Summary of Terminal Evaluation

<table>
<tr><th colspan="3">I. Outline of the Project</th></tr>
<tr><td colspan="2">Country:
The People’s Democratic Republic of Algeria</td><td>Project title:
Sahara Solar Energy Research Center Project</td></tr>
<tr><td colspan="2">Issue/Sector: Renewable Energy</td><td>Cooperation scheme: Technical Cooperation (SATREPS)</td></tr>
<tr><td colspan="2">Division in charge: Industrial Development and Public Policy Department</td><td>Total cost: JPY 300,000,000</td></tr>
<tr><td rowspan="2">Period of Cooperation</td><td rowspan="2">(R/D):
November, 2011 to November, 2015
(Extension):
(F/U) :
(E/N)（Grant Aid）</td><td>Partner Country’s Implementing Organization:
University of Science and Technology of Oran “Mohamed Boudiaf (USTO-MB), Saida University, Renewable Energy Development Center(CDER) Adrar</td></tr>
<tr><td>Supporting Organization in Japan:
Tokyo University, Tokyo Institute of Technology, Hirosaki University, Chubu University, National Institute of Informatics (NII), National Institute for Materials Science (NIMS), and Shimizu densetsu Kogyo Co., Ltd. etc.</td></tr>
<tr><td colspan="3">Related Cooperation:</td></tr>
<tr><td colspan="3">1. Background of the Project
The economy of the People’s Democratic Republic of Algeria (hereinafter referred to as “Algeria”) has been in strong condition with increasing oil and natural gas export due to surge of energy price in recent years. Thus both trade and current balance have been in surplus.
However, employment absorption rate of this sector is only 2% of the total. Such sectional economic structure to the same sector (occupied about 98% of export, approximately 50% of GDP and approximately 75% of revenue of Algeria) become factors of social anxiety.
President Abdelaziz Bouteflika won the presidential election three times consecutively and has established the "Algeria National Action Plan 2009". The plan takes up diversification of industry and the human resource development for the diversification as high priority issue, and the plan draw up various policies toward the correction of disparities such as 1) expansion of opportunities for practical professional education 2) of higher education, and 3) job creation for three million people
At the same time, in the field of the mainstay energy sector, Algerian government plans to figure out the overall picture oil and natural gas of Algerian national energy resources and to carry on research study aimed to strategic utilization. In addition, as a priority research topics Algerian government takes up aggressive research development (such as development of policy and regulations, promotion of research and development, and industrialization) related to next</td></tr>
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generation renewable energy.

Particularly, solar power generation is placed as the most important issue in terms of promoting science and technology, formulating and creating new jobs opportunity, and industries, in addition expanding local power supply network and stable power supply.

Internationally, in the absence of energy committee in Africa, Algerian government advocated an establishment of African Energy Commission (the headquarters is located in Algiers), and realized the commission taking over the seven years this Commission. It has become a driving force to promote mutually complementary cooperation and integration of energy in continent scale.

In addition, Algerian government proposed clean development mechanism in the region based on three components such as 1) reduction of flare gas by devising and implementation of trans-Sahara gas pipeline project linking from Niger and Nigeria to Algeria, 2) securing resources for solar power and improvement of energy efficiency and 3) strengthening network of intra-African research institutions. Algerian government functions as a base to spread new technology to African countries and of natural energy supply. Moreover in the COP (Conference of the Parties) -new phase development, Algerian government plays a leading role for search of global warming prevention measures in Africa as African Group chairperson.

In this circumstance, Algerian government has positioned “solar power generation” as the top priority field for next generation energy, thus Algerian government requested assistance to Japan which owes advanced technology in this field, through the "global issues corresponding international science and technology cooperation".

The project has a purpose to verify the possibility of sustained expansion of solar breeder (solar power plants and solar silicon factory), and to establish basic research of new earth energy system (performance of solar cells, introduction of a superconducting cable) and to establish basic human resources development. The project has been carried out with USTO-MB, Saida University and CDER Adrar as a counterpart (C/P) organization. The project has implemented in the plan for five years from November 2010 to November 2015, currently one expert in long-term expert as a project coordinator has been dispatched.

