reduction process using silica stone, the silicon production test plant and the solar cell have been utilized at the Research Center in Semiconductors Technology for Energy (CRTSE) in Algiers. For example, CRTSE conducts diverse research for instance in processing and enrichment of the raw material and crystal growth of silicon. It also developed knowhow of putting crystal growth technology into industrial use in photovoltaic and silicon electronics
	<p>(Indicator 2) Current situation of sustainable basic research and education for new global energy supply system.</p>	<p><u>Status of the achievement: achieved (continued)</u> (Project Completion)</p> <ul style="list-style-type: none"> The human resource had been developed steadily based on Project's research results through the dispatch of students and researchers to Japan. USTO-MB established a PhD and master's degree courses related to solar cells and superconductivity for platform of technology introduced from Japan. Several master and PhD theses were submitted under the framework of the Project. Thus, the institutional capacity of research institutes also had been strengthened through the project. The researchers and students in Algeria had continued their research activities by utilizing the project equipment and technologies introduced from Japan. The remote education system utilizing WebELS was established, and USTO-MB signed MOU with Japanese universities for joint studies. The experimental sites in Saida University were of great help for USTO-MB and Saida University to continue research. Other universities were also concerned such as Pan African University Institute of Water and Energy Sciences (PAUWES) which was a center of excellence at the University of Tlemcen in Algeria. <p>(Ex-post Evaluation)</p> <ul style="list-style-type: none"> The cooperation between Japanese universities/research institutes and USTO-MB has been maintained and a collaborative research on silicon production from sand and diatom has been undertaken. A Japanese professor and an Algerian researcher jointly attended to the International Conference on Renewable Energy and Energy Conversion organized in November 2019 at USTO-MB.

Source: Questionnaire and interviews

3 Efficiency

Although the project period was within the plan, the project cost exceeded the plan (100% and 125% respectively). The outputs were produced as planned. Therefore, efficiency of the project is fair.

4 Sustainability

<Policy Aspect>

The Strategic Energy Research and Innovation Plan for Transition and Security in Algeria (2020-2030) established by the Ministry of Energy Transition and Renewable Energies aims at establishing a scientific research database in the field of energy security in order to consolidate the research outputs and outcomes to achieve a transition to renewable energy and enhance energy efficiency. The research outputs/outcomes acquired by the project are expected to be integrated in this database and used for the implementation of the national strategic plan.

<Institutional/Organizational Aspect>

USTO-MB, Saida University, CDER Adrar, and CRTSE have been responsible to utilize the research outputs by the Project. USTO-MB and Saida University have undertaken operation and maintenance of the equipment provided by the Project. Approximately 100 students and researchers in Algeria have been continuously involved in research activities related to the Project. The cooperation between Algerian and Japanese universities has been maintained for promoting joint studies. Also, the collaborative mechanisms between government authorities and researchers, such as an advisory board with experts in energy and climate change, were established for reinforcing the government-academic policy dialogue to promote renewable energy and enhance energy efficiency.

<Technical Aspect>

The researchers have been sustained and improved their research capacity by exchange of knowledge among them and other personnel, under the continuous support of USTO-MB and Saida University. They often start new research projects based on the research outputs of the Project. Also, many master and PhD research related to the research areas of the Project have been carried out in several Algerian universities. For instance, they studied, in a PhD project in October 2017, the installation of a large photovoltaic system at USTO-MB in order to provide enough energy for the university. They also studied the possibility of connecting this system to the Sonelgaz (national power utility)'s power grid. WebELS system and user manual have been used. By using WebELS system, national and international universities and research organizations benefit from distance education, online meeting, and international conference distribution without difficulty even in areas with low-speed Internet. The skills and knowledge to operate and maintain the research facilities in USTO-MB and Saida University have been sustained and improved with the support of specialized and qualified persons.

<Financial Aspect>

USTO-MB and Saida University have managed to obtain the budgets from the Ministry of High Education and Scientific Research to continue the operation and maintenance of the equipment installed by the Project to a minimum degree. Given this track record, it is likely that the operation and maintenance budget for some years will continue to be allocated. However, it is desirable in the long term to mobilize additional financial support to develop further research related to the Project within the framework of funding from the Ministry of Energy Transition and Renewable Energies, the Ministry of High Education and Science Research or an international cooperation program.

<Evaluation Result>

Therefore, the sustainability of the effects through the Project is high.

5 Summary of the Evaluation

The Project achieved the Project Purpose and the project outcomes have been utilized through the continuous research to scale up the solar breeder concept based on the research output of the Project. As for efficiency, the project cost exceeded the plan. Considering all of

the above points, this Project is evaluated to be highly satisfactory.

III. Recommendations & Lessons Learned

Recommendations for Implementing Agency:

- Although the budget to sustain the project outputs/outcomes is mobilized so far, given their importance on renewable energy sector development of the Algerian authorities, as well as some prospect of industrialization of the outputs/outcomes in new projects, further mobilization of financial resources is recommended to scale up the impact of the Project.

Lessons Learned for JICA:

- Based on the establishment of a good relationship between Algerian and Japanese researchers, Algerian researchers are highly motivated to utilize the project outputs/outcomes and continue to do so after the project completion through communication with relevant parties including Japanese researchers. The main reasons are as follows:
 - Implementation of the training programs not only in the project but also in other cooperation schemes such as JICA's Knowledge Co-Creation Programs (KCCP) or the Scholarship Program of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT)) created abundant opportunities for the researchers to interact each other,
 - They established a practice to frequently share and exchange the research results on a regular and remote basis, and
 - Research theme was of great interest not only for Japanese researchers but also Algerian authorities who seek to diversify energy resources other than hydrocarbons (untap the unexploited potential of the Algerian Sahara to create solar breeder)



Installation of a solar cell



Visit to Adrar in deep Sahara desert of Algeria