2. Project Overview

The Project conducts technology development of Si reduction process from desert sand and establishes foundation on human resource development in collaboration with Algerian side. Through these researches, the Project contributes to establishment on sustainable solar breeding, and diversification of energy structure and industry of Algeria.

(1) Project Purpose

To verify the feasibility of sustainable scaling up of the solar breeder concept (construction of Si solar cell plants and solar power plants) and to establish basic research and education for new global

energy supply system.

(2) Outputs

[Output 1]

To develop Si reduction process not from the widely used silica stone but from abundant sand in the desert by designing new thermodynamics for Si production.

[Output 2]

To construct a Si production test plant from sand and to establish Si reduction process in Algeria.

[Output 3]

To find problems and solutions in the use of solar cells in the desert by accumulating quantitative data about cell performance such as efficiency and reliability and to find new applications of solar energy in this area.

[Output 4]

To point out problems with operation of high critical temperature superconducting cable system and to find out solutions for them.

[Output 5]

To establish bases for energy engineering education in the Africa area and to perform remote education by complex education system with the use of WebELS system which was developed in Japan.

[Output 6]

Organizing Annual Sahara Solar Energy Workshop alternately in Japan and Algeria.

(3) Inputs

Japanese side:

Dispatch of Experts: Forty five short-term experts/researchers and one long-term expert (Project Coordinator)

Equipment: A total of JPY150,000,000

*( )Number of procurement in the project:

Scanning Electron Microscope(SEM-EDX) (1), Atomic Force Microscope (AFM) (1), Optical microscope(1), Deionized water (DIW) (1), Solar Panel monitoring(1), Weather monitor(1) and WebELS server(1)

Trainings in Japan: 54 persons

Total Cost: JPY 148,327,000 (by the end of March 2015)

Algerian side:

Assignment of counterpart personnel: Thirty seven researchers and eighteen PhD and Master course students in total

Provision of facilities: Working spaces for Japanese experts and installation space for WebELS and for procured equipment in laboratories in USTO-MB

Local cost: Approximately 54,313 thousand DA (as of April, 2015)		
II. Review Team		
Members of Review Team	Mr. Kaoru Suzuki, Leader, Senior Advisor (Energy), Industrial Development and Public Policy Department, JICA Mr. Takayuki Kurita, Evaluation Analysis, Senior Consultant, ICONS Inc. Mr. Noboru Okada, Interpreter, Japan International Cooperation Center Dr. Kotaro Inoue, Principal fellow, Japan Science and Technology Agency	
Period of Review	April 18 to 30, 2015	Type of Evaluation: Terminal Evaluation

III. Results of Review

1. Summary of Achievements

(1) Project Purpose

To verify the feasibility of sustainable scaling up of the solar breeder concept (construction of Si solar cell plants and solar power plants) and to establish basic research and education for new global energy supply system.

As of the terminal evaluation, two indicators to verify the achievement of the Output were partly achieved. The Project Purpose expects to be achieved by the completion of the Project.

Each indicator and their degree of achievements are as follows.

Indicator 1) “Current feasibility situation of sustainable solar breeding with solar power plants and cell production plants.”

[Degree of achievement]

Generating a high-purity silica and silicon reduction, which is the core of the technology in the Project are carried out in both Japan and Algeria. Silicon reduction from sand has been achieved. Cost and energy balance of Silicon reduction with the technology has come up with a result that is less than the current silicon manufacturing. It should be noted that silicon reduction from diatom have been successful in USTO-MB. As installation of a test plant is completed in June 2015, silicon reduction from the sand will be carried out in Algeria as planned. Furthermore towards the realization of solar bleeding, it is necessary to continuously promote to other organizations (government institution such as Ministry of higher education and scientific research, other universities, and private companies) in order to get support from these organizations in the remaining period of the Project.

Indicator 2) “Current situation of establishing basic research and education for new global energy supply system”.

[Degree of achievement]

Through the dispatch of students and researchers to Japan, human resource development have been carried out steadily from research results under the Project so far.

In addition, USTO-MB established a PhD and master's degree courses related to solar cells and superconductivity for platform of technology introduced from Japan. Thus, the organization capability as a research institute also has been strengthened through the Project.

The experimental equipment by equipment provision under the Project, researchers and students in Algeria has been continued by utilizing equipment procured under the Project and technologies introduced from Japan. Despite experimental equipment is not enough in some fields in USTO-MB, researchers and students in Algeria have achieved outputs, utilizing equipment granted by Japan in 1980's and devising present facilities under support from Japanese researchers. Remote education system utilizing WebELS also been established. Moreover USTO-MB is also signed MOU with Japanese universities. Therefore continuous technical support system was also constructed. Thus, basis of research was already established.

(2)Activities under Output 1 "To develop Si reduction process not from the widely used silica stone but from abundant sand in the desert by designing new thermodynamics for Si production."

1-1 To design thermodynamics for Si production process: 100% has been achieved.

1-2 Purification of sands from the desert: 100% has been achieved.

1-3 To develop Si reduction techniques from the sands（SiO2）in the desert （*solely in Japan）: 100% has been achieved.

In laboratory level in Japan, it has been verified that Si with B/P concentration is less than 10ppm with a new Si reduction process. Moreover researchers of USTO-MB developed Si reduction process from diatom utilizing technology introduced under the Project (the purity is more 99%)

(2) Activities under Output 2 "To construct a Si production test plant from sand and to establish Si reduction process in Algeria."

2-1 To tune the reduction apparatus in Japan: 100% has been achieved.

2-2 To set up the reduction apparatus in Algeria:
100% expects to be achieved by June, 2015.

2-3 To establish the Si reduction process in Algeria:
100% expects to be achieved by July, 2015.

It was verified that 130g/h of Si produced with Si reduction process developed in research in Output1 (at Hirosaki University). When the results is converted to amount of production per year, more than one ton of Silicon production was to be achieved.

Installation of the Si production test plant plans to be completed in June, 2015. The Project conducted training on operation and maintenance of the test plant for two (2) researchers from UDTO-MB. In addition, after the installation, the Project plans to have instruction for the test plant. Through these activities, the Project established a system to operate and maintain the test plant continuously even after the completion of the Project.

(3) Activities under Output 3 "To find problems and solutions in the use of solar cells in the desert by accumulating quantitative data about cell performance such as efficiency and reliability and to find new applications of solar energy in this area."

3-1 To get and set up solar panels: 100% has been achieved.
3-2 To collect the data and to find problems and solutions:
100% expects to be achieved by September, 2015.
3-3 To find applications: 100% expects to be achieved by September, 2015.

Five types of solar cells which has a total of 10kW was installed at Saida University in December, 2013, and its monitoring has been conducting. Due to delay of solar cell installation, the solar cells have been operated for one year and five months as of the terminal evaluation. The monitoring data has been shared between Algerian researchers and Japanese researchers. The analysis has been carried out using two kinds of data (data for six months and twelve months). In the results of the analysis, characteristics of outdoor conditions in Saida area and performance evaluation such as power generation efficiency of the five types of solar cells due to changes of the natural conditions were clarified. It is scheduled to perform the analysis using data for 12 months in the future.

In addition, the Project has receive two researchers (for solar cell evaluation). The Project has conducted training about solar cell system, and the trainees acquired enough knowledge about solar cell operation.

(4) Activities under Output 4 "To point out problems with operation of high critical temperature superconducting cable system and to find out solutions for them."

4-1 To get and set up measurement system: 100% had been achieved.
4-2 To collect and analyze data: 100% had been achieved.

Underground temperature measuring equipment was installed in September 2013, and the Project started to measure the earth temperature. The monitoring has been conducted for more than 375 days as of the terminal evaluation. The system is capable to monitor the data on the internet. However due to internet circumstances in Saida University, the Japanese researchers are not able to monitor the data from Japan these days. Therefore the data has been sent by researchers of Saida University by way of researchers of USTO-MB every a few months. As a result of measurement in September which the earth temperature is the hottest, it is clarified that earth temperature is less than 25℃ as long as 2.5m underground level. Similar superconducting system in Japan is usable.

(5) Activities under Output 5 "To establish bases for energy engineering education in the Africa area and to perform remote education by complex education system with the use of WebELS system which was developed in Japan."

5-1 To establish infra-structure for the use of WebELS system and to educate instructors in Algeria: 100% had been achieved.

5-2 To support the research works in SSERC at USTO and to educate engineers in the field of global energy by the use of WebELS: 100% had been achieved.

As internet system in Algeria was improved, the Project held a lecture (Introduction to Inorganic Material Science and Process) using WebELS at Hirosaki University and USTO-MB for three hours on 7 February, 2014.A number of the participants was approximately twenty (20). So far only once lecture on WebELS has been held, however the lecture was attracted favorite comment.

(6) Activities under Output 6 "Organizing Annual Sahara Solar Energy Workshop alternately in Japan and Algeria."

6-1 Organizing Annual Sahara Solar Energy Workshop alternately in Japan and Algeria: 100% had been achieved.

The workshop has been held annually as planned. The project has invited not only Algerian researchers involved in the Project but also researchers worldwide.
In the workshop the Project activity report and information exchange about the research has been held. As in academic society has not established, the workshops were utilized as effective opportunities for young Algerian researchers to present their research.

2. Summary of Evaluation Results

(1) Relevance : High

The Algerian industry depends largely on the fossil energy such as gasoline and natural gas. However, there is concern of the depletion of these resources. In addition, the employment rate of the fossil energy industry sector is only around 2 %. In such a context, the Algerian government is promoting technology development such as Solar power energy to create employment by diversifying the energy and the industry. As the Project has conducted to develop the new technology of solar breeder and to diversify the energy and the industry, the Project is relevant to the Algerian needs.

USTO-MB is an institution of higher technician training. Researches of electrical also have been implemented in USTO-MB, and USTO-MB has been involved in the targeting research of the Project before the Project started. Also Saida University has a strong cooperation with USTO and Saida University is located close to desert area, which is in the proper location to install solar cell and measurement equipment for superconducting.

The CDER Adrar is a research institute of renewable energy in Algeria, research contents of the Project correspond exactly.

(2) Effectiveness : High

The Project Purpose is achieved by the achievement of the each Output such as technology development including development of Si reduction process, establishment of Si reduction process in Algeria, and site test of solar panel and superconductivity, and foundation establishment of human resource development including installation of Web-ELS and holding of the workshops. Thus, the logicality between the Project Purpose and the Outputs is appropriate.

Achievement of the Outputs

Si reduction process technology in Output 1 was already developed. Regarding Output2, the Test Plant was prepared and planned to be installed at USTO-MB in June, 2015, based on the achievement of Output1. Performance evaluation of solar cell was clarified through the installation of solar cell and the monitoring in Output3. Regarding Output4, method of superconducting system usage in desert area was clarified. Web-ELS system described in Output5 was installed and the system is utilized for remote education. The workshop in Output 6 was held annually as planned.

Achievement of the Project Purpose

The degree of the Project purpose achievement was verified in terms of 1) Current feasibility situation of sustainable solar breeding, and 2) Current situation of establishing basic research and education. The foundation of basic research and education was established through the establishment of master and Ph. D course of the research related to the Project. However the sustainable solar breeding has not been verified as the installation of the test plant was not completed. The indicators were judged to be achieved partly as of the terminal evaluation. However the technology on Si reduction was developed and the test plant planned to be installed in June, 2015. Therefore the Project Purpose expects to be achieved by the completion of the Project.

(3) Efficiency : High

Efficiency of Inputs:

Toward the achievement of the Project purpose, inputs such as experts dispatching and procurement of the equipment were appropriate quantitatively and qualitatively.

The custom clearance for equipment took long time (approximately three months). Consequently, the metrological data collection and some experiments get delayed. The test plant for the Si reduction being subjected to the security trade control standard of Ministry of Economy, Trade and Industry (METI) in Japan, the shipping of the test plant get delayed from one to two months. However, if the custom clearance of this equipment and the setting up of the equipment are carried out smoothly, there is no concern about the progress of the Project.

Efficiency of Activities:

Although Activities in Algeria is so limited for Japanese researchers, the Project utilized schemes such as training in Japan and receiving students effectively in order to achieve the project purpose. In particular, it is confirmed that by being exposed to Japanese research, motivation of Algerian researchers has been increased. These inputs contribute to promote each activity.

(4) Impact : High

The outputs of the research which were presented by means of scientific literature, academic meeting, and the forum of this project which raised the interest of some countries such as Tunisia, Turkmenistan. Particularly Turkmenistan is ready to implement the same research by their own budget.

Furthermore, the flowing impacts are found through these public relation activities.

- Networking among researchers was strengthening. In addition, Chubu University and USTO-MB signed on MOU, and relationship was strengthened institutionally and individually.
- Before the Project Algerian researchers did not have connection to Japanese companies. However through the Project the connection has been constructed. The motion toward collaboration with the private sector expects to contribute to realize social implementation of the technology developed under the Project.
- Young Algerian researchers obtained opportunities to present their research output in international workshops held in Output 6 (As here is not academic societies in Algeria, and it is difficult to present research output for young Algerian researchers). These opportunities contribute to capacity development of the young Algerian researchers.

In addition, it is noted that utilizing the technology introduced under the Project, Algerian researchers proposed pure silica production from Diatom which is available in huge amount of 6 million tons at a low price.

(5) Sustainability High

Policy aspects:

Algeria is promoting to diversify the energy such as Photovoltaic energy under the policy of public investment (2010 to 2014). It is advantageous for Algeria to realize the solar breeder technology and make progress in the field of Photovoltaic energy because of the structure in the industrial and energy sector. Algerian government support for this activity is likely to be maintained even after the Project is completed.

Financial Aspects:

The part in charge of the Algerian side is provided as planned. There is a part of research financed by the Algerian side. In the future, the Algerian side is willing to provide the budget for the assignment of researchers and the operation and maintenance cost of equipment in order to continue the research.

Organizational Aspects:

Many researchers of Saida University are graduated from USTO-MB. In this circumstance, the

relationship between two universities is very active. Also, CDER Adrar plays role of the renewable energy institute in Algeria. Japanese side is willing to continue the research of the Project in the future. In USTO-MB, the master course in the field of PV and superconductivity was created in order to have researchers in this field. In this condition, these institutes are likely to conduct the collaborative research by maintaining the relationship with Japanese researchers through PhD and master course even after the Project is completed.

Technological Aspects:

A number of researchers are have been prepared to accomplish their task in each field through the collaborative research of the Project which will be continued by means of WebELS and participation to forums and seminars etc. even after the Project is completed. Moreover USTO-MB schedule to sign on MOU with Japanese University. Thus, the condition required to follow up technically is on the way to be secured.

3. Factors that Promoted Realization of Effects

(1) Factors Relevant to Planning

None.

(2) Factors Relevant to the Implementation Process

The rector and the vice-rector of USTO-MB are very interested in the Project and willing to support to carry out activities under the Project. Through the collaboration research under the Project between two parties in laboratory level by experiencing research output, relationship between both parties have been strengthening.

In addition, despite the very limited activities in Algeria for Japanese researchers, the two parties has maintained a good communication because of the factors as follows:

- Utilizing the Project and other schemes, Algerian researchers and students have opportunities for trainings and studies in Japan. Through these opportunities good relationship between two parties have been constructed.
- Sharing information regarding their works by email or in academic meetings;
- A good communication skill of the Project coordinator enabling to win the confidence among the Algerian researchers;
- Willingness of the Algerian researchers to communicate in English with the Japanese researchers

Moreover technical transfer has been also conducted adequately as follows.

- Information sharing regarding the research results among the researchers of two parties contacting frequently by email or academic meeting, etc.;
- Counterpart trainees' reports to USTO-MB regarding the content of their training in Japan.
- On the basis of this, the Algerian researchers have been carried out their research, utilizing the new equipment installed under the Project, and develop some devices for experimentation by themselves. The former trainees also play active roles for the researches in Algeria with high motivation.

By having experiences to research in Japan, installing the equipment and acquiring technology,

Algerian researchers have environment in Algeria to continue their research in Japan. The factor contribute to improvement of their motivation to carry their research.

4. Factors that impeded realization of effects

(1) Factors Relevant to Planning

None**.**

(2) Factors Relevant to the Implementation Process

Some parts of the activities and achievement of the Outputs in the project delayed due to unanticipated situation such as the Great East Japan Earthquake in March, 2011 and hostage restraint incident in January, 2013 and to take longer time than expected for custom clearance. The Project made effort to minimize the delay utilizing training in Japan.

5. Conclusion

The relevance of the Project is high as the Project is in line of the policies and social needs in Algeria. As the Project Purpose expects to be achieved during the Project period, the effectiveness is high. Therefore it is judged that it is not necessary to extend the Project period. The efficiency of the Project is judged to be relatively high as the delay of the equipment procurement did not significantly affect to the achievement of the Project. The Impact of the Project is judged to be high as other countries have interest in the technology developed under the Project and the network to promote the research was established through the Project. The sustainability of the Project is assessed as high in terms of policies, finance, organization and technology.

6. Recommendations

[Recommendation to Algerian side]

(1) Preparation to install Si reduction test plant (Output 2)

The Si production test plant plans to be installed at USTO-MB in June 2015. First, the Project should continuously operate the Si production test plant smoothly to establish sustainable Si reduction process in Algeria.

(2) Safety and appropriate measures for equipment (Output 1, 3 and 4)

It is expected to take necessary safety and appropriate measures continuously for equipment which has been procured and installed at USTO-MB and Saida University under the Project.

[Recommendation to the Project]

(3) Utilization of WebELS (Output 5)

By installing WebELS system, academic intercommunion among Japan and many countries in the world will work easily. Algerian side should utilize WebELS continuously because WebELS is

useful to facilitate education for young researchers and for dissemination of research output.

(4) Dissemination of the research result of the project (Output 6)

Through several international sustainable energy forums, network between Japanese and Algerian researchers has been strengthened. The researchers would be willing to extend the collaborative research to the next stage;

- NIMS and DGRSDT already signed on comprehensive cooperation agreement.
- Chubu University and USTO-MB are willing to sign an MOU on research and education, mainly for superconducting power transmission system.

Thus structure to carry out research continuously has been constructed. It is necessary that the researchers of Japanese and Algerian sides should share clear vision and necessary step to realize solar breeder. Besides, the researchers of both sides should design road map such as;

in order to help promoting new visions for Algerian government, to strengthen network of the Algerian energy industry (including silicon production and renewable energy industries), and to facilitate institutional improvement on human resource development.

7. Lessons Learned

In case of SATREPS, it is important to manage a project (1)to provide a opportunities to experience actual experiment by trainings in Japan in the field of Si reduction process, solar cell and solar conductivity, etc., (2) to develop a place to replicate the experiment by procurement of equipment, (3) to establish master and PhD course to hold technology introduced under a project and (4) under strong top management by rector.

Moreover, in case of SATREPS, there are some cases to take long time to achieve a project purpose and overall goal. Toward the social implementation of the technology introduced under the project, it is expected to promote to sign MOU between Japanese and recipient institutes and to introduce other schemes (such as international student supported by Ministry of Education, Culture, Sports, Science and technology in Japan(MEXT)).

There were some fairly difficulties in procedural, security and communication aspects in technical cooperation projects implementation including SATREPS in non-English speaking countries where does not have JICA office and requires special considerations in security aspects. In order for smooth project implementation it is essential to arrange project coordinator who deeply understand frameworks of SATREPS, and as communication improvement links to the smooth project implementation, it is important to arrange the project coordinator in the early stage of the project.

8. Follow-up Situation

(Not applicable)